

ORGANO-MINERAL FERTILIZATION ON THE MORPHOLOGICAL AND BIOMETRIC TRAITS OF SUGAR BEET (*Beta vulgaris* L.) UNDER THE ECOPEDOLOGICAL CONDITIONS OF COVASNA COUNTY

Bianca-Anamaria POPA¹, Mircea MIHALACHE¹, Lorena ADAM^{1,2}

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

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

Corresponding author email: popa.bianca22@yahoo.com

Abstract

The application of organo-mineral fertilization in sugar beet cultivation stimulates plant growth and development, reflected by significant changes in their appearance and structural parameters, as a result of optimized nutrient availability and uptake. This study aims to evaluate the effects of different fertilization schemes on the development and biometric performance of three sugar beet hybrids under the ecopedological conditions of Covasna County during the 2022-2023 and 2023-2024 growing seasons. The experimental treatments consisted of three sugar beet hybrids (Darvas, Deseda, and Tatry) combined with different fertilization schemes, including varying doses of manure, nitrogen (N), phosphorus (P), and potassium (K). All applied fertilization schemes increased crown length and diameter, root weight, tuber yield, and sugar content compared to the untreated control, regardless of hybrid or climatic conditions. During the 2022-2023 growing season, the Tatry hybrid recorded the highest yield (60.05 t/ha) with a sugar content of 18.27°S, while in 2023-2024, the Darvas hybrid achieved the highest yield (85.79 t/ha) and a sugar content of 19.02°S across the different fertilization schemes.

Key words: climatic conditions, fertilization, hybrid, plant traits, sugar beet.

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is a strategically important crop for sucrose production in temperate regions, contributing substantially to both agricultural economies and the food industry. Achieving high root yield while maintaining elevated sugar concentration remains a major agronomic objective, as these two traits jointly determine sugar yield and processing efficiency. Crop performance in sugar beet is strongly influenced by genotype, climatic conditions, soil properties, and crop management practices, among which fertilization plays a decisive role (Draycott, 2006; Milford & Watson, 1971; Hoffmann et al., 2020; Kenter & Hoffmann, 2021). Recent studies emphasize that optimized nutrient management is essential for improving productivity while maintaining sugar quality under increasingly variable climatic conditions (Hoffmann et al., 2018; Safina et al., 2022). Nitrogen fertilization is a key factor governing sugar beet growth and yield formation.

Adequate nitrogen supply promotes leaf area development, photosynthetic capacity, and biomass accumulation, thereby enhancing root yield. However, the effect of nitrogen on sugar yield and root quality is strongly dose-dependent. Excessive nitrogen application can negatively affect sugar concentration and technological quality by increasing amino-N and other non-sucrose impurities in the root, ultimately reducing sugar extraction efficiency (Draycott & Christenson, 2003; Milford et al., 1988; Hoffmann & Kluge-Severin, 2011; Zarski et al., 2020). Consequently, optimizing nitrogen rates according to crop demand and soil nitrogen supply is essential to balance yield and quality in sugar beet production systems (Hoffmann et al., 2018; Pulkrábek et al., 2022).

Phosphorus and potassium are equally important macronutrients in sugar beet nutrition. Phosphorus supports early root development, energy transfer, and metabolic activity, while potassium plays a crucial role in carbohydrate transport, osmotic regulation, enzyme activation, and nitrogen utilization. Adequate

potassium availability has been associated with increased root yield, improved sugar accumulation, and enhanced tolerance to abiotic stress, particularly under conditions of intensive nitrogen fertilization (Christenson & Draycott, 2001; Johnston et al., 1999; Koch et al., 2020; Wakeel et al., 2021). Balanced N–P–K fertilization schemes are therefore widely recognized as fundamental for sustaining both yield and quality in sugar beet cultivation (Kenter et al., 2016; Hoffmann et al., 2020).

