

INVESTIGATION OF PRODUCTIVE AND NUTRITIONAL VARIABILITY IN SUNFLOWER HYBRIDS IN PEDOCLIMATIC CONDITIONS SPECIFIC TO THE WESTERN ROMANIA

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Abstract

This paper aims to analyze the performance of five sunflower hybrids in the agricultural years 2023 and 2024 by evaluating physical and quality indicators. The experimental setup was located in the moderate continental climate with sub-Mediterranean influences, specific to the West of Romania, specifically Banat's microclimate. Average productions recorded significant increases in 2024, with an increase of around 16%, attributable to favorable climatic conditions and technological advances. Hybrids LE99 and SURELI HTS showed the highest yields, while AROMATIC SU showed the most modest results. Harvest humidity ranged between 4.0-5.5%, registering decreases in 2024 for all hybrids, confirming better ripening conditions; DAVERO stood out for its lowest values. Quality analyses indicated differences between hybrids, with LE99 demonstrating superior mineral content (2.99%), crude protein (19.33%) and total fat (35.73%), associated with a higher quality oil and a slightly higher energy value. The carbohydrate content ranged from 38.43% to 41.61%, with AROMATIC SU showing higher values. The results confirm the high agronomic and nutritional potential of the analyzed hybrids focusing on optimization of production and recovery processes.

Key words: sunflower hybrids, productions, quality analyses.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most important oilseed crops cultivated worldwide, ranking fourth after palm oil, soybean, rapeseed and sunflower in global vegetable oil production (Eurostat, 2023; FAOSTAT, 2023). In Europe, and particularly in Romania, sunflower represents a strategic crop due to its adaptability to semi-arid conditions and its high oil content, which may exceed 45% depending on genotype and environmental conditions (Skoric et al., 2012; Kaya et al., 2019).

Romania consistently ranks among the leading sunflower producers within the European Union, benefiting from favorable pedoclimatic conditions in regions such as the Western Plain and Banat area (Eurostat, 2023; Imbrea & Mocioi, 2001). However, increasing climatic variability characterized by irregular rainfall distribution, prolonged drought periods, and high summer temperatures has intensified the need for stable and adaptable hybrids (IPCC, 2021; Olesen et al., 2011).

Sunflower productivity is strongly influenced by genotype × environment interaction. Yield performance depends on hybrid genetic potential, soil fertility, crop management practices, and climatic factors during critical phenological stages (Unger & Thompson, 2018; Hussain et al., 2018). Moreover, harvest moisture plays a key role in post-harvest management, influencing storage stability and processing costs.

Beyond yield, the nutritional composition of sunflower seeds is of increasing interest for both the food and feed industries. Sunflower seeds are valued for their high lipid content, favorable fatty acid profile, protein concentration, and mineral composition (Salas et al., 2014; Grompone, 2011). The balance between saturated and unsaturated fatty acids determines oil quality and market value.

Crude protein content generally ranges between 15–20%, while oil concentration may vary depending on hybrid and environmental conditions (Dreccer et al., 2007). Mineral content also contributes to nutritional value and

reflects nutrient uptake efficiency under specific soil conditions (Marschner, 2012).

Given the increasing demand for sustainable oilseed production systems, evaluating both productive and nutritional variability of sunflower hybrids under specific regional conditions becomes essential (Velasco et al., 2016; Zheljazkov et al., 2008). Western Romania, characterized by moderate continental climate with sub-Mediterranean influences, offers a relevant framework for assessing hybrid adaptability and performance stability.

The vegetal fats contain mostly unsaturated fatty acids such as: oleic, linoleic, linolenic, arachidonic, ricinoleic, erucic and saturated fatty acids such as palmitic and others (Panaiteescu et al., 2011). An important index by which vegetal oils can be appreciated and classified is the iodine index, namely the grams of iodine fixed by 100 g of oil (Tabără et al., 2018)

Therefore, the objective of this study was to investigate the productive and qualitative variability of five sunflower hybrids cultivated under Western Romanian pedoclimatic conditions during the agricultural years 2023–2024, focusing on yield performance, harvest moisture, and key nutritional indicators.

