NARDI FUNDULEA, ROMANIA ROMANIAN AGRICULTURAL RESEARCH, NO. 43, 2026
www.incda-fundulea.ro; doi.org/10.59665/rar4341 First Online: March, 2026. DII 2067-5720 RAR 2026-99

Yield and Quality of Soybean Crop under the Influence of Tillage Systems

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ABSTRACT

Soybean cultivation requires appropriate soil tillage and effective weed management to ensure high and stable yields of good quality. Therefore, identifying suitable methods of soil preparation and weed control represents an essential technological component in soybean production. A polifactorial experiment was conducted at the Agricultural Research and Development Station (ARDS) Turda over two consecutive growing seasons (2024 and 2025), based on the split-plot design. The biological material studied was the soybean variety Felix, sown at 50 cm between rows and 55 g.g./m². The study aimed to assess the stability of yield, thousand kernel weight, and seed quality (oil content, protein content, and fatty acids) under two soil tillage systems (plowing and chisel) and different weed control methods (a control variant without treatment, pre- and post-emergent herbicides for monocots and dicots, as well as combinations with mechanical or manual hoeing). The results obtained in both experimental years indicate a high level of weeding, especially in the non-herbicidal variant. Average yields were higher in the plowing system, while chisel ensured more pronounced stability of yield. Average yields were higher in the plowing system, while the chisel system provided greater stability in yield capacity. The best results were obtained then chemical herbicide application with hoeing, confirming the effectiveness of integrated weed management. The maximum yield (2034 kg/ha) was achieved under plowing with chemical weed control, whereas in the untreated control, yields were 785 kg/ha for plowing and 500 kg/ha for chisel system. Thousand kernel weight was similar in both systems (130-145 g), slightly higher and more stable under the chisel system. Seed chemical composition was relatively consistent: the chisel system promoted higher oil content (21.06%) and oleic acid (26.44%), whereas plowing slightly increased protein content (33.93%) and linolenic acid (5.24%). Low coefficients of variation indicated high stability of seed quality traits. While the conservative chisel system provided stable yield and quality, plowing offered a higher productive potential, especially under favorable environmental conditions.

Keywords: plowing, quality, chisel, yield, soybean.

INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] is a valuable crop in the context of the current global challenges in the agri-food sector, owing to its high protein (≈40%) and oil (≈20%) content, its supply of essential amino acids (Hudson, 2022), and its ability to integrate readily into agricultural soils.

However, yield potential is constrained by biotic and abiotic stress, including weed competition (Pannacci et al., 2018) and unfavorable climatic conditions during the growing season.

Weeds compete with soybean plants for water, nutrients, and light, thereby limiting growth and development and directly reducing yield and quality (Soltani et al., 2017; Zhang et al., 2023).

The intensity of weed competition depends on weed species composition and density, as well as soil and crop management practices (Chauhan and Mahajan, 2014), a critical consideration given the high susceptibility of soybean to weed infestation, particularly in low-input and organic production system (Davis et al., 2005).

Unfavorable climatic conditions during the reproductive phase of soybean can substantially reduce grain production, with reported losses of up to 74% (Jumrani and Bhatia, 2018).

Effective agricultural management is essential for sustaining future production and meeting global food and energy demands (Arora, 2019), and the adoption of alternative technologies may enhance crop productivity while reducing log-term costs.

Received 26 January 2026; accepted 30 March 2026.

However, reduced tillage can promote the rapid spread of certain weed species compared with conventional system (Buhler, 1995), thereby increasing the need for effective weed management.

In this context, our study aims to identify sustainable approaches for reducing weed pressure in soybean crops to improve yield and quality.

MATERIAL AND METHODS

In order to evaluate the weeds spectrum present in the soybean crop as well as the influence of different weed control methods on the degree of weeding, yield and quality of soybeans, a field experiment was conducted at Agricultural Research and Development Station (ARDS) Turda in two consecutive years (2024-2025).

The experiment was based on the split-plot design with two replications, using plots of 48 m^2. The Felix soybean variety, developed at ARDS Turda and registered in 2005, was sown at a distance of 50 cm between rows, at a density of 55 germinate grains/m^2.

The study aimed to assess the stability of yield, thousand kernel weight (TKW), and seed quality (oil content, protein content, and fatty acids) under two soil tillage systems (plowing and chisel) and different weed control methods (a control variant without treatment, pre- and post-emergent herbicides for monocots and dicots, as well as combinations with mechanical or manual hoeing).