In recent years, increasing attention has been directed toward the use of organic fertilizers, such as farmyard manure, either alone or in combination with mineral fertilizers. Organic amendments contribute to improved soil structure, increased microbial activity, enhanced nutrient buffering capacity, and improved long-term nutrient availability, which may positively influence crop growth and yield stability (Edmeades, 2003; Diacono & Montemurro, 2010; Lazcano et al., 2018; Diacono et al., 2019). The integration of organic and mineral fertilizers has been shown to provide synergistic effects by combining the immediate nutrient availability of mineral sources with the long-term soil fertility benefits of organic inputs (López-Bellido et al., 2012; Chen et al., 2020; Safina et al., 2022).

Previous studies have demonstrated that organo-mineral fertilization strategies can improve root yield, sugar content, and overall nitrogen use efficiency compared to exclusive mineral or organic fertilization, particularly when nutrient rates are adjusted to crop demand and soil fertility status (Hoffmann & Kenter, 2018; Safina & Abou-Shanab, 2019; Pulkrábek et al., 2022). Nevertheless, the magnitude of these effects varies depending on fertilization rate, nutrient combination, soil conditions, and genotype, highlighting the need for region-specific and hybrid-specific research under field conditions.

Therefore, the objective of the present study was to evaluate the effects of different fertilization schemes, including organic, mineral, and organo-mineral fertilization, on morphological traits, yield components, and sugar content of sugar beet hybrids under field conditions over a two-year study period. The obtained results aim to contribute to the optimization of fertilization

strategies for sustainable and economically efficient sugar beet production.

MATERIALS AND METHODS

The field experiment was conducted in 2023 and 2024 in the locality of Zăbala, Covasna County, Romania, on a moderately acidic soil with a pH of 6.13, which is below the optimal value for sugar beet cultivation.

The field experiment was organized as subdivided plots with 4 replications being of type 3 x 6, with the following experimental factors:

Factor A – hybrids, with 3 graduations:

- a1. Darvas;
- a2. Deseda;
- a3. Tatry.

Factor B – fertilized with organic and mineral fertilizers, with 6 graduations:

- b1. 20 t/ha farmyard manure;
- b2. 20 t/ha farmyard manure + 150 kg/ha N + 150 kg/ha P + 150 kg/ha K;
- b3. 10 t/ha farmyard manure + 150 kg/ha N + 150 kg/ha P + 150 kg/ha K;
- b4. 10 t/ha farmyard manure;
- b5. 150 kg/ha N + 150 kg/ha P + 150 kg/ha K;
- b6. unfertilized control.

The **DARVAS** hybrid is a new, robust sugar beet hybrid characterized by high tolerance to foliar diseases and abiotic stress factors, including drought. The hybrid demonstrates stable performance in yield and root quality, making it suitable for cultivation under variable environmental conditions and ensuring consistent and efficient production.

The **DESEDA** hybrid is a sugar beet hybrid characterized by high sugar content, high yield per hectare, and excellent tolerance to cercospora (*Cercospora beticola*). The hybrid demonstrates stable performance in yield and root quality, making it suitable for cultivation under variable environmental conditions and ensuring consistent and efficient production.

The **TATRY** hybrid is a sugar beet hybrid characterized by high root yield and superior sugar content. It exhibits an increased juice purity coefficient, making it optimal for industrial processing. The hybrid shows high tolerance to cercospora leaf spot (*Cercospora*

beticola) and abiotic stress factors, including drought and temperature fluctuations. Its agronomic characteristics make it suitable for stable and efficient production, even under suboptimal environmental conditions.

The hybrids were sown on 13th of May in 2023 and 2nd of May in 2024 using a precision planter on 6 rows, with a row spacing of 45 cm and a sowing depth of 5 cm, under controlled field conditions.