MATERIALS AND METHODS

The study was conducted on five sunflower hybrids (*Helianthus annuus* L.): AROMATIC SU, CEYLON SU, DAVERO SU, P64LE99, and SURELI HTS, evaluated during the 2023–2024 experimental cycle. These hybrids were selected to compare agronomic performance, seed quality, and nutritional potential under variable pedoclimatic conditions.

The experiments were monofactorial and arranged in the field using the randomized block method. During the two experimental years, the following hybrids were cultivated:

- P64LE99 (Pioneer);
- SURELI HTS (Syngenta);
- CEYLON SU (Lidea);
- AROMATIC SU (Lidea),
- DAVERO (Saaten Union).

Sunflower hybrids show good plasticity and adaptability and respond well to intensive cultivation conditions. The results obtained for these hybrids are good across all regions of Romania.

The objectives of the research fall within the main goals of sunflower cultivation: selecting the most suitable hybrids for each area and developing economically efficient and environmentally friendly cultivation technologies, correlated with crop requirements and the pedoclimatic characteristics of each region.

In this context, the research presented in this paper aimed to perform comparative trials with five sunflower hybrids and to evaluate the nutritional value of sunflower seeds under the pedoclimatic conditions of the Pecica area. The preceding crop was rapeseed.

In April, two insecticide treatments were carried out using SUMI ALPHA (esfenvalerate 5%), applied at a rate of 0.2 l/ha on 16.04 and 27.04.2024, targeting early-season pest pressure.

During May, post-emergence herbicide applications were implemented in accordance with the herbicide tolerance technology specific to each sunflower hybrid. The experiment was formed with the expresssun hybrids SURELI HTS (Syngenta), P64LE99 (Pioneer), CEYLON SU and AROMATIC SU (Lidea), as well as DAVERO SU (Saaten Union), a tribenuron-methyl-based herbicide FLUENCE was applied 30 g ha⁻¹, in line with their specific tolerance to sulfonylurea herbicides, providing selective control of dicotyledonous weeds.

Additionally, EVOLUTIO (cletodim 140 g/l and quizalofop-P-ethyl 70 g/l, 0.5 l/ha) was applied uniformly across all variants for the control of annual and perennial grass weeds, complementing the broadleaf weed management strategy.

The soil on which the experiment was established is classified as gleic chernozem.

The area where the experiment was conducted falls within a moderate continental climate, at the interference between the climatic province sector with oceanic influences and the sector with sub-Mediterranean influences, specific to the southwestern part of the country, corresponding to the microclimate characteristic of the Banat region.

This area is characterized by a temperate climate with precipitation throughout the year, but with moisture deficits during the summer months. The average annual precipitation would provide favorable conditions for most agricultural crops if it were evenly distributed throughout the year

and appropriately distributed across months. In some years, deviations occur from the multiannual averages of temperature and precipitation, especially regarding their distribution during the crop vegetation period. These deviations can be corrected through appropriate agrotechnical measures (drainage and controlled soil water storage) as well as through careful adaptation of cultivation technologies to climatic parameters.

Compared to the multiannual average of 13.6°C, the spring and summer of 2023 can be considered very warm from a thermal perspective (Figure 1). The year 2024, like the previous one, was also very warm, especially during the summer months.

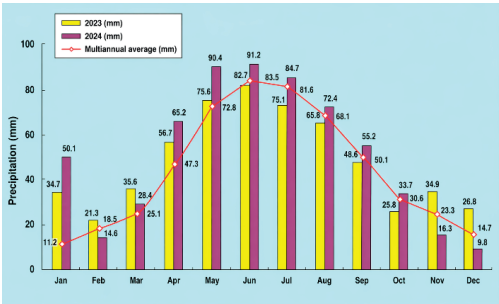


Figure 1. Average monthly temperatures (°C) recorded during the experiment period (Sănnicolau Mare Meteorological Station)

Overall, compared to the multiannual averages, both years can be characterized as very warm throughout the sunflower vegetation period. The multiannual precipitation as well as the precipitation recorded during the experimental period (2023-2024) are shown in Figure 2.

