

EVALUATION AND DEVELOPMENT OF SUNFLOWER HYBRIDS ADAPTED TO CURRENT ENVIRONMENTAL CONDITIONS IN ROMANIA

Emilian ONIȘAN¹ (ORCID: 0009-0003-6288-8738), Nicolae Marinel HORBALAGA^{1*}, Ionel SAMFIRA¹ (ORCID: 0000-0002-0926-6564), Cristian MATE³, Irina PETRESCU³ (ORCID: 0009-0008-9815-5815)

¹ Agricultural Research and Development Station Lovrin: marinel.horablaga@scdalovrin.com;

² Faculty of Agriculture, University of Life Sciences "King Mihai I" from Timișoara, 119 Calea Aradului Street, 300645, Romania: marinel_horablaga@usvt.ro, ionelsamfira@usvt.ro, emilian.onisan@usvt.ro

³ Faculty of Engineering and Applied Technologies, University of Life Sciences "King Mihai I" from Timișoara, 119 Calea Aradului Street, 300645, Romania: Cristian.mate@usvt.ro; irinapetrescu@usvt.ro
Corresponding author: marinel.horablaga@scdalovrin.com

Abstract: Sunflower cultivation became more difficult as climate change influenced temperature and precipitation distribution. Romania is one of the most important countries in Europe for the cultivation of this crop. Therefore, it became one of the most important centers for testing sunflower hybrids. In this study, we evaluated 12 newly developed sunflower hybrids along with 3 commercial hybrids as references to identify material adapted to current Romanian growing conditions. The experiment was conducted at the Agricultural Research and Development Station Lovrin during two consecutive growing seasons (2024–2025). During the study we analyzed yield, flowering time, physiological maturity, seed oil content, oleic acid content, linoleic acid content, and plant height. Correlation analysis demonstrates strong positive associations between yield and oil content ($r = 0.75$). Additionally, oil yield and maturity exhibit a positive correlation ($r = 0.69$). According to the results, cluster analysis had identified Hib13, Hib14, Hib15, Hib11, and Hib10 as superior high-oleic hybrids with favorable adaptation and performance under Romanian conditions. Other research reports confirm these findings. However, further multi-environment testing is required to confirm the stability and adaptability in Romania of the selected hybrids, as the environment was determining factor of traits evaluated ($p < 0.05$).

Keywords: sunflower breeding; yield; oil content; correlation analysis; hybrid adaptation.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is an increasingly important source of edible vegetable oil worldwide due to its high content of polyunsaturated fatty acids and the absence of cholesterol (FRANCOIS, 1996). Cultivated on more than 28 million hectares, with an annual seed production exceeding 55 million tons worldwide, sunflower demonstrates remarkable adaptability to diverse climatic conditions, although environmental factors can significantly influence hybrid performance. Romania is among the leading sunflower producers within the European Union, frequently cultivating more than one million hectares annually (ABDILOVA et al., 2023; ION et al., 2015).

In sunflower breeding programs, seed yield and oil content remain the primary objectives (RADANOVIĆ et al., 2018). The development of hybrids with superior performance and adaptability begins with the creation and selection of inbred lines. However, several factors limit the rapid development of new hybrids and parental lines. One of the major constraints in

sunflower breeding is the large number of generations required to achieve genetic stabilization. Nevertheless, biotechnological approaches can substantially reduce the time required for cultivar development.

Specifically, the application of *in vitro* culture techniques for cycle enhancement through immature embryo rescue represents one of the most effective technologies for accelerating breeding programs (BRECCIA et al.; CHOWDHURY, 2015; ONISAN et al., 2025). However, the implementation of biotechnological methods requires additional financial resources, specialized equipment, and trained personnel.

Therefore, reducing breeding costs and optimizing the use of biological material remain important objectives for breeding programs. Early selection of biological material using conventional methods may provide an efficient alternative for breeders. Identifying correlations among yield components, oil content, flowering traits, and plant architecture may facilitate the early classification and selection of promising breeding material (BILGEN et al., 2018; ONISAN et al., 2023). Previous studies have shown that seed yield is positively associated with the number of seeds per capitulum, seed mass per capitulum, capitulum diameter, and leaf area, whereas oil content is favored by a high kernel percentage and a reduced hull content (HLADNI et al., 2006; MIJIĆ et al., 2009). Moreover, photosynthetic efficiency and biomass accumulation contribute substantially to yield improvement. In contrast, oil content is strongly influenced by kernel proportion and environmental conditions during the seed-filling period (SADRAS & VILLALOBOS, 2021).

