Scientific Papers. Series A. Agronomy, Vol. LXIX, No. 1, 2026
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

EFFECTS OF CULTIVAR, LOCATION, AND NITROGEN FERTILIZATION LEVEL ON MORPHOLOGICAL AND YIELD TRAITS OF SOYBEAN (*Glycine max* L.)

Raul JURCUT, Ștefan Laurențiu BĂTRÎNA, Densia HETEA, Ilinca Merima IMBREA, Ioana HÎNDA, Lucian NIȚĂ, Florin IMBREA

University of Life Sciences "King Mihai I" of Timisoara, 119 Calea Aradului Street, Timisoara, Romania

Corresponding author email: ilinca_imbrea@usvt.ro

Abstract

The present study evaluated the effects of cultivar, location, and nitrogen fertilization level on the morphological and yield traits of soybean (Glycine max L.). Field experiments were conducted at four locations - Caracal, Crișcior, Jimbolia, and Grabat - under different pedoclimatic conditions. Two soybean cultivars, Amyata and Orakel PZO, were evaluated using three nitrogen fertilization levels (N75, N125, and N150) in a factorial experimental design. The analyzed traits included plant height, number of nodes, height of first pod insertion, number of pods per plant, thousand-seed weight, and hectoliter mass. The results revealed significant differences between cultivars for most of the analyzed traits, reflecting distinct genetic characteristics. Location significantly influenced all morphological and yield traits, highlighting the impact of environmental conditions on soybean development. Nitrogen fertilization level had a significant effect on plant architecture and seed physical characteristics, with variable responses depending on cultivar and location. Significant interactions among cultivar, location, and nitrogen fertilization level emphasize the importance of optimizing nitrogen management according to local conditions in order to improve soybean productivity and seed quality.

Key words*: location, morphological traits, nitrogen fertilization, soybean, yield traits.*

INTRODUCTION

Soybean (*Glycine max* L. Merr.) is one of the most important grain legumes worldwide due to its high protein and oil content, playing a key role in human nutrition, animal feed, and industrial applications. The increasing demand for soybean products, combined with the challenges posed by climate variability, has intensified the need for production systems that ensure both yield stability and seed quality under diverse environmental conditions (Ray et al., 2015; Smuleac et al., 2020; Cooper & Messina, 2023).

Among field crops, soybean is particularly sensitive to environmental factors, as its growth and yield formation depend strongly on temperature, water availability, and radiation during critical phenological stages. Several studies have shown that interannual climatic variability can induce substantial fluctuations in soybean yield and its components, often exceeding the effects of management practices or genetic differences (Hatfield et al., 2011; Jurcut et al., 2024). Extreme weather events, such as droughts and heat waves, further exacerbate these effects by disrupting vegetative growth, flowering, and seed filling processes (Lesk et al., 2016).

Soybean yield is determined by the interaction between vegetative growth and reproductive development, with seed number and seed size acting as primary yield components. The balance between these components is highly plastic and responsive to environmental stress. Under favorable conditions, increased vegetative growth often supports a higher number of pods and seeds, whereas under stress conditions, soybean plants tend to reduce seed number while partially compensating through increased seed size (Egli et al., 2017). This compensatory mechanism represents an adaptive response that allows plants to optimize resource allocation under limiting conditions, but it may not fully offset yield losses when stress intensity is high.

In addition to climatic variability, site-specific conditions such as soil properties, water-holding capacity, and local microclimate play a crucial role in shaping soybean performance (Setiyono et al., 2010). Spatial variability in yield and

quality parameters has been widely reported, emphasizing the importance of location as a determinant of crop response (Morrison et al., 2008). Differences in soil fertility and moisture availability can influence both vegetative architecture and reproductive success, thereby affecting not only yield but also harvest efficiency and seed quality (Wójcik-Gront et al., 2022).

Genetic factors further modulate soybean responses to environmental and management conditions (Smuleac et al., 2020). Cultivar selection is a key strategy for improving yield stability, particularly under variable or stress-prone environments. Modern breeding efforts increasingly focus on enhancing adaptability and resilience rather than maximizing yield under optimal conditions alone (Morrison et al., 2008; Cooper & Messina et al., 2023). Genotype × environment interactions have been shown to significantly affect soybean yield components and quality traits, highlighting the need to evaluate cultivars across multiple environments and years (Abebe et al., 2024).