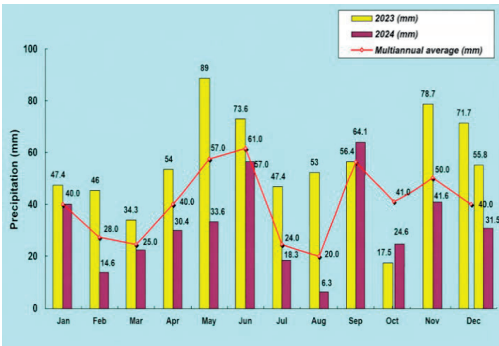


Figure 2. Average monthly rainfall (mm) recorded during the experiment period (Sănnicolau Mare Meteorological Station)

Compared to the multiannual average (430 mm), the year 2024, with a total precipitation of 315 mm, can be considered very dry overall, including during the sunflower vegetation period.

The year 2023, with a total precipitation of 558 mm, although overall relatively dry, provided favorable water supply conditions for sunflower during the vegetation period (except for July, when abundant rainfall created harvesting difficulties). These different conditions visibly influenced the level of weed infestation as well as the sunflower yields obtained.

The main chemical components of the oilseed samples were determined according to ISO standard methods, as follows:

Seed moisture content (%) was determined in accordance with ISO 665. The method is based on drying a known mass of sample in an oven (typically at $103 \pm 2^\circ\text{C}$) until constant weight, the loss in mass being expressed as moisture content.

Mineral content (%) (ash) was determined using ISO 749. The sample is incinerated in a muffle furnace at approximately 550°C until complete combustion of organic matter, and the remaining inorganic residue is weighed.

Crude protein content (%) was determined by the Kjeldahl method according to ISO 5983-1. The method involves digestion of the sample in sulfuric acid, distillation of the released ammonia, and titration; the nitrogen content is converted to protein using an appropriate factor (usually 6.25).

Total fat content (%) was determined in accordance with ISO 659 by solvent extraction (e.g., Soxhlet). The oil is extracted with an organic solvent, the solvent is removed, and the residue is weighed as total fat.

The relatively low fat content values recorded in the present study (34.14-35.73%) can be explained by the combined influence of pedoclimatic conditions and sample characteristics.

Firstly, the experimental years were characterized by high temperatures throughout the growing season and significant water deficit, particularly in 2024, when total precipitation reached only 315 mm compared to the multiannual average of 430 mm. These conditions, especially during the seed filling period, are known to limit lipid biosynthesis and oil accumulation in sunflower seeds.

Secondly, the analysis was performed on intact seeds (whole seed samples), including the hull fraction. This aspect is important, as the presence of the hull reduces the relative proportion of extractable lipids compared to values reported for dehulled kernels, which are typically higher in oil content.

Therefore, the obtained fat content values should be interpreted as representative of whole seeds cultivated under drought-affected conditions, rather than as maximum oil concentrations under optimal conditions.

It is also worth noting that the use of the ISO 659 reference method (Soxhlet extraction) ensures that the reported values reflect the actual lipid content of the analyzed samples and are not underestimated due to methodological limitations.

Fatty acid composition (% saturated) was analyzed by gas chromatography following preparation of fatty acid methyl esters, according to ISO 12966-2. Individual fatty acids are separated and quantified, allowing calculation of the proportion of saturated fatty acids.

Carbohydrate content (%) was calculated by difference, using the relation:

$$\text{Carbohydrates(\%)} = 100 - (\text{moisture} + \text{protein} + \text{fat} + \text{ash})$$

This indirect method assumes that carbohydrates represent the remaining fraction after the quantified components.

RESULTS AND DISCUSSIONS

The comparative analysis of sunflower hybrid performance during the agricultural years 2023 and 2024 was based on seed yield (kg/ha) as the main indicator, according to the data presented in Table 1.