Following sowing, the first herbicide application was conducted for weed management using Betanal Tandem 390 SC (MCPA 250 g/l + Phenmedipham 140 g/l) at a rate of 1 l/ha, Venzar 500 SC (Bentazone 500 g/l) at a rate of 0.3 l/ha and Safari (Diflufenican 500 g/kg) at a rate of 30 g/ha. The treatment targeted annual dicotyledonous and monocotyledonous weeds, as well as susceptible perennial broadleaf weeds. One week after the initial application, the herbicide treatment was repeated at the same rates to ensure uniform and effective weed control under field conditions.

The experimental plot area for each treatment was 16.2 m², corresponding to six rows of sugar beet, with a row spacing of 45 cm (2.7 m) and a row length of 6 m.

Crown length (cm), crown diameter (cm), and root weight (g) were measured on two representative plants from each treatment and replication

Sugar beet was harvested on 13th of November in 2023 and 24th of November in 2024; the root weight of each plot and replication was determined, and the yield per hectare was subsequently calculated. Sugar content was analyzed on 11th of December in 2023 and 4th of December in 2024 at the Laboratory of Technology and Good Agricultural Practices of the National Institute of Research and Development for Potato and Sugar Beet Braşov (NIRDPSB). Statistical analyses were performed using Microsoft Excel. The experimental data were subjected to analysis of variance (ANOVA), and treatment means were compared with the unfertilized control using the Least Significant Difference (LSD) test at the 5%, 1%, and 0.1% probability levels. The levels of statistical significance are indicated as follows: *significant ($p < 0.05$), **distinctly significant ($p < 0.01$), and ***very significant ($p < 0.001$).

RESULTS AND DISCUSSIONS

Root collar length

The root collar length was determined on 13th November 2023 (Table 1). Thus, the Darvas hybrid recorded very highly significant values compared to the unfertilized control in all treatments fertilized with organic fertilizer or with a combination of organic and mineral fertilizers. In the case of the treatment fertilized exclusively with mineral fertilizer, namely 150 kg/ha N + 150 kg/ha P + 150 kg/ha K (a1b5), no significant differences were recorded.

For the Deseda hybrid, the lowest mean value of root collar length was identified in the treatment fertilized with 10 t/ha farmyard manure (a2b4), reaching 2.45 cm, this value being 0.1 cm lower than that of the unfertilized control. All other treatments fertilized with standard organo-mineral fertilizer doses showed no significant differences compared to the control treatment.

Compared to the Deseda hybrid, the Tatry hybrid recorded very highly significant differences in terms of root collar length in the treatment fertilized with 20 t/ha farmyard manure + 150 kg/ha N + 150 kg/ha P + 150 kg/ha K (a3b2), and distinctly significant differences in the treatment fertilized with 20 t/ha farmyard manure (a3b1). All other experimental treatments showed no significant differences compared to the unfertilized control. In contrast to the year 2023, in 2024, on 24th November, very highly significant differences in root collar length values were recorded for all three studied hybrids in the treatments fertilized with 20 t/ha farmyard manure + 150 kg/ha N + 150 kg/ha P + 150 kg/ha K and with 20 t/ha farmyard manure (Table 1).

Regarding the treatments fertilized with 10 t/ha farmyard manure + 150 kg/ha N + 150 kg/ha P + 150 kg/ha K, these recorded distinctly significant values in the case of the Darvas hybrid and very highly significant values in the case of the Deseda and Tatry hybrids.

Significant differences compared to the unfertilized control were identified in the treatments fertilized with 10 t/ha farmyard manure in the Darvas (a1b4) and Tatry (a3b4) hybrids, as well as in the treatment fertilized with 150 kg/ha N + 150 kg/ha P + 150 kg/ha K in the Darvas hybrid (a1b5). Non-significant differences compared to the unfertilized control

were identified in the treatments fertilized with 150 kg/ha N + 150 kg/ha P + 150 kg/ha K in the Deseda (a2b5) and Tatry (a3b5) hybrids.

