

BIOSTIMULATOR INFLUENCE ON THE NUMBER AND WEIGHT OF TUBERS PER HILL AT DIFFERENT CLIMATIC AND TECHNOLOGICAL CONDITIONS

Lorena ADAM^{1,2}, Manuela HERMEZIU², Camelia URDĂ³, Viorel ION¹

¹University of Agronomic Sciences and Veterinary Medicine of Bucharest,
59 Marasti Blvd, District 1, 011464, Bucharest, Romania

²National Institute of Research and Development for Potato and Sugar Beet Brasov,
2 Fundaturii Street, 500470, Brasov, Romania

³Agricultural Research and Development Station Turda, 27 Agriculturii Street, Turda, Romania

Corresponding author email: adam_lorena98@yahoo.com

Abstract

The use of biostimulators in potato crop is a modern agricultural practice aimed at enhancing plant physiological processes, nutrient efficiency, and yield stability under variable environmental conditions. This study evaluated the effects of biostimulator application on the yielding elements of the Romanian potato variety Darilena, considering cultivation location and planting density. Field trials were conducted over three consecutive years (2023-2025) at the National Research and Development Institute for Potato and Sugar Beet Braşov and at a private farm (Lorad Agro SRL, Codlea) in Romania. Two planting densities (45,000 and 53,000 plants/ha) and five treatment variants were tested: control, three biostimulators (Genaktis 1, Irys, Terram Number One), and one foliar fertilizer (Wuxal Macromix). Results indicated that all biostimulants treatments significantly increased the number and weight of tubers per hill, independent of location and annual climatic variations.

Key words: potato, biostimulator, climatic conditions, plant density, number of tubers, weight of tubers, tuber yield.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is widely recognized as a crop of global importance, contributing substantially to food security and agricultural sustainability (Devaux et al., 2020; Birch et al., 2012). Maximizing tuber yield and quality is essential not only for meeting food security goals but also for enhancing the sustainability and profitability of production systems (Barbaš et al., 2025). Recent advances in crop management have identified plant biostimulants as promising agents capable of improving growth, stress tolerance, nutrient use efficiency, and overall yield performance (Moura et al., 2023).

Biostimulants encompass a diverse range of substances and microorganisms - including seaweed extracts, humic and fulvic acids, amino acids, and beneficial microbes - that exert positive effects on plant physiological processes independent of conventional fertilization (Du Jardin, 2015). These agents have been shown to stimulate root system development, enhance nutrient uptake, modulate hormonal balance,

and improve photosynthetic activity, thereby contributing to enhanced biomass production and yield stability (Colla et al., 2015; Di Sario et al., 2025).

In potato cultivation, the use of biostimulants has been widely reported to enhance tuber number, average tuber weight, and yield contributing to improved crop performance under variable environmental conditions (Rouphael et al., 2020; Bulgari et al., 2019).

Environmental conditions play a decisive role in modulating plant responses to biostimulant applications. Climatic and edaphic factors, including temperature regimes, water availability, and soil moisture dynamics, strongly influence nutrient uptake, metabolic activity, and plant stress physiology. Consequently, the effectiveness of biostimulants is highly context-dependent and may vary substantially across environmental conditions. Recent studies emphasize that biostimulant-induced improvements in crop performance are often associated with enhanced tolerance to abiotic stresses such as drought, salinity, and temperature extremes, which are themselves governed by environmental

variability (Bhupenchandra et al., 2022; Di Sario et al., 2025). Furthermore, experimental evidence suggests that soil water status and stress intensity can significantly alter plant responsiveness to biostimulant treatments, ultimately affecting yield formation and biomass allocation (Wadduwage et al., 2024). For example, thermal and drought stresses are well-known constraints on tuber initiation and expansion, whereas biostimulant applications may partially alleviate these limitations through enhanced antioxidant activity, osmotic adjustment, and metabolic regulation (Santi et al., 2018a; Yakhin et al., 2017). Technological factors such as sowing date, fertilizer regime, and crop management practices further influence biostimulant efficacy. Delayed sowing may shorten the active tuber growth period, potentially limiting treatment effectiveness (Kołodziejczyk & Gwóźdź, 2022). Conversely, synchronized biostimulant application strategies integrated with optimized crop management practices have been reported to improve plant physiological performance and yield-related traits, including tuber size distribution and biomass accumulation (Cortiello et al., 2024; Santi et al., 2018b).