Table 1. Analysis of production results in the 2023-2024 experimental cycle

Variant	Yield (kg/ha)		Difference (kg/ha)	Relative difference (%)
	2023	2024		
Field average	2416	2807	391	16
AROMATIC SU	1860	2139	279	15
CEYLON SU	2330	2749	419	18
DAVERO SU	2080	2412	332	16
P64LE99	3020	3503	483	16
SURELI HTS	2790	3236	446	16

The objective of this evaluation was to identify hybrids characterized by high yield potential,

production stability, and adaptability to varying pedoclimatic conditions.

The obtained results, supported by comparative graphical representations and the table of relative differences, indicate a favorable evolution of the analyzed genetic material.

The comparison of seed yields between the two years highlights a general increase in productivity, with relative values ranging between 15% and 18%.

The field average yield increased from 2416 kg/ha in 2023 to 2807 kg/ha in 2024, representing an absolute gain of 391 kg/ha, equivalent to a relative increase of 16%. This positive trend can be attributed to more favorable climatic conditions.

The hybrid AROMATIC SU recorded the lowest yields in both experimental years (1860 kg/ha in 2023 and 2139 kg/ha in 2024). Although the relative increase of 15% is close to the field average, the absolute gain of 279 kg/ha suggests a limited yield potential.

The hybrid CEYLON SU showed an increase of 419 kg/ha (18%), representing the highest relative gain among the analyzed variants, indicating a strong responsiveness to the favorable conditions of 2024.

The hybrid DAVERO SU achieved a yield increase of 332 kg/ha (16%), corresponding exactly to the field average, which reflects good agronomic stability and consistent performance under different growing conditions.

The hybrid P64LE99 recorded the highest absolute yields in both years (3020 kg/ha in 2023 and 3503 kg/ha in 2024), with a gain of 483 kg/ha (16%). This hybrid combines high yield potential with very good production stability.

The hybrid SURELI HTS registered an increase of 446 kg/ha, maintaining the same relative growth rate (16%) as the field average. Its consistently high yield level indicates good agronomic performance and high stability.

Harvest moisture analysis of sunflower hybrids (AROMATIC SU, CEYLON SU, DAVERO SU, P64LE99, and SURELI HTS) during the 2023-2024 growing seasons revealed values ranging between 4.0% and 5.5% (Figure 3). A general decrease in moisture in 2024 compared to 2023 suggests the influence of warmer and drier climatic conditions, promoting natural seed dehydration.

The DAVERO SU hybrid exhibited the lowest and most stable moisture content (4.1% in 2023 and 4.0% in 2024), indicating uniform maturity and superior adaptability for mechanical harvesting and storage without artificial drying. In contrast, AROMATIC SU and P64LE99 showed higher moisture levels (5.5% in 2023 and 5.0% in 2024), still within safe storage limits, while CEYLON SU and SURELI HTS presented intermediate values, with a noticeable decrease in 2024.

The similar curve patterns between the two years highlight the predictable and stable behavior of these hybrids regarding moisture loss. Low moisture values allow direct seed storage, reducing risks of mold, rancidity, and oil quality deterioration, and provide economic advantages in post-harvest handling by lowering drying and handling costs.

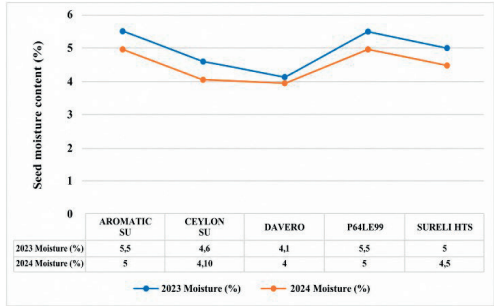


Figure 3. Analysis of moisture content in the five sunflower hybrids in the experimental cycle 2023-2024

Analysis of mineral content in two sunflower hybrids, AROMATIC SU and P64LE99

Sunflower (*Helianthus annuus* L.) is one of the most important oilseed crops in Romanian agriculture due to its ability to adapt to diverse pedoclimatic conditions, as well as its high seed oil content. Crop quality is influenced by genetic, agronomic, and environmental factors, and one of the relevant indicators for assessing seed nutritional value is mineral content. Minerals in sunflower seeds include essential macronutrients (phosphorus, potassium, calcium, magnesium) and micronutrients (zinc, iron, manganese, copper), which play a crucial role in plant metabolism and seed quality. The P64LE99 hybrid showed a mineral content of 2.99%, higher than the AROMATIC SU hybrid, which recorded 2.74% (Figure 4).