The experiment was multifactorial and included the following factors:

- **S-tillage system with 2 graduations:**
  - ✓ Classic system with ploughing;
  - ✓ Conservative system with chisel.
- **D-sowing time with two graduations:**
  - ✓ D1 - sown on April 09, 2024; April 23, 2025;
  - ✓ D2 - sown on April 14, 2024; May 14, 2025.
- **M-method of weed control with 12 graduations:**
  - ✓ **V1**: Untreated (control variant);
  - ✓ **V2:** Pre-emergence herbicide variant (monocots + dicots);
  - ✓ **V3** Pre-emergence herbicide variant (monocots);
  - ✓ **V4** Pre-emergence herbicide variant (dicotyledonous);
  - ✓ **V5** Pre-emergence herbicide variant (mono + dicotyledonous) + post-emergence herbicide (mono + dicotyledonous);
  - ✓ **V6** Pre-emergence herbicide variant (mono + dicotyledonous) + post-emergence herbicide (dicotyledonous);
  - ✓ **V7** Variant with pre-emergence herbicide (mono + dicotyledonous) + post-emergence herbicides (monocots);
  - ✓ **V8** Post-emergence herbicide variant (mono + dicotyledonous);
  - ✓ **V9** Variant with herbicide in pre-emergence + a mechanical hoeing.
  - ✓ **V10** Mechanical hoeing (2 times);
  - ✓ **V11** Pre-emergence herbicide variant + a manual hoeing;
  - ✓ **V12** Manual hoeing (2 times).

Statistical data analysis

Statistical data processing was carried out using descriptive statistics and boxplot analysis, performed with Past4 software. In addition, the stability method based on environmental indices was applied, as proposed by Eberhart and Russell (1966).

RESULTS AND DISCUSSION

In 2024, a progressive decline rainfall, was observed at ARDS Turda, particularly during the summer months. Combined with high temperatures (Figure 1), this negatively affected soybean plants growth and development, with visible field effects and a consequent reduction in grain yield.

In 2025, climatic conditions at the beginning of the growing season significantly affected soybean emergence. For soybeans sown in the last decade of April (23 April 2025), emergence occurred on 2 May 2025, nine days after sowing, and was uniform, with an appropriate density.

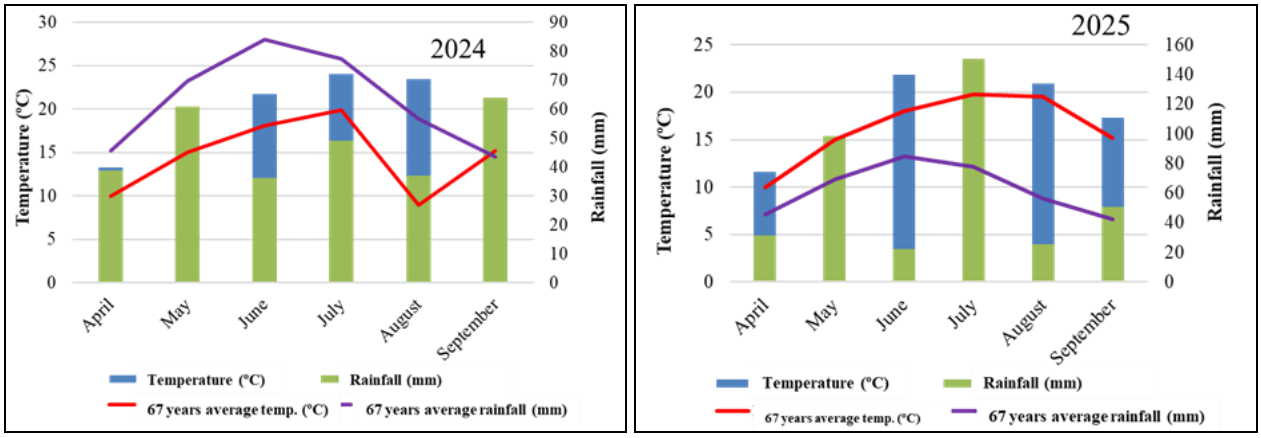


Figure 1. Thermal regime and rainfall regime of the experimental period (Turda, 2024-2025)

Regarding weed infestation in the soybean crop in 2024, two soil tillage systems, chisel and ploughing, were compared using 12 weed control methods (Figure 2). The results indicate the infestation level for each species, with error bars indicating variation among the 12 control methods. In both systems, *Setaria glauca* was dominant species, with higher plant numbers recorded under the conventional ploughing system, in some cases exceeding 25 plants. In contrast, under the conservative system, the values were more balanced and remained below 20 plants. Similar trends regarding the dominance of annual grasses in soybean crops under conventional tillage were also reported in studies conducted by Cociu, who highlighted the influence of soil disturbance intensity on the distribution of weed species (Cociu and Alionte, 2011; Cociu and Cizmaş, 2013).