The objectives of the present study were: (i) to evaluate newly developed sunflower hybrids under the pedoclimatic conditions of Romania and (ii) to identify relationships among seed yield, oil content, maturity, flowering traits, and plant height in order to determine factors that may influence breeding efficiency and support sunflower improvement programs.

MATERIAL AND METHODS

For the experiment, three commercial sunflower hybrids (Hib1, Hib2, and Hib3) were used as reference hybrids for the evaluation of newly developed genotypes. In addition, 12 newly developed sunflower hybrids were included in the study.

The experiment was conducted at the Lovrin Agricultural Research and Development Station during the 2024 and 2025 growing seasons. The experimental hybrids were evaluated for oil yield (kg ha^{-1}), days to physiological maturity, seed oil content (%), oleic acid content (%), linoleic acid content (%), days from sowing to flowering, plant height (cm), and head curvature ($^{\circ}$) (KAYA et al., 2012; ONISAN et al., 2023).

The experiment was carried out over two growing seasons, with three replications each year. Each microplot covered an area of 22.5 m^2 and consisted of four rows, 10 m in length, with 0.75 m spacing between rows. Plant spacing was 0.30 m within rows and 0.75 m between rows. To minimize border effects, only the two central rows of each plot were considered for the evaluation of the studied parameters. A basal NPK fertilizer (15:15:15) was applied before sowing at a rate of 200 kg ha^{-1} . Sowing was performed on 15 April.

Conventional cultivation practices were applied throughout the experiment. For weed control, Pantera 40 EC herbicide (quizalofop-P-tefuryl 40 g L^{-1} , 1.0 L ha^{-1}) was used (AUTHORITY (EFSA) et al., 2017). Harvesting was carried out after physiological maturity, when seed moisture content reached approximately 9%. Maturity references were established using Hib1 as a semi-early commercial hybrid and Hib2 and Hib3 as semi-late commercial hybrids.

Hybrids were harvested simultaneously, as the determination of maturity groups can be challenging under field conditions. Therefore, maturity classification was expressed relative to the moisture content of the reference hybrids. Oil content and fatty acid composition were determined using spectrometric procedures (MATTHÄUS & BRÜHL, 2001).

All obtained data were subjected to statistical analysis. Analysis of variance (ANOVA) was performed to assess significant differences among the analyzed hybrids (ABDILOVA et al., 2023). Descriptive statistical analyses were performed using Tukey's multiple comparison test. Significant differences among hybrids were identified using Compact Letter Display (CLD) at a significance level of $p < 0.05$.

Furthermore, Pearson correlation analysis was performed to examine relationships among agronomic, morphological, and quality traits. Principal component analysis (PCA) was conducted to investigate multivariate relationships among the evaluated parameters. All statistical analyses, graphical representations, dendrogram construction, and correlation coefficient calculations were performed using RStudio software (DEGE & BRÜGGEMANN, 2024).

RESULTS AND DISCUSSIONS

The study was conducted over two consecutive years (2024 and 2025). Analysis of variance (Table 1) revealed that genotype had a highly significant effect on the evaluated agronomic, morphological, and quality traits.

According to the results, genotypic impact with the highest variations was registered for oleic acid content linoleic acid content ($p < 0.001$) and overall oil yield ($p < 0.001$). However, different environments did not influence the yield and oil content homogeneity of the hybrids. The results suggest that the oil composition, particularly oleic and linoleic acid contents, is influenced by environmental factors.

Results suggest also that maturity was significantly affected by both genotype ($p < 0.001$) and year ($p < 0.05$), a clear indicator that environmental conditions slightly altered the the growing cycle and the of genetic factor on the control of maturity. Similarly, flowering period was significantly affected by both genotype and year ($p < 0.001$).

Table 1.