Nitrogen nutrition represents another important aspect of soybean management. Unlike non-leguminous crops, soybean has the ability to meet a large proportion of its nitrogen demand through biological nitrogen fixation, reducing its dependence on mineral nitrogen fertilization. Numerous studies have reported inconsistent or limited yield responses to nitrogen application in soybean, particularly when nodulation and fixation processes are efficient (Salvagiotti et al., 2008; Maluk et al., 2023; Jurcut et al., 2025). However, nitrogen availability can still influence specific physiological processes, including seed composition, especially oil accumulation (Hungria et al., 2015).

Seed quality traits such as protein and oil content, thousand seed weight, and test weight are critical determinants of soybean market value and end-use suitability. These traits are influenced by both genetic and environmental factors, often exhibiting trade-offs that complicate management decisions. Environmental conditions during seed filling, in particular, have been shown to affect protein and oil concentration, sometimes independently of yield responses (Rotundo & Westgate, 2009; Bellaloui et al., 2009). Understanding how management and environmental factors interact to shape both yield and quality is therefore essential for developing sustainable soybean production system. Despite extensive research on individual factors affecting soybean performance, there remains a need for integrated, multi-year and multi-location studies that simultaneously assess vegetative growth, yield components, and seed quality under contrasting environmental conditions. Such approaches are particularly valuable for disentangling the relative contributions of climate, location, genotype, and management practices to overall crop performance (Sitnicki et al., 2024; Chitu et al., 2024). Moreover, quantifying the relative contribution of these factors provides practical insights for prioritizing management interventions and breeding objectives.

In this context, the present study aimed to evaluate the combined effects of year, location, cultivar, and nitrogen fertilization on soybean vegetative traits, yield components, and seed quality parameters over multiple growing seasons. By integrating analysis of variance with an assessment of factor contributions and compensatory relationships between growth and yield components, this study seeks to clarify the mechanisms underlying soybean performance under variable environmental conditions. The results contribute to a better understanding of how adaptive strategies based on cultivar selection and site-specific management can enhance soybean productivity and quality in the face of increasing climatic variability.

MATERIALS AND METHODS

The objective of the study was to evaluate the effect of the variety, location and level of nitrogen fertilization on the morphological and yield traits of soybean (*Glycine max* L.). Field experiments were carried out in four locations - Caracal, Crișcior, Jimbolia and Grabat - under different pedoclimatic conditions. Two soybean varieties, Amyata and Orakel PZO, were evaluated using three levels of nitrogen fertilization (N75, N125 and N150) in a factorial experimental design.

The study was conducted between 2022 and 2025 in four representative locations for the main agricultural areas of Romania: Caracal (Olt County), Crișcior (Hunedoara County), Jimbolia and Grabați (Timiș County). These

locations were selected to capture a distinct pedoclimatic gradient, from lowland areas with frequent water deficit to hilly areas with better water resources.

The multiannual climate analysis (Table 1) indicates average annual temperatures between 10.9°C (Crișcior) and 13.7°C (Caracal).

Table 1. Multiannual climate characterization of experimental sites (2022-2025)

Location	Average annual temperature (°C)	Average annual rainfall (mm)	Average rainfall during the growing season (Apr.-Sept.) (mm)	The difference in temperature during the growing season compared to the annual average (°C)
Caracal	13.7	492	301	+6.8
Crișcior	10.9	572	356	+6.1
Jimbolia	12.2	447	273	+6.3
Grabați	12.3	482	296	+6.5

Note: The values represent multi-year averages calculated for the period 2022–2025. The temperature difference expresses the increase in the average temperature during the growing season (April–September) compared to the annual average, indicating the thermal favorability for the soybean crop.

During the growing season of the soybean crop (April-September), the average temperatures exceeded the annual average by 6.1-6.8°C, confirming a favorable thermal regime for growth and development processes.

The average annual rainfall varied between 447 mm (Jimbolia) and 572 mm (Crișcior), and those in the vegetation period between 273 mm and 356 mm, highlighting a different water availability between locations.

From a pedological point of view (Table 2), the soils are predominantly represented by chernozems and cambic chernozems at Caracal, Jimbolia and Grabați, characterized by good natural fertility, and by brown clay-alluvial soil at Crișcior, with medium fertility and lower phosphorus content.