Despite the growing body of research on biostimulants in horticultural and field crops, there remains a need for comprehensive studies that examine their effects under diverse climatic and technological scenarios, especially in relation to tuber yield structure and stability across different potato cultivars (Barbaś et al., 2024; Ginter et al., 2023). Elucidating how biostimulants interact with environmental stresses and agronomic practices is critical for optimizing their use in precision agriculture. In this context, the present study investigates the influence of some biostimulant products on tuber number and weight per hill and tuber yield under varying climatic and technological conditions. The objective is to identify strategies to improve potato productivity and quality in temperate cropping systems (Calvo et al., 2014; Van Oosten et al., 2017).

MATERIALS AND METHODS

The research was performed in field experiments carried out during 2023-2025 on the Romanian semi-early potato variety

Darilena, developed by National Research and Development Institute for Potato and Sugar Beet Braşov, Romania (NIRDPSB Braşov). The tubers of Darilena variety are characterized by oval-shaped tubers with yellow skin and light yellow flesh.

The experiment was arranged as a subdivided plot design ($3 \times 2 \times 2 \times 5$) with four replications, including as experimental factors the year of study (2022-2023, 2023-2024 and 2024-2025), the experimental location (NIRDPSB Braşov and the Lorad Agro farm, Codlea), plant density (45,000 and 53,000 plants ha^{-1}), and biostimulator treatments (control, Genaktis 1, Irys, Terram Number One and Wuxal Macromix). Both experimental locations are located in Braşov county, in the center of Romania.

During the vegetation period, two successive harvests were carried out in order to evaluate the main productivity traits, namely the number and weight of tubers formed per hill. For this purpose, two plants were taken from each experimental variant, and the samples were analysed in the Laboratory of Technology and Good Agricultural Practices of NIRDPSB Braşov.

At the first experimental location (NIRDPSB Braşov), the first assessment was conducted on 3rd of July in 2023, 10th of June in 2024 and 2nd of July in 2025, while the second assessment took place on 28th of July in 2023, 17th July in 2024 and 23th of July in 2025.

At the second experimental location (the Lorad Agro farm in Codlea), the first assessment was carried out on 1st of July in 2023, 17th of June in 2024 and 30th of June in 2025, and the second assessment on 26th of July in 2023, 16th July in 2024 and 22th of July 22 in 2025.

At the end of the vegetative period, the final harvest was carried out using a semi-mechanized system on the two middle rows, which had been monitored throughout the growing season for all physiological and morphological traits. At the first experimental location, harvesting took place on 21th of September in 2023, 20th of September in 2024 and 19th of September in 2025, while at the second experimental location harvesting was conducted on 30th of September 2023, 30th of September in 2024 and 20th of September in 2025.

As biostimulator treatments, there were used one foliar biostimulator, two root biostimulators

and one foliar fertilizer with a biostimulating effect (Table 1).

Genaktis 1 is a foliar biostimulator based on seaweed and silica extracts, which stimulates metabolic processes. The product was applied twice during the vegetation period, at the beginning of flowering and 15 days thereafter, at a rate of 3 l/ha/application.

Irys is a root biostimulator based on humic substances and plant extracts, with an effect on the growth and development of the root system. The product was applied at planting and at the three-differentiated-leaf stage, at a rate of 4 l/ha/application.

Terram Number One is a root biostimulator with a high content of carbon, organic substances, amino acids, and polysaccharides. The product was applied during the vegetation period in two applications at 15-day intervals, at a rate of 3 l/ha/application.