Analysis of variance for oil yield, phenological, morphological, and quality traits.				
Trait	Genotype (F)	Genotype (p)	Year (F)	Year (p)
Yield (kg ha ⁻¹)	365.26	< 0.001 ***	0.64	0.436
Maturity (days)	181.39	< 0.001 ***	4.65	< 0.05 *
Oil Content (%)	18.95	< 0.001 ***	3.19	0.096
Oleic Acid (%)	1183.96	< 0.001 ***	9.89	< 0.01 **
Linoleic Acid (%)	1183.96	< 0.001 ***	9.89	< 0.01 **
Flowering (days)	3.25 × 10 ²⁸	< 0.001 ***	7.99 × 10 ²⁷	< 0.001 ***
Plant Height (cm)	5.72	< 0.01 **	11.57	< 0.01 **

Note: ns = non-significant ($p > 0.05$); * = significant at $p < 0.05$; ** = significant at $p < 0.01$; *** = significant at $p < 0.001$.

On the morphological aspect, plant height was significantly influenced by genotype ($p < 0.01$) and year ($p < 0.01$). Proportionally, year had a greater impact on most traits. This reflects the importance of developing hybrids adapted to climatic conditions, as it is the most sensitive factor influencing the general parameters (Table 1). Substantial genetic variability among the hybrids analyzed where registered (Figure 1)

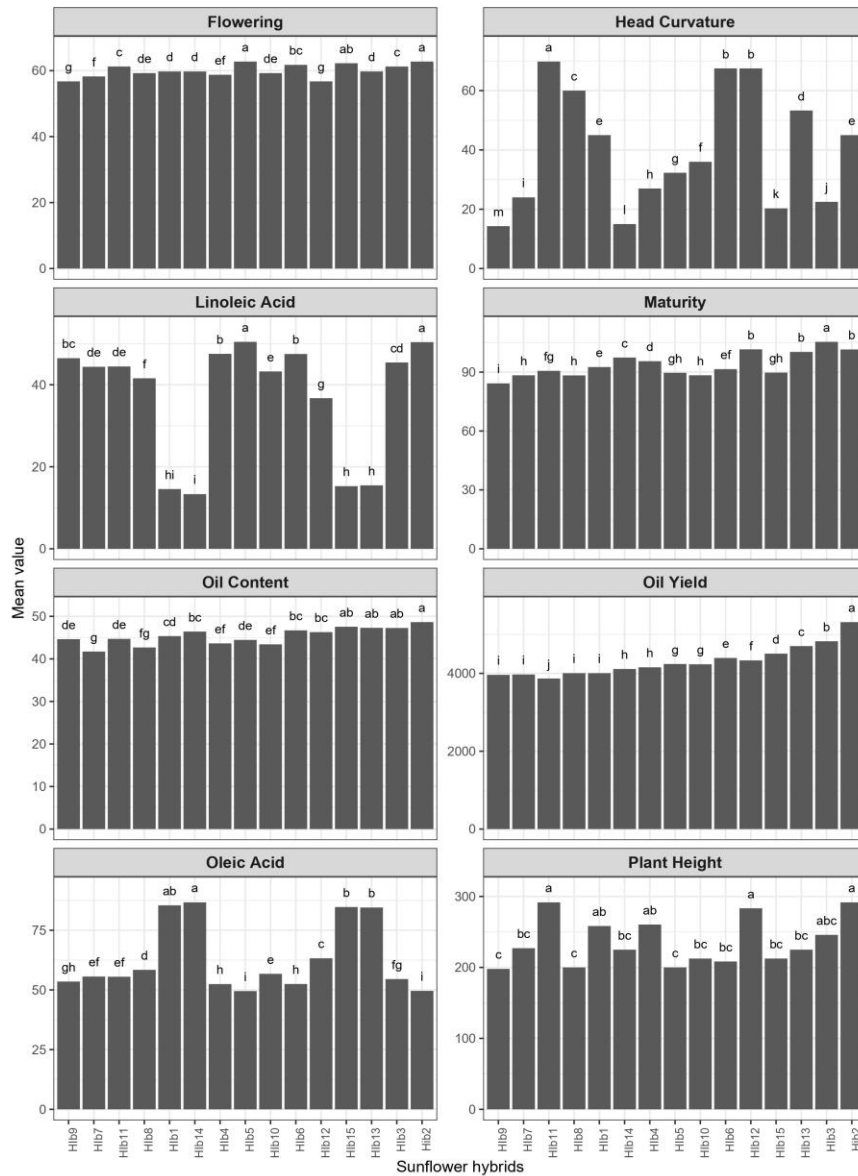


Figure 1. Comparison of sunflower hybrids for agronomic, morphological, and quality traits.