Table 2. Synthesis of the main agrochemical indicators of soils in experimental sites

Location	Type of soil	pH (H_2O)	Humus (%)	Total N (%)	Mobile P (ppm)	Mobile K (ppm)
Caracal	Chernozems	7.6	2.58	0.189	93	235
Crișcior	brown clay-alluvial soil	6.2	2.51	0.15	33	166
Jimbolia	Chernozems	7.81	4.26	0.27	111.5	192.9
Grabați	Cambic chernozems	7.5	3.13	0.19	62.3	241.4

Note: Agrochemical analyses were performed in the 0-20 cm layer, before the installation of the experiment.

This pedoclimatic diversity allowed the evaluation of the behavior of the soybean crop in contrasting agroecological conditions and the formulation of conclusions with regional applicability.

RESULTS AND DISCUSSIONS

Analysis of variance for morphological traits

The table synthetically highlights that year was the dominant factor, significantly affecting all analyzed traits (Table 3).

Location exerted a strong influence on reproductive and architectural traits, while cultivar showed selective significance.

Table 3. Significance of experimental factors (ANOVA) on soybean morphological traits

Trait	Year (A)	Location (B)	Cultivar (C)	Fertilization (D)
Plant height	***	ns	ns	ns
Pods per plant	***	***	*	ns
Fertile nodes	***	**	ns	ns
First pod height	***	***	**	ns

ns - not significant ($p > 0.05$); *$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.

Nitrogen fertilization had no statistically significant effect on the analyzed morphological parameters. Location exerted a strong influence on reproductive and architectural traits, while

cultivar showed selective significance. Nitrogen fertilization had no statistically significant effect on the analyzed morphological parameters.

Effect of year on soybean morphology

The results regarding the effect of the experimental year on soybean morphology are presented in Table 4.

Table 4. Mean values of morphological traits as affected by year

Year	Plant height (cm)	Pods per plant	Fertile nodes	First pod height (cm)
2023	82.38 a	42 a	11 a	14.71 a
2024	82.17 a	40 a	3 c	11.52 b
2025	47.32 b	17 b	8 b	4.22 c

Means followed by different letters differ significantly (Duncan test, $p \leq 0.05$).

The drastic reduction observed in 2025 across all traits indicates a strong climatic stress, most likely drought and high temperatures during vegetative and reproductive stages. Similar values recorded in 2023 and 2024 suggest favorable and stable environmental conditions during these growing seasons**.**

Effect of location

The results regarding the effect of the experimentation site on soybean morphology are presented in Table 5.

Table 5. Mean values of morphological traits as affected by location

Location	Plant height (cm)	Pods per plant	Fertile nodes	First pod height (cm)
Caracal	67.97 a	37 a	6 c	8.64 b
Crișcior	74.18 a	26 b	9 a	12.29 a
Jimbolia	69.71 a	35 a	7 bc	11.26 a
Grabat	70.64 a	33 a	8 ab	8.41 b

Locations with more favorable soil and moisture conditions (Crișcior and Jimbolia) promoted higher insertion of the first pod and increased number of fertile nodes.

Differences among locations confirm the importance of site-specific adaptation in soybean cultivation.

Effect of cultivar

The results regarding the effect of the cultivar on soybean morphology are presented in Table 6.

Table 6. Mean values of morphological traits as affected by cultivar

Cultivar	Plant height (cm)	Pods per plant	Fertile nodes	First pod height (cm)
Amiata	68.88 a	31 b	7 a	9.01 b
Orakel	72.36 a	35 a	8 a	11.29 a

The cultivar Orakel PZO showed superior performance for pods per plant and first pod height, traits directly related to yield potential and harvest efficiency. These results highlight the genetic contribution to yield-forming traits under variable environmental conditions.

Effect of nitrogen fertilization

The results regarding the effect of the nitrogen fertilization on soybean morphology are presented in Table 7.

Table 7. Mean values of morphological traits as affected by nitrogen fertilization

Fertilization	Plant height (cm)	Pods per plant	Fertile nodes	First pod height (cm)
N75	69.77 a	30 b	7 a	10.90 a
N125	70.63 a	33 ab	8 a	9.88 a
N150	71.48 a	35 a	8 a	9.67 a

Although numerical increases were observed with higher nitrogen doses, the lack of statistical significance suggests that nitrogen was not the limiting factor under the experimental conditions, in agreement with soybean's biological nitrogen fixation capacity.

Thousand-seed weight (TSW) and hectoliter mass

Thousand-seed weight (Table 8) was significantly affected by location, cultivar, and nitrogen fertilization level, highlighting the combined influence of pedoclimatic conditions and technological inputs on seed development.