Table 1. Root collar length (cm)

2023						
Variant	a1-DARVAS		a2-DESEDA		a3-TATRY	
	Value (cm)	Difference	Value (cm)	Difference	Value (cm)	Difference
b1	4.48***	2.00	2.68	0.13	3.88**	1.13
b2	4.58***	2.10	3.13	0.58	4.15***	1.40
b3	4.40***	1.93	3.05	0.50	3.40	0.65
b4	3.80***	1.33	2.45***	-0.10	3.08	0.33
b5	2.85	0.38	2.63	0.08	3.58	0.83
b6	2.48	Mt	2.55	Mt	2.75	Mt
DI 5%= 0.661						
DI 1%= 0.882						
DI 0.1%= 1.155						
2024						
Variant	a1-DARVAS		a2-DESEDA		a3-TATRY	
	Value (cm)	Difference	Value (cm)	Difference	Value (cm)	Difference
b1	4.98***	1.18	4.85***	1.13	4.83***	1.35
b2	5.35***	1.55	5.10***	1.38	5.15***	1.68
b3	4.53***	0.73	4.68***	0.95	4.43***	0.95
b4	4.35*	0.55	4.65***	0.93	4.15*	0.68
b5	4.30*	0.50	4.15	0.43	3.85	0.38
b6	3.80	Mt	3.73	Mt	3.48	Mt
DI 5%= 0.515						
DI 1%= 0.688						
DI 0.1%= 0.901						
*** - very significant; ** - distinctly significant, * - significant						

Root collar diameter

The root collar diameter recorded the highest value in 2024 in the treatment fertilized with 20 t/ha farmyard manure + 150 kg/ha N + 150 kg/ha P + 150 kg/ha K in the Darvas hybrid (a1b2), reaching 7.35 cm. This value was 1.83 cm higher than the maximum value recorded in 2023, namely 5.53 cm, observed in the Tatry hybrid fertilized with the same organo-mineral fertilizer dose. Regarding the minimum value identified for root collar diameter in 2024, it was 5.23 cm, differing by only 0.3 cm from the maximum value recorded in 2023 (Table 2). In contrast, in 2023, the root collar diameter showed very highly significant differences compared to the unfertilized control for each treatment, with two exceptions: the treatment fertilized with 10 t/ha farmyard manure in the Deseda hybrid (a2b4), where the difference was distinctly significant, and the Tatry hybrid fertilized with 150 kg/ha N + 150 kg/ha P + 150 kg/ha K (a3b5), where the difference was significant (Table 2).

Analyzing the two study years, these did not show the same uniformity in terms of differences between experimental treatments and their respective controls. Thus, very highly significant differences were evident in treatments fertilized with the maximum dose of organic fertilizer or with combinations of organic and mineral fertilizers. An exception was observed in the Darvas hybrid fertilized with 20 t/ha farmyard manure (a1b1) and in the treatment fertilized with 10 t/ha farmyard manure + 150 kg/ha N + 150 kg/ha P + 150 kg/ha K (a1b3), where the differences were distinctly significant and positive.

Significant differences were recorded in the Darvas and Tatry hybrids fertilized with 10 t/ha farmyard manure + 150 kg/ha N + 150 kg/ha P + 150 kg/ha K, as well as in the Deseda hybrid fertilized with 150 kg/ha N + 150 kg/ha P + 150 kg/ha K.

The Darvas and Tatry hybrids fertilized exclusively with organic fertilizer did not show significant differences.