For yield, values ranged from 3868.22 to 5317.08 kg ha⁻¹. The best results were recorded for the commercial Hib2 (5317.08 kg ha⁻¹) followed by the commercial Hib3 (4824.94 kg ha⁻¹). From the developed hybrids, Hib13 (4701.38 kg ha⁻¹), and Hib15 (4506.46 kg ha⁻¹) registered the most promising results as they differ significantly from the maturity group of the commercial hybrids Hib2 and Hib3 (semi-late maturity group) (Figure 1). Oil

content ranged from 41.73% in Hib7 to 48.65% in Hib2. The highest oil content was observed in Hib2 (48.65%), Hib15 (47.56%), Hib13 (47.30%) and Hib3 (47.27%). However, most hybrids exhibited oil contents above 44%. Considering acid composition, Oleic acid concentration ranged from 49.53% in Hib5 to 86.68% in Hib14. Four hybrids, namely Hib14 (86.68%), Hib1 (85.43%), Hib15 (84.72%), and Hib13 (84.53%), formed the high-oleic group. Plant height ranged from 197.90 cm in Hib9 to 291.65 cm in Hib2 and Hib11.

Correlation analyses revealed strong positive correlations with oil content ($r = 0.75$) and maturity ($r = 0.69$). The results indicate hybrids with a longer growth cycle and higher seed oil concentration tended to produce greater yields. Positive correlation was also observed between oil yield and flowering time ($r = 0.50$). In contrast, oil yield showed weak positive correlation with plant height ($r = 0.23$).

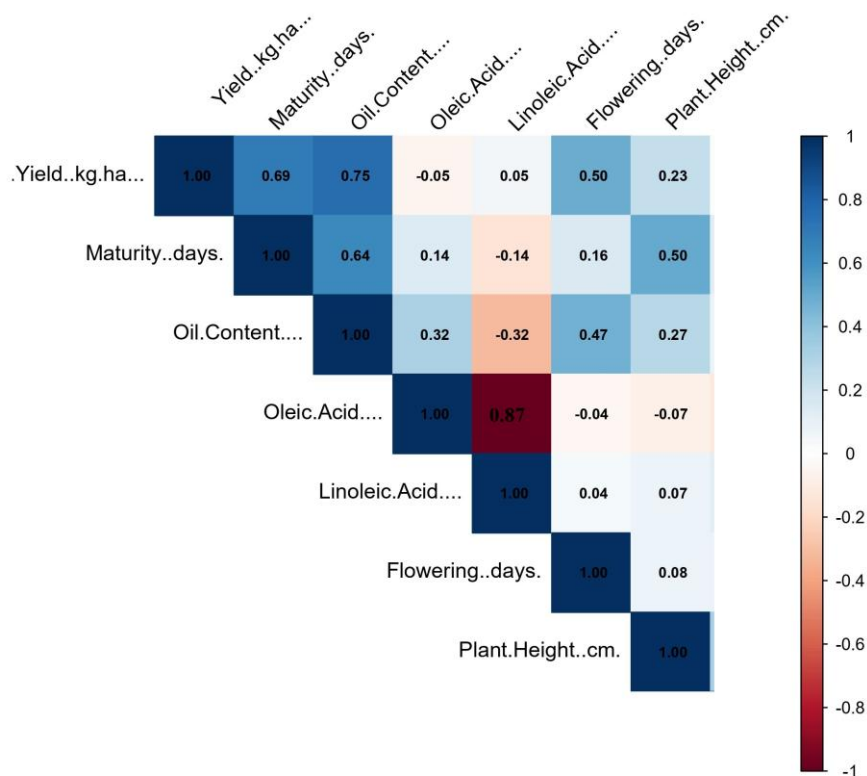


Figure 2. Correlations of sunflower hybrids for agronomic, morphological, and quality traits.

Maturity was positively correlated with oil content ($r = 0.64$) and plant height ($r = 0.50$). Oil content showed a strong positive correlation with yield ($r = 0.75$) and a moderate positive correlation with flowering traits ($r = 0.47$). Regarding oil compositions, oil content was also weakly positively correlated with oleic acid concentration ($r = 0.32$) and negatively associated with acid concentration ($r = -0.32$).