Velykis and Satkus (2010) showed that conservative tillage system alters weed species composition relative to conventional tillage systems. Species such as *Amaranthus retroflexus* or *Stachys annua* occurred only sporadically, however, authors such as Hock et al. (2006) reported that broadleaf weeds, particularly, *Amaranthus retroflexus* and *Chenopodium album*, exhibit grater competitiveness with soybean than monocotyledonous or late-emerging weeds. Herbicide application, particularly pre- and post-emergence combinations, significantly reduced weed density, whereas mechanical control had a moderate effect. The chisel maintained a more balanced species compositions, while ploughing favoured the dominant species. Several studies indicate that conservative tillage system can lead to increased weed infestation in crops (Woźniak and Rachoń, 2019; Gawęda et al., 2020). The choice of the tillage system, together with the control method, influenced the community structure of the weed community and the stability however, Petcu et al. (2023) emphasize that weed infestation is strongly influenced by weather conditions of the experimental years.

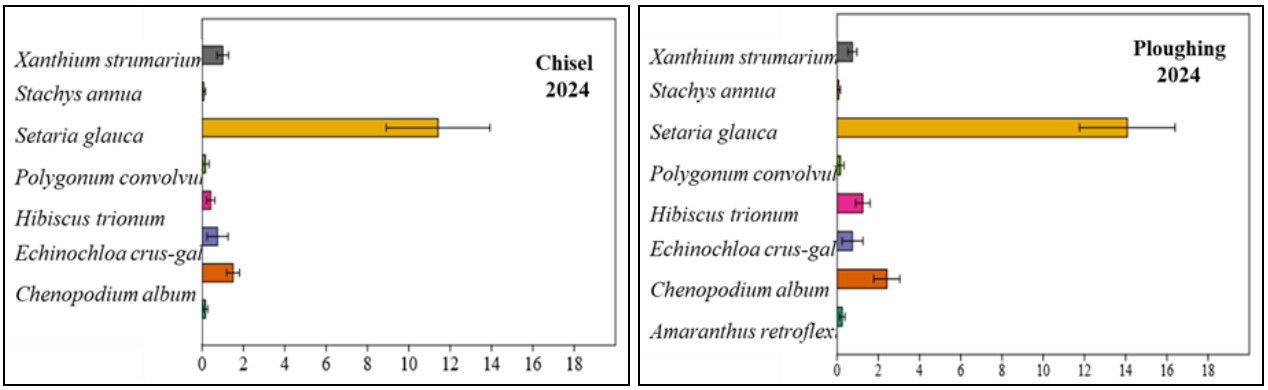


Figure 2. Existing weed species before harvest in 2024

In the second experimental year, analysis of the two tillage systems, ploughing and chisel, revealed clear differences in weed infestation before soybean harvest (Figure 3). Under the chisel system, weed pressure was much higher, with *Setaria glauca* strongly dominant, reaching levels up to three times those recorded under ploughing. Grasses were generally favoured by reduced soil disturbance. In contrast, ploughing system significantly reduced the density of most species and maintains a more uniform weed spectrum. These second year results confirm that ploughing provides more effective weed control than the chisel system. According to Campiglia et al. (2018), conservative tillage practices can increase the emergence of perennial weeds, often including species that are difficult to control, emphasizing the necessity of an appropriate weed control strategy.

Weed green biomass measured before the harvest showed that, although the monocot species *Setaria glauca* had a high number of individuals in both tillage systems, it did not produce a substantial vegetative mass. In contrast, the largest biomass was contributed by dicotyledonous species such as *Xanthium strumarium* and *Chenopodium album*, which develop extensively by maturity and cause difficulties during harvest (Figure 4). Gawęda et al. (2020) reported comparable findings, showing that the conservative tillage system leads to a marked increase in both the abundance and biomass of weeds compared with conventional tillage.