Table 1. Chemical and organic profile of studied biostimulators

Element / Substance / Symbol	Genaktis 1	Irys	Terram Nr. One	Wuxal Macromix
Macronutrients				
Total Nitrogen - N (%)	9	7	1.2	16
Phosphorus Pentoxide - P ₂ O ₅ (%)	5	9	0	16
Potassium Oxide - K ₂ O (%)	7	13	7.5	12
Micronutrients				
Boron - B (%)	0.01	0.01	0	0.02
Copper - Cu (%)	0.002	0.002	0	0.05
Iron - Fe (%)	0.02	0.04	0	0.1
Molybdenum - Mo (%)	0.001	0.001	0	0.001
Manganese - Mn (%)	0	0.01	0	0.05
Zinc - Zn (%)	0	0.002	0	0.05
Organic substances				
Organic Carbon - C org (%)	0	0	12	0
Organic Matter <50 kDa, OM<50 kDa(%)	0	0	35.5	0
Alginate Acid - AA (%)	0	0	7	0
Mannitol - Man (%)	0	0	2	0

Wuxal Macromix is a foliar fertilizer with a biostimulating effect, containing a well-balanced nutrient suspension, used to support plant growth under physiological stress conditions and to stabilize plant health. The product was applied at the beginning of tuber formation and again 14 days after the first application, at a rate of 5 l/ha/application.

RESULTS AND DISCUSSIONS

The analysis of the climatic regime over the 2022-2025 interval reveals significant interannual variability, with direct implications for the progression of the phenological stages of the potato crop. Thermal and pluviometric characteristics exerted differentiated influences on the phases of emergence, vegetative growth, tuber initiation, and yield accumulation (Figure 1).

During the 2022-2023 season, the thermal regime was characterized by values close to the multiyear average, ensuring relatively favorable conditions for the early developmental stages, namely emergence and canopy formation. However, summer temperature maxima occasionally reached the upper limit of the optimal range for tuberization, a factor that may reduce the intensity of tuber differentiation and growth processes. The uneven distribution of precipitation led to episodes of water deficit, with potential effects on the critical stages of tuber initiation and formation, which are particularly sensitive to water stress.

The 2023-2024 agricultural season provided favorable agroclimatic conditions throughout the entire growing cycle. The relative stability of the thermal regime supported physiological processes specific to the vegetative growth phase and promoted optimal tuber initiation. Furthermore, the adequate distribution of precipitation during periods corresponding to intensive biomass accumulation and tuberization, particularly in May and June, contributed to maintaining a favorable water balance and reduced the likelihood of abiotic stress occurrence.

The 2024-2025 season was marked by pronounced climatic instability, with potentially disruptive effects on plant developmental dynamics. Rapid temperature increases during the early part of the growing season may accelerate phenological development, potentially shortening critical stages, including tuber initiation. Variability in the precipitation regime, coupled with episodes of excessive rainfall, may favor the occurrence of soil water excess, with negative consequences for root respiration, nutrient uptake, and the incidence of crop-specific diseases.

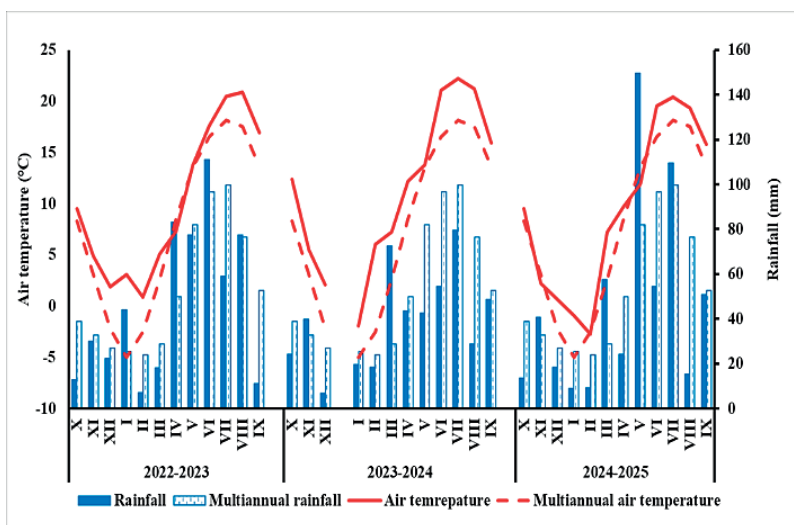


Figure 1. Monthly air temperature and precipitation patterns during the 2022-2025 period in relation to multiyear averages

The multifactorial experiment highlighted differentiated effects of the studied factors on tuber formation dynamics and final yield of the potato cultivar Darilena (Table 2). The experimental year had no significant influence on tuber number and tuber weight at either determination, except the the tuber weight at first determination in the year 2024, where the effect was negativ significant.