Oleic acid concentration reflected no association with oil yield ($r = -0.05$) or flowering time ($r = -0.04$). Plant height displayed moderate positive correlations with maturity ($r = 0.50$) but weak associations with oil yield ($r = 0.23$) and oil content ($r = 0.27$).

Results reflect that correlations between yield and oil content ($r = 0.75$) and between oil yield and maturity ($r = 0.69$) appear to be the most relevant for sunflower breeding programs aimed at increasing oil production.

The principal component analysis (PCA) revealed that the first two principal components explained 62.8% of the total variation. PC1 is responsible for 36.5% and PC2 accounting for 26.3%. Analysis indicated that oil content, oil yield, and maturity were the major contributors to PC1. In contrast, oleic acid and linoleic acid has contributions to PC2, accounting for more than 40% of the variation Figure 3. PCA results revealed that the evaluated sunflower hybrids are different mainly by two variables: productivity-related traits (yield, oil content or maturity) and fatty acid composition (oleic and linoleic acid content).

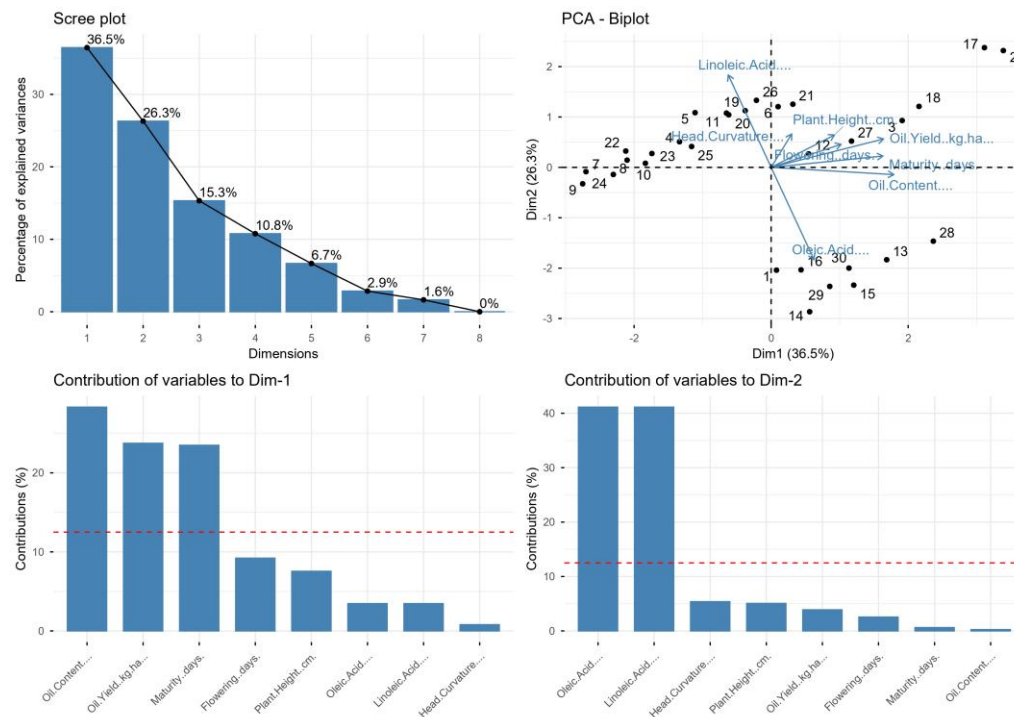


Figure 3. Principal component analysis (PCA) of sunflower hybrids for agronomic, morphological, and quality traits.