In 2025 (Figure 5), variant 6 despite the application of both pre-emergence and post-emergence chemical control targeting dicotyledonous weeds, recorded the highest measured plant biomass.

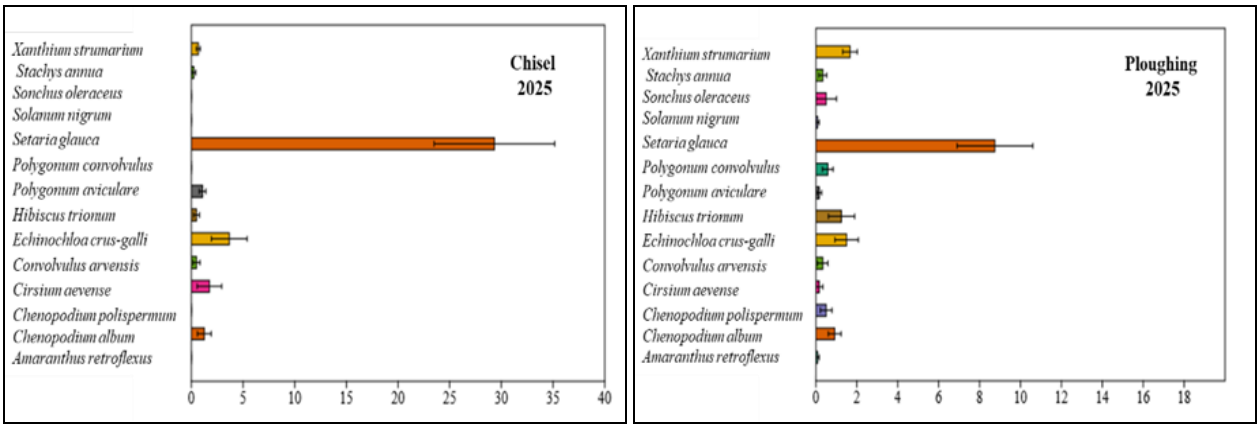


Figure 3. Existing weed species before harvest in 2025

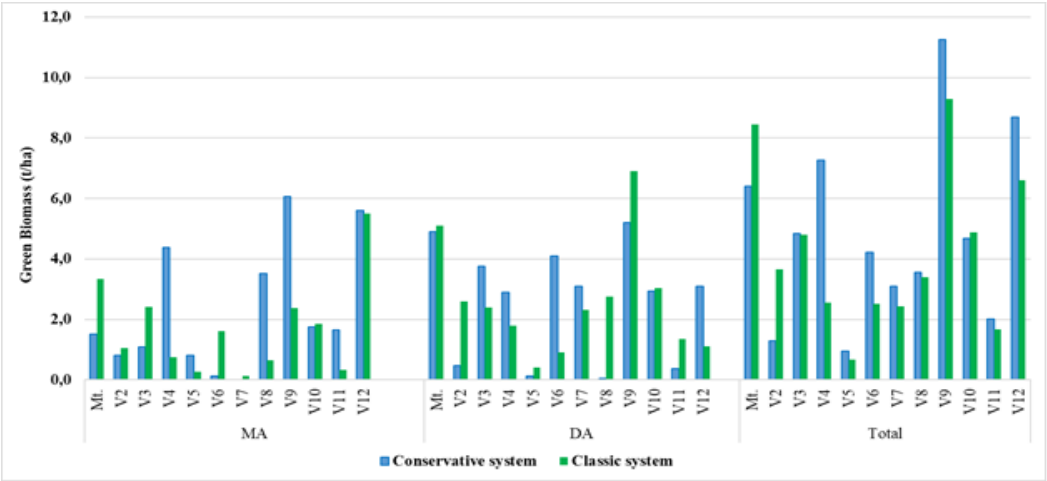


Figure 4. Green biomass of weeds in 2024
(MA - Annual monocotyledonous weeds; DA - Annual dicotyledonous weeds, Total: MA+DA)