Among locations, the highest thousand-seed weight values were recorded at Jimbolia (149.7 g) and Grabați (148.1 g), while lower values were observed at Caracal (142.4 g) and Crișcior (151.9 g), with statistically significant differences among sites. These results reflect the more favorable pedoclimatic conditions in the Banat Plain, particularly improved water availability during the seed-filling period, which enhances assimilate accumulation in seeds.

Table 8. Thousand-seed weight (g) as affected by experimental factors

Factor	Level	Mean ± SE
Location	Caracal	142.4 ± 3.06 b
	Crușcior	151.9 ± 2.77 a
	Jimbolia	149.7 ± 1.84 a
	Grabat	148.1 ± 2.31 ab
Cultivar	Amiata	146.7 ± 1.86
	Orakel	149.4 ± 2.07
Nitrogen Level	N75	144.9 ± 2.44
	N125	148.2 ± 2.49
	N150	151.0 ± 2.07

Regarding the genetic factor, Amyata (146.7 g) showed a significantly higher thousand-seed weight compared with Cypress (149.4 g), indicating cultivar-specific differences in seed filling capacity and reserve accumulation.

Nitrogen fertilization had a positive effect on thousand-seed weight, with values increasing as nitrogen dose increased.

The highest value was obtained at N150 (151.0 g), significantly exceeding those recorded at N75 (144.9 g) and N125 (148.2 g).

This response highlights the role of nitrogen in supporting photosynthetic activity and assimilate translocation during the seed-filling stage. Among locations, the highest hectoliter weight values were recorded at Jimbolia (71.9 kg hL^{-1}) and Grabaț (71.8 kg hL^{-1}), significantly higher than those observed at Caracal (70.3 kg hL^{-1}) and Crișcior (70.9 kg hL^{-1}). These results are associated with more balanced climatic conditions in western Romania, which favor the formation of well-developed and uniform seeds.

Hectoliter weight, an important indicator of physical seed quality, was also significantly influenced by all experimental factors (Table 9).

Cultivar significantly affected hectoliter weight, with Cypress (71.5 kg hL^{-1}) showing higher values compared with Amyata (70.8 kg hL^{-1}), suggesting a higher seed density and more compact internal structure.

Nitrogen fertilization had a smaller but consistent effect on hectoliter weight. The highest values were recorded at N125 (71.3 kg·hL^{-1}) and N150 (71.3 kg·hL^{-1}), whereas the lowest value was observed at N75 (70.7 kg·hL^{-1}).

This trend indicates that adequate nitrogen nutrition contributes to improved seed uniformity and density.

Table 9. Hectoliter mass (kg·hl^{-1}) as affected by experimental factors

Factor	Level	Mean ± SE
Location	Caracal	70.28 ± 0.16 c
	Crușcior	70.92 ± 0.19 bc
	Jimbolia	71.81 ± 0.22 a
	Grabat	71.46 ± 0.45 ab
Cultivar	Amiata	70.76 ± 0.22 b
	Orakel	71.48 ± 0.25 a
Nitrogen Level	N75	70.74 ± 0.22
	N125	71.28 ± 0.29
	N150	71.34 ± 0.39

Relationship between vegetative growth and yield components

A comparative analysis of morphological data (Table 10) shows that the reduction in plant size is not always associated with proportional losses in berry quality. For example, the year 2025, although characterized by shorter plants and a reduced number of pods, recorded the highest values for the mass of 1000 grains (MMB) and hectoliter mass (MH).

This compensation suggests a redistribution of assimilates to a smaller number of grains, a phenomenon frequently reported in soybeans under moderate-severe stress conditions. From an agronomic point of view, this mechanism explains why production decreases are not always proportional to the decrease in vegetative vigor.

Table 10. Integrated relationship between vegetative growth traits and yield components (yearly means)

Year	Plant height (cm)	Fertile nodes (no.)	Pods per plant (no.)	TSW (g)	Test weight (kg·hl^{-1})
2023	82.38 a	11 a	42 a	140.4 b	70.45 b
2024	82.17 a	3 c	40 a	140.2 b	70.70 b
2025	47.32 b	8 b	17 b	163.6 a	72.20 a

Different letters indicate significant differences (Duncan test, $p \leq 0.05$).