The experimental year very strongly influenced final yield. Compared with the multi-year average, the year 2023 resulted in a very significant positive yield increase, whereas in 2024 and 2025 significant negative yield deviations were recorded.

The experimental location mainly influenced the early stages of tuberization, with a significantly higher number of tubers at the first assessment at Codlea, while differences in final yield between locations were not significant relative to the average of both sites.

Planting density did not significantly influence tuber number or tuber weight during the growing season; however, the higher density (53,000 plants ha⁻¹) resulted in a significantly greater yield compared with the other one density (45,000 plants ha⁻¹).

Biostimulator treatments exerted a consistent and highly significant positive effect on all evaluated traits, leading to increases in tuber number, tuber weight at both assessment times, and final yield compared with the untreated

control. Overall, yield formation in the potato cultivar Darilena was predominantly influenced by year-specific conditions and biostimulator application, while experimental location and planting density had a secondary contribution, mainly expressed during the early stages of tuber development.

The stability of tuber yield of the potato cultivar Darilena was analyzed over three experimental years at two locations, NIRDPSB Braşov (BV) and the Lorad Agro farm in Codlea (CDL), under the influence of five experimental variants treated with biostimulants. The average yields recorded in the years 2024 and 2025 were considerably lower compared with those obtained in 2023, a period in which environmental conditions favored the expression of a higher yield potential (Figure 2). In years characterized by less favorable conditions, the NIRDPSB Braşov location consistently recorded higher yields, regardless of the treatment applied. At the Lorad Agro farm in Codlea, similar yield levels were obtained for the variants treated with Terram Number One (V4) and Wuxal Macromix (V5). The beneficial effect of biostimulant application on yield was evident, as the untreated control variant (V1) consistently produced lower yields compared with all treated variants throughout the entire study period.

The experimental variant treated with the biostimulant Genaktis 1 (V2) exhibited the most

pronounced yield response at the Lorad Agro farm in Codlea, particularly in 2023, a year characterized by favorable climatic conditions,

when it outperformed all other experimental variants. Under these conditions, the Darilena cultivar reached a yield level of 32.13 t/ha.

Table 2. Effects of experimental year, site, planting density, and biostimulator treatments on tuber number, tuber weight, and yield of the potato cultivar Darilena

Experimental factor		Number of tubers		Tubers weight (g)		Yield (t/ha)
		First determination	Second determination	First determination	Second determination	
Experimental year (Y)	Average^{Ct}	7.0^{Ct}	7.79^{Ct}	226^{Ct}	465^{Ct}	20.76^{Ct}
	2023	6.59 ^{ns}	8.17 ^{ns}	250 ^{ns}	507 ^{ns}	28.79***
	2024	7.26 ^{ns}	7.93 ^{ns}	159 ⁰	434 ^{ns}	16.04 ⁰⁰⁰
	2025	7.15 ^{ns}	7.26 ^{ns}	270 ^{ns}	455 ^{ns}	17.44 ⁰⁰
	LSD (p 5%)	0.84	0.99	67	83	1.45
	LSD (p 1%)	1.27	1.50	101	125	2.2
	LSD (p 0.1%)	2.04	2.41	162	201	3.53
Site (S)	Average^{Ct}	7.0^{Ct}	7.79^{Ct}	226^{Ct}	465^{Ct}	20.76^{Ct}
	Braşov	6.53 ⁰⁰	7.0 ^{ns}	195 ^{ns}	452 ^{ns}	21.68 ^{ns}
	Codlea	7.47**	8.57 ^{ns}	257 ^{ns}	479 ^{ns}	19.84 ^{ns}
	LSD (p 5%)	0.27	0.88	40	51	1.6
	LSD (p 1%)	0.39	1.27	58	72	2.3
	LSD (p 0.1%)	0.57	1.87	85	107	3.38
Planting Density (D)	45,000^{Ct}	7.12^{Ct}	7.62^{Ct}	226^{Ct}	469^{Ct}	20.32^{Ct}
	53,000	6.88 ^{ns}	7.96 ^{ns}	227 ^{ns}	462 ^{ns}	21.20*
	LSD (p 5%)	0.54	0.59	25	49	0.77
	LSD (p 1%)	0.74	0.81	35	67	1.06
	LSD (p 0.1%)	1.01	1.10	48	91	1.44
Biostimulator treatment (T)	V1- Without treatment^{Ct}	5.85^{Ct}	6.49^{Ct}	176^{Ct}	371^{Ct}	18.69
	V2- „Genaktis”	7.64***	8.01***	238***	503***	21.41***
	V3- „Irys”	6.79**	7.99***	245***	474***	21.33***
	V4- „Number One”	7.32***	8.24***	229***	490***	20.83***
	V5- „Wuxal Macromix”	7.40***	8.21***	243***	489***	21.52***
	LSD (p 5%)	0.65	0.71	26	51	1.13
	LSD (p 1%)	0.86	0.93	34	67	1.49
	LSD (p 0.1%)	1.10	1.20	44	86	1.91
ANOVA (F test)	Y	2.2 ^{ns}	2.7 ^{ns}	9.55*	2.49 ^{ns}	279***
	S	60.3***	15.87**	11.88**	1.51 ^{ns}	6.7*
	D	0.8 ^{ns}	1.48 ^{ns}	0.01 ^{ns}	0.09 ^{ns}	5.74*
	T	9.38***	8.49***	10.07***	8.7***	8.69***