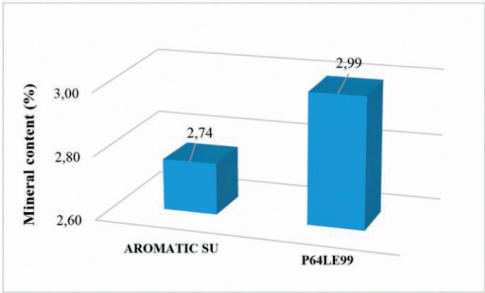


Figure 4. Mineral content (%)

Although the differences are seemingly small, they provide useful information regarding the agronomic behavior of the hybrids in terms of soil mineral uptake and their nutritional potential. A difference of 0.25% may appear minor, but it can have significant effects on the nutritional value of the seeds and the quality of the oil produced.

The values obtained fall within the normal range for sunflower.

Analysis of crude protein content in sunflower hybrids AROMATIC SU and P64LE99

Beyond their high oil content, one of the key indicators for evaluating seed quality is the crude protein content. Crude protein content represents the total percentage of organic nitrogen converted into protein and is essential for assessing the nutritional value of seeds, particularly for use as feed or for protein concentrate extraction.

The P64LE99 hybrid, with a crude protein content of 19.33%, exceeds the AROMATIC SU hybrid by approximately 0.69% (Figure 5). Both values (18.64% and 19.33%) are above average for sunflower, reflecting favorable growing conditions and appropriate cultivation practices.

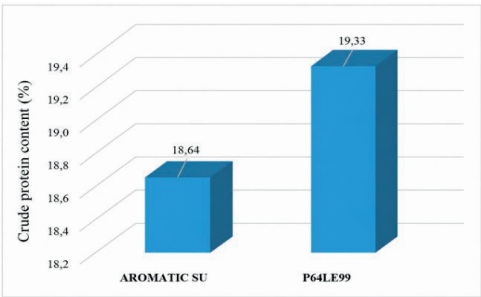


Figure 5. Crude protein content (%)

Analysis of total fat content and saturated fatty acids in sunflower hybrids AROMATIC SU And P64LE99

The total fat content and its composition in fatty acids - particularly the proportion of saturated fatty acids - are essential indicators in assessing seed quality.

The P64LE99 hybrid has a higher fat content (35.73%) compared to Aromatic SU (34.14%), as shown in Figure 6.

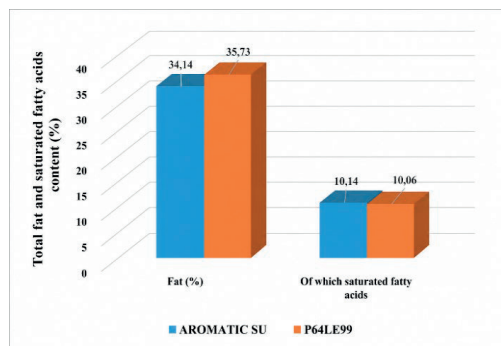


Figure 6. Total fat and saturated fatty acid content

The difference of 1.59 percentage points is significant for the industry, as it translates into greater efficiency in oil extraction. Saturated fatty acids are considered less healthy from a nutritional standpoint, and a lower content is desirable in vegetable oils. P64LE99 has a slightly lower proportion of saturated fatty acids, making it somewhat more advantageous nutritionally.

This suggests that P64LE99 not only produces more oil but also a slightly “healthier” one.

Carbohydrate analysis by difference (%)

Carbohydrates by difference in sunflower seeds represent the amount of carbohydrates estimated indirectly, by subtracting the known components of the product from 100%: water, proteins, lipids (fats), fiber, and ash (minerals). Carbohydrates by difference in sunflower seeds are a moderate source of energy, part of a complex nutritional profile along with healthy fats, proteins, and fiber. These figures (Figure 7) indicate that, in each type of sunflower, approximately 41.61% and 38.43% of the total seed mass is composed of carbohydrates

calculated by difference (i.e., what remains after subtracting water, fats, proteins, fiber, and ash).