Contribution of experimental factors to trait variability

The results regarding the contribution of experimental factors (Table 11) confirm that the year of cultivation (factor A) had the greatest contribution to the variation of all the parameters analyzed, both morphological and quality. For traits related to vegetative growth (plant height, number of pods, number of floors), the year's input frequently exceeded 60-70% of the total variation, indicating a major dependence on interannual climatic conditions.

Table 11. Contribution (%) of experimental factors to the total variance of analyzed traits

Trait	Year (A)	Location (B)	Cultivar (C)	Fertilization (D)	Error
Plant height	~76	~1	~1	<1	~22
Pods per plant	~63	~8	~2	~2	~25
Fertile nodes	~52	~9	~2	~1	~36
First pod height	~60	~9	~4	~1	~26
Thousand seed weight	~53	~6	~1	~3	~37
Test weight	~31	~18	~7	~4	~40

Values derived from sum of squares distribution; percentages rounded for clarity.

The location (factor B) had a secondary but constant contribution, especially for the characteristics of agronomic and technological relevance, such as the height of the first pod, the hectoliter mass and the moisture of the grains.

This contribution reflects the influence of soil conditions and the local microclimate on the stability of the crop.

The variety (factor C) had a relatively low contribution to most of the traits, but its contribution was evident for the parameters associated with grain quality and mechanized harvesting (MH, height of the first pod), confirming the genetic role in optimizing these traits.

Nitrogen fertilization (factor D) showed a limited contribution for most morphological traits. From a practical point of view, the analysis of the contribution of factors demonstrates that the management of the soybean crop must be adapted as a priority to climatic and local conditions, and technological interventions (fertilization) have a complementary role.

The choice of variety becomes essential in particular to reduce the technological risks associated with harvesting and to stabilize the quality of production.

CONCLUSIONS

The multi-year, multi-location analysis demonstrated that environmental conditions were the primary drivers of soybean performance, exerting a dominant influence on both vegetative growth and seed quality traits. Among the experimental factors, year of cultivation accounted for the largest proportion of total variability, highlighting the strong dependence of soybean development on interannual climatic conditions.

Vegetative growth parameters, including plant height, number of fertile nodes, pod number, and first pod height, were particularly sensitive to climatic stress.

Years characterized by reduced vegetative vigor resulted in pronounced decreases in pod number and first pod height, increasing the risk of harvest losses.

However, these unfavorable conditions also triggered a compensatory response, leading to increased thousand seed weight and test weight, which partially mitigated yield reductions.

Location effects were consistent but secondary to year effects, indicating that site-specific pedoclimatic conditions contribute to stabilizing yield components and seed quality. Locations with more favorable soil and moisture regimes supported improved plant architecture and better technological traits, especially thousand seed weight and test weight.

Cultivar influence was selective but agronomically relevant. The cultivar *Orakel* showed superior performance for traits directly related to harvest efficiency and yield formation, particularly pod number and first pod height, confirming the importance of cultivar selection under variable environmental conditions.

Nitrogen fertilization had a limited impact on vegetative traits, reflecting the capacity of

soybean to rely on biological nitrogen fixation. Its effect was mainly expressed through oil accumulation, suggesting that nitrogen management should be adapted to quality objectives rather than vegetative growth enhancement.

The results emphasize that adaptive strategies in soybean cultivation should prioritize cultivar choice and site-specific management, while acknowledging that climatic variability remains the main limiting factor.

Integrating environmental adaptation with optimized genetic selection represents a sustainable approach to improving soybean productivity and seed quality under increasingly variable climatic conditions.

REFERENCES

Abebe, A. T., Adewumi, A. S., Adebayo, M. A., Shaahu, A., Mushoriwa, H., Alabi, T., Derera, J., Agbona, A., & Chigeza, G. (2024). Genotype × environment interaction and yield stability of soybean (*Glycine max* L.) genotypes in multi-environment trials (METs) in Nigeria. *Heliyon*, *10*(19), e38097.

Bellaloui, N., Smith, J. R., Ray, J. D., & Gillen, A. M. (2009). Effect of maturity on seed composition in the early soybean production system as measured on near-isogenic soybean lines. *Crop Science*, *49*(2), 608–620.

Chitu, C., Imbrea, I., Batrina, S., & Imbrea, F. (2024). Developing a digital twin model for corn, wheat and rapeseed yields computation. *Scientific Papers. Series "Management, Economic Engineering in Agriculture and Rural Development", 24*(2), 287–294

Cooper, M., & Messina, C. D. (2023). Breeding crops for drought-affected environments and improved climate resilience. *The Plant Cell, 35*(1), 162–186.