The analysis of potato tuber yield stability over the three experimental years, in relation to planting density, revealed that under unfavorable climatic conditions, a density of 45,000 plants/ha ensured higher yield levels compared with 53,000 plants/ha at both studied locations. In contrast, in 2023, characterized by

favorable conditions, the Darilena cultivar achieved the maximum yield of 30.38 t/ha at the Lorad Agro farm in Codlea when grown at a density of 53,000 plants/ha. Furthermore, this location exhibited the highest yield stability at the lower planting density of 45,000 plants/ha (Figure 3).

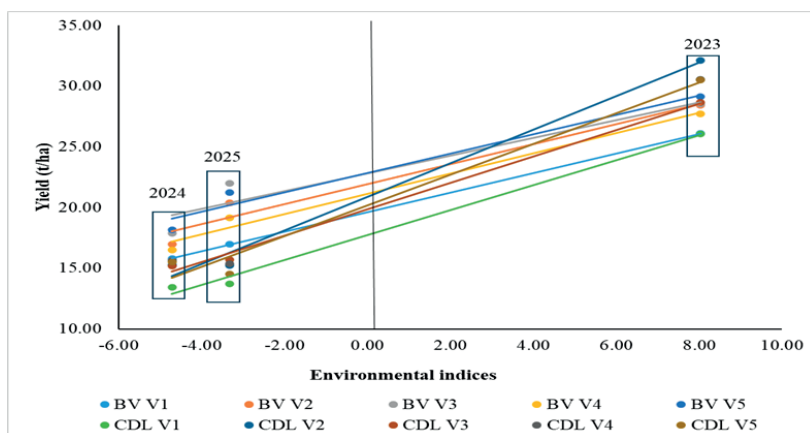


Figure 2. Stability of tuber yield in the potato cultivar Darilena with biostimulant treatments at Braşov and Codlea across three experimental years

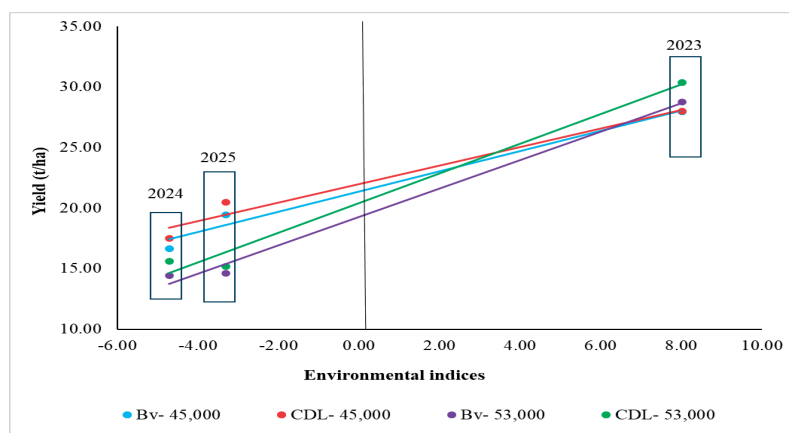


Figure 3. Stability of tuber yield in the potato cultivar Darilena with two plant densities (45,000/ 53,000 plant/ha) at NIRDPSB Braşov and Codlea across three experimental years