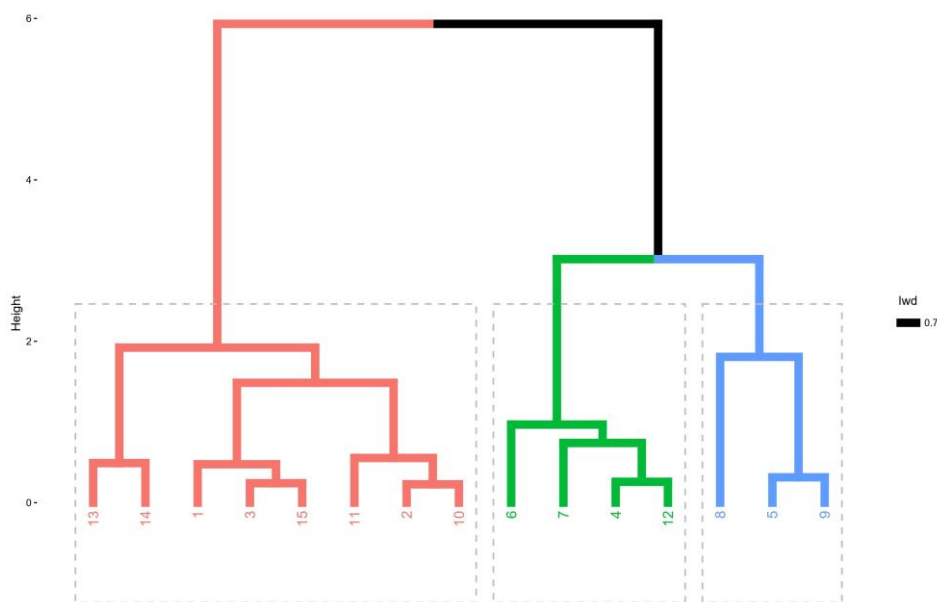


Figure 4. Clusterin analyses of the sunflwoer hybrids based on oil content and yield.

Cluster analyses revealed distinct group depending on the adaptability and efficiency on the Romanian conditions. References, or prefers group of hybrids developed where the ones that where integrated with the commercial hybrids Hib1, Hib2 and Hib3. Therefore, figure 4 reveals 3 distinct groups.

-*Group 1* - superior high-oleic hybrids adapted to the Romanian conditions, this included hybrids :Hib13 (the most equilibrated of yield and oil content) , Hib14, Hib15, Hib11 and Hib10;

-*Group 2* - modarate hybrids with modarate yield and oil content: Hib6, Hib7, Hib4 and Hib12;

-*Group 3* - low performance hybrids: Hib8, Hib5 and Hib9.

The results obtained in this study permitted the selection of the best-performing hybrids. Oil content showed a strong positive correlation with yield ($r = 0.75$) and a moderate positive correlation with flowering traits ($r = 0.47$). This relationship represents a strong indicator for the selection of new hybrids (Figure 3). Also, from a breeding point of view, this finding is of major importance in predicting the potential performance of hybrids. Previous studies are in agreement with the results obtained in the present research. A strong correlation between oil content and yield was also reported by HLADNI et al. (2006). Similarly, significant positive correlations between oil content, yield, and days to maturity were reported by SUPRIYA et al. (2017). However, the positive relationship between oil content and yield may also depend on the genotypes evaluated, as reported by FICK et al. (1974).

CONCLUSIONS

Different environments influence the yield and oil content homogeneity of the hybrids. Particularly oleic and linoleic acid contents, is influenced by environmental factors. From the morphological point of view plant height was significantly influenced by genotype and climate factor. Correlation analyses revealed strong positive correlations with oil content ($r = 0.75$) and maturity ($r = 0.69$). Positive correlation was also observed between oil yield and flowering time ($r = 0.50$). Maturity registered positively correlated with oil content ($r = 0.64$) and plant height ($r = 0.50$). Furthermore, the analyses permitted in identifying hybrids close to the commercial demands in Romania PCA revealed that the first two principal components explained 62.8% of the total variation, out of which PC1 is responsible for 36.5% and PC2 accounting for 26.3%. In perspective, further development and testing are needed to confirm these conclusions using more hybrids and additional seasons under different environmental conditions, as this is the most impactful factor.