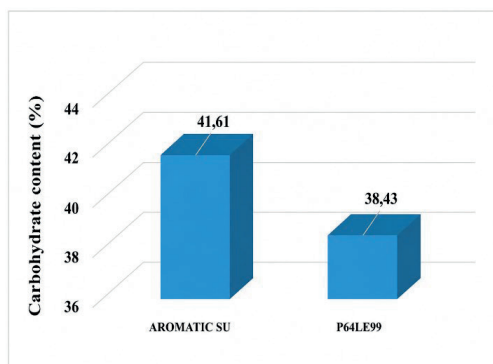


Figure 7. Carbohydrate analysis by difference (%)

Values over 38% are relatively high for sunflower seeds, which means that the AROMATIC SU and P64LE99 hybrids have either fewer fats (which usually dominate sunflower seeds) or more dry matter rich in carbohydrates (likely starch or complex sugars). AROMATIC SU (41.61%) has a slightly higher carbohydrate content compared to P64LE99 (38.43%). The difference of approximately 3.2% could be significant in certain uses (e.g., animal feed, industrial processing, dietary products).

Energy value

The energy value represents the amount of energy that a food provides to the body through digestion and metabolism. Usually expressed in kilocalories (kcal) or kilojoules (kJ), this value is essential both for assessing the nutritional contribution of foods and for rational diet planning, in both human and animal contexts.

The energy value of a food is determined based on its macronutrient content: proteins, lipids (fats), and carbohydrates. From the presented figure (Figure 8), both hybrids have over 540 kcal/100 g, which means they are very calorie-dense. These values are characteristic of foods high in fat. The P64LE99 hybrid has an energy value 4.35 kcal higher than AROMATIC SU.

This difference is small (less than 1%), so it may result from natural variations between batches (differences in fat, moisture, or protein content).

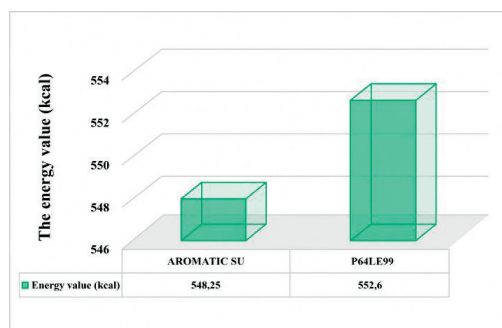


Figure 8. The energy value of the two sunflower hybrids

CONCLUSIONS

- Overall, all variants showed increases in yield in 2024 compared to 2023, indicating favorable agronomic conditions.
- Regarding moisture content, there was an improvement in harvest quality in 2024, with all five analyzed hybrids reaching levels that allow safe and efficient storage without additional treatments. This reflects a successful combination of hybrid selection and favorable harvesting conditions in the 2024 growing season.
- The P64LE99 hybrid exhibits a higher mineral content compared to AROMATIC SU, which may indicate more efficient nutrient uptake and greater agronomic potential.
- P64LE99 stands out with a higher protein content, making it suitable for uses where the nutritional quality of the seeds is a priority.
- P64LE99 surpasses AROMATIC SU in total fat content, showing higher oil-producing potential. The 1.59% difference in favor of P64LE99 can translate into increased economic yield during oil extraction.
- Saturated fatty acid content is nearly identical, with a slight advantage for P64LE99 (0.08% lower). P64LE99 presents itself as a balanced hybrid, offering both high oil productivity and a favorable fat composition.
- AROMATIC SU is richer in carbohydrates than P64LE99, making it potentially more suitable for applications where a higher energy contribution from carbohydrates is desired (e.g., animal feed, certain processed foods). P64LE99's slightly lower carbohydrate content may indicate higher fat content (beneficial for oil extraction) and a more balanced composition for human or industrial use.

- Although both hybrids have high energy content, P64LE99 stands out with a slightly higher energy value, which has direct technological and economic implications.

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