Table 2. Root collar diameter (cm)

2023						
Variant	a1-DARVAS		a2-DESEDA		a3-TATRY	
	Value (cm)	Difference	Value (cm)	Difference	Value (cm)	Difference
b1	5.3***	2.40	4.65***	1.55	4.65***	0.98
b2	5.5***	2.60	4.85***	1.75	5.53***	1.85
b3	5.1***	2.20	4.45***	1.35	4.68***	1.00
b4	4.55***	1.65	3.58**	0.48	4.30***	0.63
b5	3.95***	1.05	3.80***	0.70	4.08*	0.4
b6	2.90	Mt	3.10	Mt	3.68	Mt
DI 5%= 0.323						
DI 1%= 0.431						
DI 0.1%= 0.564						
2024						
Variant	a1-DARVAS		a2-DESEDA		a3-TATRY	
	Value (cm)	Difference	Value (cm)	Difference	Value (cm)	Difference
b1	6.78**	1.13	6.63***	1.40	6.85***	1.35
b2	7.35***	1.70	7.35***	2.13	7.20***	1.70
b3	6.65**	1.00	6.60***	1.38	6.90***	1.40
b4	6.40*	0.75	6.13**	0.90	6.35*	0.85
b5	5.93	0.28	6.10*	0.88	5.88	0.38
b6	5.65	Mt	5.23	Mt	5.50	Mt
DI 5%= 0.671						
DI 1%= 0.895						
DI 0.1%= 1.172						
*** - very significant; ** - distinctly significant, * - significant						

Plant weight

From an analytical perspective, across the two study years, the highest mean plant weight was

recorded in the treatment fertilized with 20 t/ha farmyard manure + 150 kg/ha N + 150 kg/ha P + 150 kg/ha K for the Darvas hybrid (a1b2). In 2023 (Table 3), Darvas represented the hybrid of extremes, also showing the lowest plant weight in the unfertilized control (302.11 g).

Table 3. Plant weight (g)

2023						
Variant	a1-DARVAS		a2-DESEDA		a3-TATRY	
	Value (cm)	Difference	Value (cm)	Difference	Value (cm)	Difference
b1	1193.35 ***	891.2 5	846.37** *	385.97 3	1006.03 ***	467.6 8
b2	1318.20 ***	1016. 1	1063.88 *	603.48 8	1126.59 ***	588.2 4
b3	804.94** *	502.8 3	744.623 *	284.23	896.91** *	358.5 6
b4	732.78** *	430.6 7	523.74 *	63.35	805.56** *	267.2
b5	501.49** *	199.3 8	477.87 *	17.475	701.79** *	163.4 4
b6	302.105	Mt	460.39	Mt	538.35	Mt
DI 5%= 99.205 DI 1%= 132.476 DI 0.1%= 173.391						
2024						
Variant	a1-DARVAS		a2-DESEDA		a3-TATRY	
	Value (cm)	Difference	Value (cm)	Difference	Value (cm)	Difference
b1	1445.03 ***	636.7 8	1417.13 ***	625.35	1248.15 ***	431.6 5
b2	1715.9** *	907.6 5	1588.73 ***	796.95	1485.08 ***	668.5 8
b3	1264.45 ***	456.2 *	1196.4** *	404.63	1202.78 ***	386.2 8
b4	1077.18 ***	268.9 3	1020.1** *	228.33	1074.25 ***	257.7 5
b5	973.03** *	164.7 8	906.98** *	115.2	939.65** *	123.1 5
b6	808.25	Mt	791.78	Mt	816.5	Mt
DI 5%= 62.127 DI 1%= 85.027 DI 0.1%= 116.477						
*** - very significant; ** - distinctly significant, * - significant						

From a statistical standpoint, in 2023, all fertilization treatments of the Darvas hybrid showed very highly significant differences compared to the unfertilized control. A similar trend was observed for the Tatry hybrid, except that it presented one treatment with distinctly significant differences relative to the control, specifically the treatment fertilized exclusively with mineral fertilizer (a3b5). The differences recorded for the Darvas hybrid in treatments with 10 t/ha farmyard manure

(a2b4) and 150 kg/ha N + 150 kg/ha P + 150 kg/ha K (a2b5) were not significant compared to the unfertilized control.

Regarding 2024, compared to 2023, it was uniform in terms of the statistical significance of differences among the experimental treatments, all of them being very highly significant. The only treatment standing out in terms of plant weight, showing distinctly significant differences compared to the unfertilized control, was the Deseda hybrid fertilized exclusively with 150 kg/ha N + 150 kg/ha P + 150 kg/ha K (Table 3).