The correlation analysis revealed strong positive relationships among the parameters describing tuber development during the growing season. The number of tubers per hill at the first and second determinations was strongly correlated ($r = 0.78$), indicating a stable ranking of variants over time.

Both determinations of the number of tubers per hill showed strong to very strong positive correlations with tuber weight during the growing season, particularly with tuber weight per hill at the first assessment ($r = 0.82$ and $r = 0.91$), suggesting that a higher number of tubers per hill was generally associated with greater early biomass accumulation. Tuber weight at the first and second determinations was also

strongly correlated ($r = 0.76$), reflecting continuity in tuber growth dynamics.

In contrast, correlations between parameters measured during the growing season and final yield were weak or insignificant. The number of tubers at both determinations showed no significant relationship with yield ($r = -0.02$ and $r = -0.03$), while tuber weight at the first assessment was very weakly and negatively correlated with final yield ($r = -0.10$). Only tuber weight per hill at the second determination showed a weak positive correlation with final yield ($r = 0.26$), indicating that biomass accumulation at later stages was more closely related to yield formation than early tuberization (Figure 4).

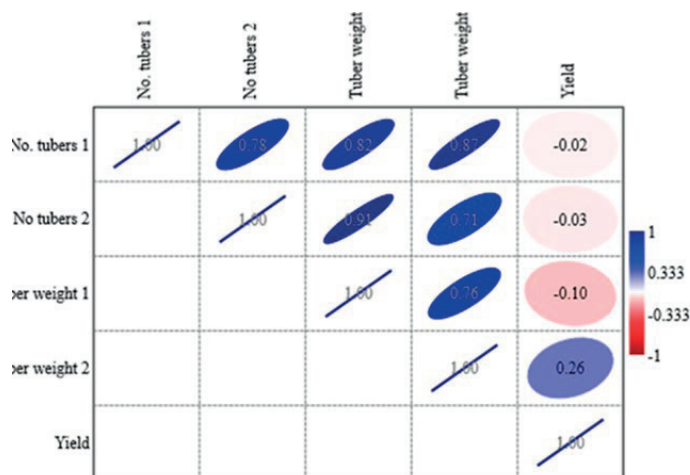


Figure 4. Pearson coefficients for studied parameters

CONCLUSIONS

The climatic regime during the 2022-2025 period exhibited pronounced interannual variability, which significantly influenced potato growth, and development. Thermal and hydric conditions differentially affected phenological stages of potato plants, with tuber initiation and development proving particularly sensitive to climatic stress.

The 2023-2024 growing season may be considered the most favorable in terms of the alignment between climatic factors and the ecological requirements of potato phenological stages, whereas the other seasons exhibited moderate constraints primarily associated with variability in water availability and thermal extremes.

The multifactorial experiment revealed that yield formation in the Darilena cultivar was primarily governed by the experimental year and biostimulant application. While the year had no significant effect on tuber number, it exerted a strong influence on tuber weight and a very highly significant effect on final yield. Biostimulant treatments consistently improved all evaluated traits, highlighting their stabilizing and productivity-enhancing potential under variable climatic conditions.

Planting density exhibited a context-dependent effect: although the higher density increased yield under favorable conditions, the lower density ensured superior yield stability under

less favorable environments. Experimental location had a secondary influence, mainly affecting early tuberization, while its impact on final yield was limited.

Correlation analysis indicated that early tuberization parameters were strongly interrelated but poorly associated with final yield, suggesting that yield determination was more closely linked to later-stage biomass accumulation than to initial tuber formation dynamics.

Overall, the results underline the predominance of climatic variability and biostimulant use as key determinants of yield performance and stability in potato, providing valuable insights for adaptive crop management strategies under increasingly unstable environmental conditions.

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