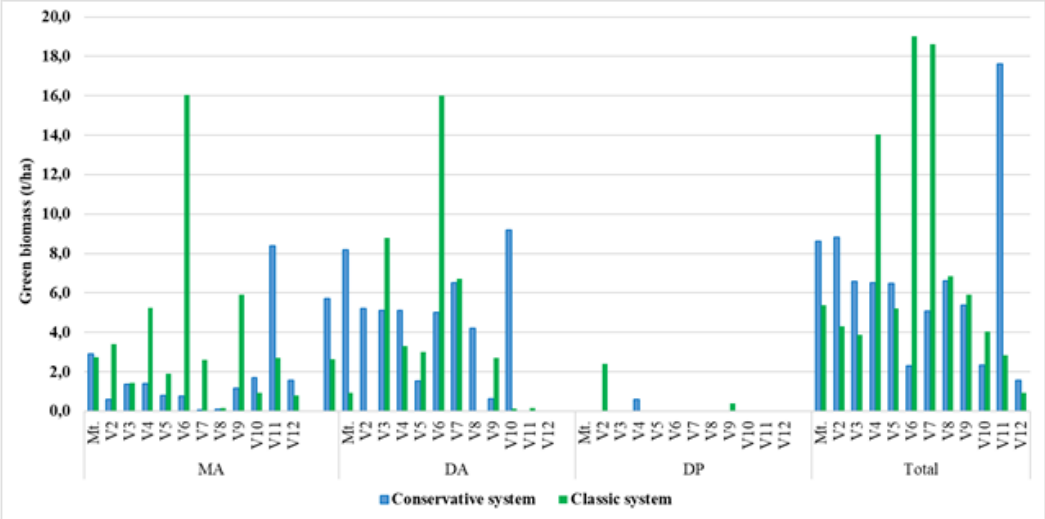


Figure 5. Green biomass of weeds in 2025 (MA - Annual monocotyledonous weeds; DA - Annual dicotyledonous weeds; DP - Perennial dicotyledonous weeds, Total: MA+DA+DP)

Average yields were higher under the ploughing system, while the chisel variant provided pronounced stability in production capacity (Figure 6). The highest results were achieved in variants combining chemical herbicide and mechanical control, confirming the effectiveness of integrated weed management, this approach is widely regarded as the most effective, a conclusion also supported by Datta and Knezevic (2013).

Maximum yield (2034 kg/ha) was recorded with ploughing and chemical weed control, whereas control variant produced 785 kg/ha under ploughing and 500 kg/ha under chisel. Chețan et al. (2022) reported a higher yield of 243 kg/ha under the conventional tillage system compared with the chisel tillage system.

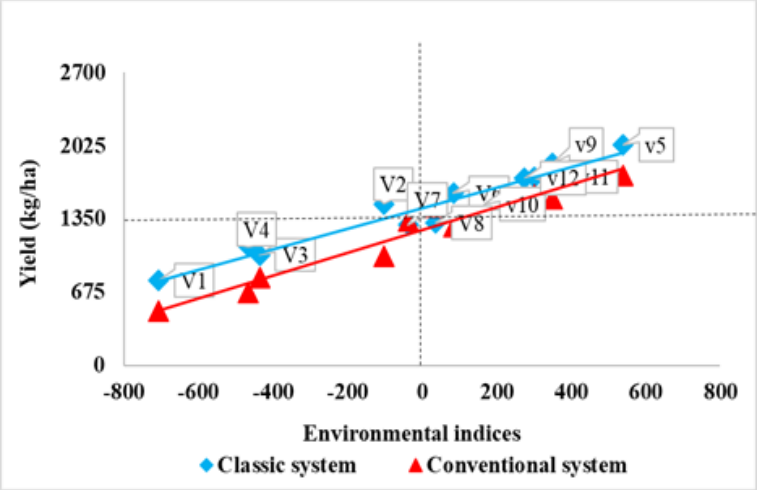


Figure 6. Effect of soil tillage system and weed control method on the yield of the soybean variety Felix

Thousand kernel weight was similar in both systems, averaging 137 g, but it was slightly higher and more stable under the chisel system (Figure 7).