Storage root yield

The maximum storage root yield reached 85.79 t/ha in 2024 for the Darvas hybrid fertilized with 20 t/ha farmyard manure + 150 kg/ha N + 150 kg/ha P + 150 kg/ha K (a1b2), which was 25.74 t/ha higher than the maximum value recorded in 2023, namely 60.05 t/ha for the Tatry hybrid fertilized with the same organo-mineral fertilizer dose (a3b2).

Regarding the minimum yield values, it can be stated that 2023 was a much more balanced year in terms of storage root production (t/ha), with the minimum value being 49.25 t/ha, resulting in a difference of 10.8 t/ha between the maximum and minimum values (Table 4).

Analyzing 2024, the difference between the minimum value of 2023 and that of 2024 (39.59 t/ha) was 9.67 t/ha, while the difference between the two extreme values in 2024 reached 46.21 t/ha, which highlights the positive influence of the fertilization dose on all yield components, ultimately leading to the achievement of considerably higher total yields.

From a statistical point of view, in 2023, for each hybrid, the treatments fertilized with 20 t/ha farmyard manure, 20 t/ha farmyard manure + 150 kg/ha N + 150 kg/ha P + 150 kg/ha K, and 10 t/ha farmyard manure + 150 kg/ha N + 150 kg/ha P + 150 kg/ha K recorded very highly significant differences compared to the unfertilized control. Distinctly significant differences were observed in the Darvas hybrid fertilized with 10 t/ha farmyard manure (a1b4) and in the Tatry hybrid fertilized with 150 kg/ha N + 150 kg/ha P + 150 kg/ha K (a3b5) (Table 4). Additionally, significant differences were reported only for the Darvas hybrid fertilized with 150 kg/ha N + 150 kg/ha P + 150 kg/ha K

(a1b5) and for the Deseda hybrid fertilized with 10 t/ha farmyard manure (a2b4). In 2023, only one treatment showed non-significant differences in storage root yield compared to the unfertilized control, namely the Deseda hybrid fertilized with 150 kg/ha N + 150 kg/ha P + 150 kg/ha K (a2b5).

Table 4. Storage root yield (t/ha)

2023						
Variant	a1-DARVAS		a2-DESEDA		a3-TATRY	
	Value (cm)	Difference	Value (cm)	Difference	Value (cm)	Difference
b1	57.88***	8.55	56.80***	6.00	58.78***	9.53
b2	59.43***	10.10	59.68***	8.88	60.05***	10.80
b3	55.23***	5.90	56.90***	6.10	58.18***	8.93
b4	52.70**	3.38	53.58*	2.78	53.88***	4.63
b5	51.88**	2.55	52.18	1.38	52.68**	3.43
b6	49.33	Mt	50.80	Mt	49.25	Mt
DI 5%= 2.161 DI 1%= 2.886 DI 0.1%= 3.778						
2024						
Variant	a1-DARVAS		a2-DESEDA		a3-TATRY	
	Value (cm)	Difference	Value (cm)	Difference	Value (cm)	Difference
b1	72.25***	31.84	70.85***	31.27	62.41***	21.58
b2	85.79***	45.38	79.43***	39.85	74.25***	33.43
b3	63.22***	22.81	59.82***	20.23	60.14***	19.31
b4	53.86***	13.45	51.00***	11.41	53.71***	12.89
b5	48.65***	8.24	45.35**	5.76	47.06***	6.23
b6	40.41	Mt	39.59	Mt	40.82	Mt
DI 5%= 3.101 DI 1%= 4.243 DI 0.1%= 5.811						
*** - very significant; ** - distinctly significant, * - significant						

Sugar content

In 2023, the highest mean sugar content at the treatment level was recorded for the Tatry hybrid fertilized with 20 t/ha of farmyard manure combined with 150 kg/ha N, 150 kg/ha P, and 150 kg/ha K (a3b2), reaching a value of 18.27%. All analyzed hybrids under the five fertilization treatments showed very significant differences compared to their corresponding unfertilized control (Table 5).