BIBLIOGRAPHY

- ABDILOVA, G., SERGIBAYEVA, Z., ORYNBKOV, D., SHAMENOV, M., ZHUMADILOVA, G., BAKIYEVA, A., MUKASHEV, N., BAYADILOVA, A., DUKENBAYEV, D., 2023 – Influence of Grinding Degree and Screw Rotation Speed on Sunflower Oil Pressing Process. *Applied Sciences*, 13(17): 9958, Switzerland.
- AUTHORITY (EFSA), E.F.S., BRANCATO, A., BROCCA, D., DE LENTDECKER, C., ERDOS, Z., FERREIRA, L. et al., 2017 – Review of the Existing Maximum Residue Levels for Quizalofop-P-Ethyl, Quizalofop-P-Tefuryl and Propaquizafop According to Article 12 of Regulation (EC) No 396/2005. *EFSA Journal*, 15(12): e05050, Italy.
- BILGEN, B.B., DANESHVAR, S., EVCI, G., PEKCAN, V., YILMAZ, M.İ., KAYA, Y., 2018 – Determination of High Oleic Type and Broomrape Resistant Sunflower Hybrids by DNA Markers. *Ekin Journal of Crop Breeding and Genetics*, 4(1), Türkiye.
- BRECCIA, G., VEGA, T., NESTARES, G., MAYOR, M.L., ZORZOLI, R., PICARDI, L. – Immature Embryo Culture for Early Screening of Imidazolinone Resistance in Sunflower.
- CHOWDHURY, M.M., 2015 – In vitro Culture Establishment from Cotyledon and Embryonic Axis Explants of Two Bangladeshi Sunflower (*Helianthus annuus* L.) Varieties. Thesis, BRAC University, Bangladesh.
- DEGE, D., BRÜGGEMANN, P., 2024 – Marketing Analytics with RStudio: A Software Review.
- FICK, G.N., ZIMMER, D.E., ZIMMERMAN, D.C., 1974 – Correlation of Seed Oil Content in Sunflowers with Other Plant and Seed Characteristics. *Crop Science*, 14(5), USA.
- FRANCOIS, L.E., 1996 – Salinity Effects on Four Sunflower Hybrids. *Agronomy Journal*, 88(2): 215-219, USA.
- HLADNI, N., SKORIC, D., KRALJEVIC-BALALIC, M., SAKAC, Z., JOVANOVIĆ, D., 2006 – Combining Ability for Oil Content and Its Correlations with Other Yield Components in Sunflower (*Helianthus annuus* L.). *Helia*, 29(44): 101-110, Serbia.
- ION, V., DICU, G., BASA, A.G., DUMBRAVA, M., TEMOCICO, G., EPURE, L.I., STATE, D., 2015 – Sunflower Yield and Yield Components under Different Sowing Conditions. *Agriculture and Agricultural Science Procedia*, 6: 44-51, Netherlands.
- KAYA, Y., JOCIC, S., MILADINOVIC, D., 2012 – Sunflower. In: *Technological Innovations in Major World Oil Crops, Volume 1: Breeding*. Springer, Germany, pp. 85-129.
- MATTHÄUS, B., BRÜHL, L., 2001 – Comparison of Different Methods for the Determination of the Oil Content in Oilseeds. *Journal of the American Oil Chemists' Society*, 78(1): 95-102, USA.
- MJIĆ, A., LIOVIĆ, I., ZDUNIĆ, Z., MARIĆ, S., MARJANOVIĆ-JEROMELA, A., JANKULOVSKA, M., 2009 – Quantitative Analysis of Oil Yield and Its Components in Sunflower (*Helianthus annuus* L.). *Romanian Agricultural Research*, 26: 41-46, Romania.

- ONISAN, E., PETOLESCU, C., TENCHE-CONSTANTINESCU, A., PETRESCU, I., HORABLAGA, M.N., SIMINA, A., GORINOIU, G., CAMEN, D., POPESCU, S., MATE, C., SARAC, I., 2025 – Application of Biotechnology for Sunflower Inbred Line Development: Immature Embryo Rescue. *Applied Sciences*, 15(3): 1576, Switzerland.
- ONISAN, E., SARAC, I., PETRESCU, I., CAMEN, D., 2023 – New Breeding Methods in Sunflower Hybrid Research and Development. *Scientific Papers. Series A. Agronomy*, 66(1): 485-491, Romania.
- RADANOVIĆ, A., MILADINOVIĆ, D., CVEJIĆ, S., JOCKOVIĆ, M., JOCIĆ, S., 2018 – Sunflower Genetics from Ancestors to Modern Hybrids – A Review. *Genes*, 9(11): 528, Switzerland.
- SADRAS, V.O., VILLALOBOS, F.J., 2021 – Physiological Characteristics Related to Yield Improvement in Sunflower (*Helianthus annuus* L.). In: *Genetic Improvement of Field Crops*. CRC Press, United Kingdom, pp. 287-320.
- SUPRIYA, S.M., KULKARNI, V., RANGANATHA, C.N., P.G., S., 2017 – Quantitative Analysis of Oil Yield and Its Components in Newly Developed Hybrids of Sunflower (*Helianthus annuus* L.). *International Journal of Current Microbiology and Applied Sciences*, 6: 3088-3098, India.