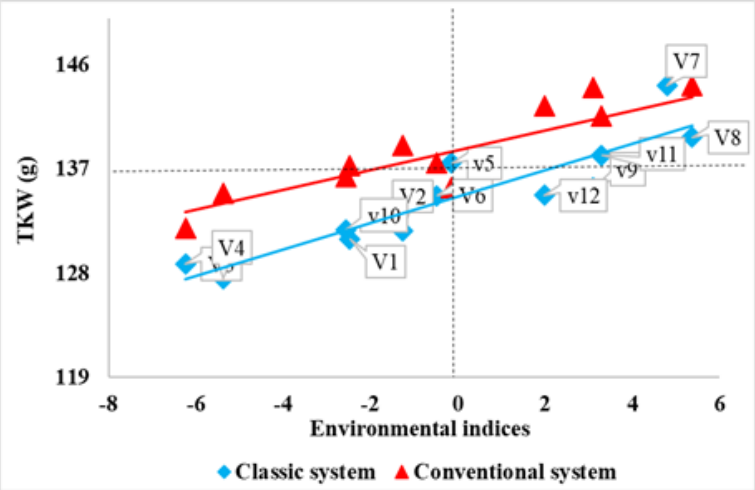
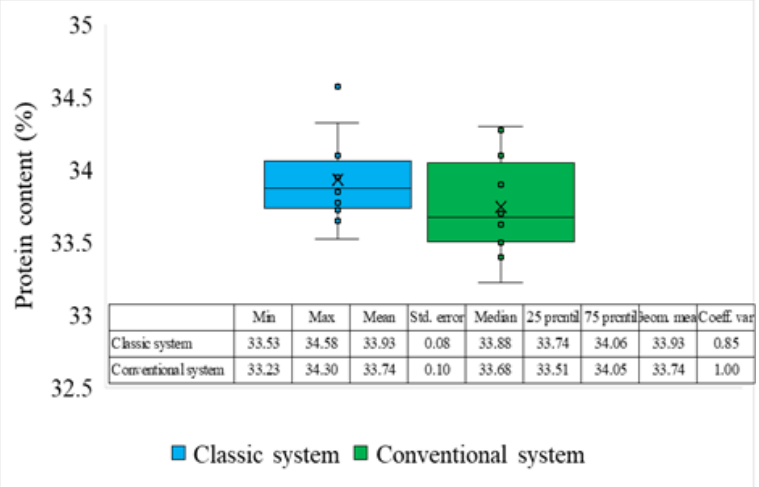


Figure 7. Effect of soil tillage system and weed control method on the thousand kernel weight (TKW) of the soybean variety Felix

As observed in crop yield, tillage system and weed control strongly affect performance. Examining seed quality, two clear trends emerge. For protein content (Figure 8), the conventional system provides slightly higher values, especially in variants with pre-emergent herbicide or in combination of pre-emergence herbicide and manual hoeing. These findings are consistent with those of Adamič and Leskovšek (2021), but in contradiction with Faligowska et al. (2025), who reported higher protein content under the conservative tillage system than under the conventional one.

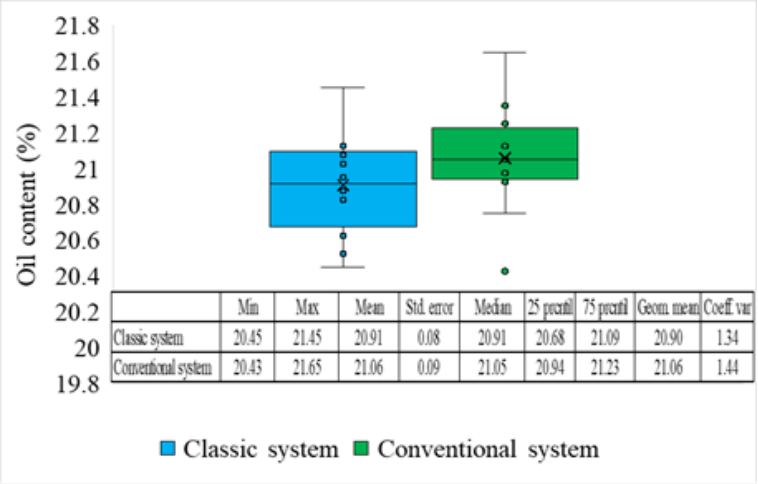


	Min	Max	Mean	Std. error	Median	25 prentil	75 prentil	Geom. mea	Coeff. var
Classic system	33.53	34.58	33.93	0.08	33.88	33.74	34.06	33.93	0.85
Conventional system	33.23	34.30	33.74	0.10	33.68	33.51	34.05	33.74	1.00

Figure 8. Effect of soil tillage system and weed control method on the protein content of the soybean variety Felix

In contrast, oil content was higher in the conservative system, reaching maximum levels in variants with post-emergence herbicide, combined pre + post-emergence herbicide or manual control (Figure 9), our results contradict those of Buczek et al (2022), who reported that conservative tillage reduces fat content.

The control variant showed the lowest values, highlighting the importance of weed management for achieving quality harvests.