In 2024, the highest mean sugar content was observed for the Darvas hybrid fertilized with 20 t/ha of farmyard manure combined with 150 kg/ha N, 150 kg/ha P, and 150 kg/ha K (a1b2), with a value of 19.02% (Table 5).

The comparative analysis of the two experimental years (2023 and 2024) revealed that the majority of the differences in sugar

content between the fertilized treatments and the unfertilized control were very highly significant. Nevertheless, two experimental treatments showed non-significant differences compared to the control, namely the Darvas hybrid fertilized with 10 t/ha of farmyard manure (a1b4) and the treatment fertilized with 150 kg/ha N, 150 kg/ha P, and 150 kg/ha K (a1b5).

Table 5. Sugar content (%)

2023						
Variant	a1-DARVAS		a2-DESEDA		a3-TATRY	
	Value (cm)	Difference	Value (cm)	Difference	Value (cm)	Difference
b1	17.04***	3.01	18.07***	4.03	17.38***	2.97
b2	17.35***	3.32	17.39***	3.34	18.27***	3.86
b3	16.55***	2.53	16.48***	2.44	17.28***	2.86
b4	16.24***	2.22	15.59***	1.55	16.29***	1.88
b5	15.17***	1.14	15.05***	1.01	15.25***	0.84
b6	14.03	Mt	14.04	Mt	14.41	Mt
DI 5%= 0.161 DI 1%= 0.216 DI 0.1%= 0.282						
2024						
Variant	a1-DARVAS		a2-DESEDA		a3-TATRY	
	Value (cm)	Difference	Value (cm)	Difference	Value (cm)	Difference
b1	18.64***	1.42	17.82***	3.46	18.36***	2.40
b2	19.02***	1.80	18.48***	4.12	18.45***	2.49
b3	18.35***	1.13	17.50***	3.14	18.09***	2.13
b4	17.60	0.38	16.92***	2.56	18.05***	2.09
b5	17.44	0.22	15.86***	1.50	17.33***	1.37
b6	17.22	Mt	14.36	Mt	15.96	Mt
DI 5%= 0.493 DI 1%= 0.658 DI 0.1%= 0.862						
*** - very significant; ** - distinctly significant, * - significant						

CONCLUSIONS

The results demonstrated that organo-mineral fertilization had a positive effect on both the morphological characteristics and productive performance of sugar beet under the ecopedological conditions of Covasna County. The combined application of farmyard manure

and mineral fertilizers improved root collar dimensions, plant weight, storage root yield, and sugar content compared with the unfertilized control.

Among the studied fertilization schemes, the application of 20 t/ha farmyard manure combined with 150 kg/ha N, 150 kg/ha P, and 150 kg/ha K produced the most favorable results. The highest values of the analyzed parameters were consistently obtained by the Darvas hybrid under this fertilization regime, regardless of the study year.

Maximum storage root yield and sugar content were achieved in the Darvas and Tatry hybrids receiving the highest organo-mineral fertilizer dose, confirming the beneficial interaction between genotype and integrated nutrient management.

Overall, the findings highlight the effectiveness of organo-mineral fertilization as a sustainable strategy for improving sugar beet productivity and quality. The study contributes to the optimization of fertilization practices under local environmental conditions and supports the wider adoption of integrated nutrient management in sugar beet cultivation.

The obtained results demonstrate the synergy of organo-mineral fertilization, which led to significant improvements in morphological traits and production parameters compared to exclusive organic or mineral fertilization.

In this context, organo-mineral fertilization represents an agronomically and economically efficient solution for sugar beet cultivation, contributing to increased yield, improved economic efficiency, and enhanced practical relevance for farmers.

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