Morrison, M. J., Cober, E. R., Saleem, M. F., McLaughlin, N. B., Fregeau-Reid, J., Ma, B. L., Yan, W., & Woodrow, L. (2008). Changes in isoflavone concentration with 58 years of genetic improvement of short-season soybean cultivars in Canada. *Crop Science*, *48*(6), 2201–2208

Egli, D. B. (2017). *Seed Biology and Yield of Grain Crops, 2nd Edition*. Kentucky, USA, Plant and Soil Sciences Faculty Book Gallery

Hatfield, J. L., Boote, K. J., Kimball, B. A., Ziska, L. H., Izaurralde, R. C., Ort, D. R., Thomson, A. M., & Wolfe, D. (2011). *Climate impacts on agriculture: Implications for crop production*. Nebraska, USA, Publications from USDA-ARS / UNL Faculty, Paper 1350

Hungria, M., Nogueira, M. A., & Araujo, R. S. (2015). Soybean seed co-inoculation with Bradyrhizobium spp. and *Azospirillum brasilense*: A new biotechnological tool to improve yield and sustainability. *American Journal of Plant Sciences, 6*(6), 811–817.

Jurcut, R.-C., Imbrea, F., Bătrîna, Ș. L., Botoș, L., & Ibric, A. I. (2024). Analyzing the impact of climate variations and fertilizer application on soybean cultivation across western, southern and central region of Romania. *Scientific Papers. Series A. Agronomy, LXVII*(1). *59,* 461–470.

Jurcut, R. C., Imbrea, F., Bătrîna, S. L., & Botoș, L. (2025). The impact of nitrogen fertilization on the productivity of soybean crops in southern and central Romania in the context of climate change. *Scientific Papers. Series A. Agronomy, LXVIII*(2), 525–535.

Maluk, M., Giles, M., Wardell, G. E., Akramin, A. T., Ferrando-Molina, F., Murdoch, A., Barros, M., Beukes, C., Vasconcelos, M., Harrison, E., Daniell, T. J., Quilliam, R. S., Iannetta, P. P. M., & James, E. K. (2023). Biological nitrogen fixation by soybean (*Glycine max* [L.] Merr.), a novel, high protein crop in Scotland, requires inoculation with non-native bradyrhizobia. *Frontiers in Agronomy*, *5*, 1196873.

Lesk, C., Rowhani, P., & Ramankutty, N. (2016). Influence of extreme weather disasters on global crop production. *Nature*, *529*(7584), 84–87.

Ray, D. K., Gerber, J. S., MacDonald, G. K., & West, P. C. (2015). Climate variation explains a third of global crop yield variability. *Nature Communications*, *6*, 5989.

Rotundo, J. L., & Westgate, M. E. (2009). Meta-analysis of environmental effects on soybean seed composition. *Field Crops Research*, *110*(2), 147–156.

Salvagiotti, F., Cassman, K. G., Specht, J. E., Walters, D. T., Weiss, A., & Dobermann, A. (2008). Nitrogen uptake, fixation and response to fertilizer N in soybeans: A review. *Field Crops Research*, *108*(1), 1–13.

Setiyono, T.D., Cassman, K.G., Specht, J.E., Dobermann, A., Weiss, A., Yang, A.H., Robinson, A.P., Conley, S.P., Pedersen, P., & De Bruin, J.L. (2010). Simulation of soybean growth and yield in near-optimal growth conditions. *Field Crops Research*, *119*(1), 161-174.

Sitnicki, M. W., Prykaziuk, N., Hlushak, L., Pimenowa, O., Imbrea, F., Șmuleac, L., & Paşcalău, R. (2024). Regional perspective of using cyber insurance as a tool for protection of Agriculture 4.0. *Agriculture, 14*(2), 320.

Șmuleac, L., Rujescu, C., Șmuleac, A., Imbrea, F., Radulov, I., Manea, D., & Paşcalău, R. (2020). Impact of Climate Change in the Banat Plain, Western Romania, on the Accessibility of Water for Crop Production in Agriculture. *Agriculture, 10*(10), 437.

Wójcik-Gront, E., Gozdowski, D., Derejko, A., & Pudełko, R. (2022). Analysis of the impact of environmental and agronomic variables on agronomic parameters in soybean cultivation based on long-term data. *Plants*, *11*, 2922.