	Min	Max	Mean	Std. error	Median	25 prcntil	75 prcntil	Geom. mean	Coeff. var
Classic system	20.45	21.45	20.91	0.08	20.91	20.68	21.09	20.90	1.34
Conventional system	20.43	21.65	21.06	0.09	21.05	20.94	21.23	21.06	1.44

Figure 9. Effect of soil tillage system and weed control method on the oil content of the soybean variety Felix

For stearic acid, both in classic system and in conservative, the values are very close. The range of variation is almost identical: ploughing: 4.9-5.1%, chisel: 4.95-5.175%, and the averages are 5.02% and 5.07%, respectively (Table 1). The medians and quartiles overlap, and the coefficient of variation is around 1.4% in both cases. This shows that stearic acid is very stable, and the working system does not significantly influence its distribution. For oleic acid, the differences are more noticeable. The ploughed system varies between 25.5 and 26.6%, and the chisel between 25.98 and 26.83%. The medians and quartiles are shifted to higher values in the conservative system, and the variability is lower (var. coef. 1.08% compared to 1.27%). The higher average in the conservative system, 26.44% compared to 26.18% in classic system, indicates a better and more uniform lipid composition. Compared to stearic acid which is not influenced by the tillage system, minimum tillage results in higher values and more stable distributions for oleic acid.

Table 1. Stearic and oleic acid profiles in soybean seeds as influenced by the soil tillage system

	Stearic		Oleic	
	Classic	Conservative	Classic	Conservative
N	12		12	
Min	4.90	4.95	25.50	25.98
Max	5.10	5.18	26.60	26.83
Mean	5.03	5.07	26.18	26.44
Std. error	0.02	0.02	0.10	0.08
Median	5.04	5.06	26.28	26.49
25 prcntil	5.00	5.01	26.03	26.14
75 prcntil	5.09	5.14	26.42	26.70
Geom. mean	5.02	5.07	26.18	26.44
Coeff. var	1.39	1.44	1.27	1.08

In the case of linoleic acid, we notice that the average values are very close between the two systems: approximately 52.3% in classic system and 52.4% in the conservative one (Table 2). The differences are minimal and the variability is low, which shows us that linoleic acid is very stable and is not influenced by the way the soil has been tilled or the herbicide methods used. And for linolenic acid the situation is similar. The averages are practically identical in both tillage systems, around 4.9%, and the statistical ranges confirm the same stability. Even though this acid shows slightly greater variability than linoleic, this does not indicate an effect of the technology applied. In short,

the results show us that neither the tillage system nor the methods of weed control visibly change the composition of the oil in soybeans.

Table 2. Linoleic and linolenic acid profiles in soybean seeds as influenced by the soil tillage system

	Linoleic		Linolenic	
	Classic	Conservative	Classic	Conservative
N	12		12	
Min	51.58	51.65	4.38	4.63
Max	53.23	53.33	6.08	5.28
Mean	52.31	52.40	5.24	4.92
Std. error	0.14	0.12	0.12	0.06
Median	52.30	52.44	5.23	4.89
25 prcntil	51.93	52.17	5.04	4.75
75 prcntil	52.43	52.55	5.42	5.08
Geom. mean	52.30	52.40	5.22	4.91
Coeff. var	0.90	0.81	7.99	4.23

These results suggest that soybean seed fatty acid profiles are relatively stable regardless of tillage system, consistent with previous findings that essential fatty acids are less affected by soil management practices.

CONCLUSIONS

The results of the two-year experiment demonstrated that proper weed management is essential for achieving high, stable and quality soybean yields.

Among the tillage systems analyzed, the ploughing system proved to be superior to the chisel system in terms of weed control, yield level and stability, as well as the quality of the grains.

Although the chisel system ensures good stability of production and quality components such as oil or oleic acid content, the weeding pressure, especially in the case of grasses, remains high.

On the other hand, the composition of essential fatty acids, linoleic and linolenic, remained stable, not influenced by the type of tillage or control methods applied.

Overall, under the pedoclimatic conditions at ARDS Turda, soybeans respond better to the conventional plowing system, and the integration of chemical control is confirmed as the most effective strategy.

The results obtained within the ADER 141 project underline the need to develop a viable technological system adapted to the specific conditions and needs of soybean farmers in Romania.

ACKNOWLEDGEMENTS

This work was supported by Ministry of Agriculture and Rural Development, ADER project financing contract no. 1.4.1./19.07.2023: „Improving weed control methods for soybean crops in order to increase economic efficiency by reducing the number of treatments and the negative impact on the environment”.

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