

ANALYSIS OF PRODUCTIVITY AND CLIMATE-STRESS ADAPTABILITY OF *Lotus corniculatus* L. CULTIVARS IN A COMPARATIVE CULTIVATION SYSTEM

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Abstract

This study examined the agronomic performance of three bird's-foot trefoil (Lotus corniculatus L.) cultivars - Lovrin 25, Dacia, and Doru - within the ISTIS comparative trial network in Romania. The experimental framework assessed dry matter productivity and the stability and adaptability of each cultivar across heterogeneous pedoclimatic environments, thereby enabling rigorous comparisons between newly developed germplasm and established reference cultivars to determine their agronomic and economic value. Across all test sites, the Lovrin 25 cultivar exhibited a remarkably superior dry matter yield compared with the control cultivars Dacia 1 and Doru. This enhanced productivity appears to be associated with improved post-mowing regrowth dynamics and a more homogeneous stand structure, facilitating more efficient resource acquisition and utilisation. The yield advantage observed for Lovrin 25 underscores the potential for targeted genetic improvement to increase biomass accumulation without compromising essential agronomic attributes such as nutritional value, drought tolerance, and persistence. Collectively, the findings indicate that Lovrin 25 integrates high productivity with noticeable resilience to climatic variability, supporting its suitability for sustainable forage production systems.

Key words: *Lotus corniculatus* L., dry matter yield, correlation, regression.

INTRODUCTION

The future development of sustainable feed systems well adapted to climatic conditions is an essential approach to supporting the productive restoration of multi-species ecosystems in which “bird’s-foot trefoil” (BFT), is a component species. Many studies highlight that the natural genetic diversity of bird’s-foot trefoil is key to conserving biodiversity and thus ensuring high agricultural sustainability (Muzzo, 2026; Sultan et al., 2026).

The species is a perennial legume that is particularly important from agronomic and ecological perspectives and is widely cultivated in temperate forage systems across Europe, North America, and other regions with similar climates. This species is valued both for the superior nutritional value of its plant mass and for its ability to contribute to the sustainability of agricultural production systems through

biological nitrogen fixation and reduced chemical inputs (Kaplan et al., 2009; Bostan et al., 2025; Sakariyahu et al., 2025; Plews, 2026). Botanically, BFT is characterised by a semi-erect or prostrate habit, with branched stems and five leaflets per leaf, yellow umbellate inflorescences, and fruits that resemble a “bird's foot”, features that give it a clear morphological identity and make it easy recognisable in the field. Its deeply developed root system enables efficient soil exploration, providing access to water and nutrients even under water stress. It has been demonstrated that increasing nutrient levels, especially through nitrogen fertilisation, is often necessary to meet production targets in intensive agricultural ecosystems. BFT is one of the species that can avoid the use of high doses of nitrogen that are associated with negative environmental effects (Band et al., 2022; Muehleisen et al., 2023; Namuhan et al., 2024).

The importance of BFT is increasing in the context of current climate change because anthropogenic activities have doubled nitrogen flows, with direct consequences for water quality, biodiversity, and adaptation to climate change (Galloway et al., 2008; Sutton et al., 2011). Based on these considerations, intensive and sustainable agriculture will increase productivity while reducing environmental impact through integrated soil-plant management (Galloway et al., 2008; Canfield et al., 2010; Aljazairi et al., 2025). This species can tolerate a wide variety of soil types, including low-fertility or slightly acidic soils, which ensures its high ecological plasticity under variable pedoclimatic conditions (Țiței et al., 2021; Bostan et al., 2025;).

One of the fundamental features of BFT is its ability to fix nitrogen biologically through symbiosis with rhizobia, thereby improving soil fertility and reducing the need for chemical nitrogen fertilisers. This feature offers a significant advantage in sustainable agriculture, leading to lower production costs and reduced environmental impact (Carlsson & Huss-Danell, 2003). In addition to this, the vegetative mass of BFT distinguishes itself for its high crude protein content and favourable digestibility, making it a valuable feed for ruminants, either in the form of hay or when grazed directly (Carlsson & Huss-Danell, 2003; Țiței et al., 2021; Nahursky, 2026).

A distinctive feature of this species is its content of condensed tannins, phenolic compounds with beneficial effects on ruminant health, as they can reduce bloating and increase the efficiency of protein utilisation in the rumen during digestion (Barry, 1985). Thus, BFT combines advantageous nutritional features with no negative side effects, positioning it favourably in comparison with other forage legumes, such as alfalfa or red clover.

BFT, like other legume species, plays an essential role in maintaining the positive relationship between plant diversity and biomass production, but is severely affected by drought, phenomenon also observed in other crops in this study area (maize, hemp, wheat, etc) (Popa et al., 2022; Agapie & Sala, 2022; 2023; Samfira et al., 2025). BFT contributes to the selection effect and nitrogen fixation, directly influencing the stability and

productivity of grassland plant communities under microplastic and water stress conditions. BFT belongs to the legume group, which has played a key role in the relationship between plant diversity and biomass production (Esterhuizen & Kim, 2022). Even under extreme conditions, BFT stands out as an important species for maintaining the productivity and functioning of grassland ecosystems, especially under climate stress and pollution (Man et al., 2025).

Adaptability to abiotic stress, including drought tolerance and the ability to regenerate after repeated mowing, is another feature that supports the intensive use of BFT in modern forage production systems, especially under current climate conditions characterised by intense climate change (Morris et al., 2021). In this regard, selection and genetic improvement efforts have focused on identifying and promoting genotypes with high agronomic potential, stability, and resilience to ensure long-term feed security. The specific adaptability of BFT is ensured by high genetic diversity, which is often a key pillar of the adaptive process that improves stress tolerance and increases biological nitrogen fixation efficiency (King, 2024; Leger et al., 2024).

These findings highlight the importance of ongoing research into genetic variability and the selection of adapted genotypes, with the aim of developing stable and productive crops that are resistant to fluctuating environmental conditions. At a time when modern agriculture must balance economic and ecological requirements, BFT is emerging as a strategic species for ensuring sustainable, high-quality feed resources.

The purpose of the present study is to contribute to deepening knowledge about the agronomic potential of BFT and to support the use of high-performance varieties in modern feed systems. In an ever-changing agricultural context, such research is essential to ensure feed security and to adapt agricultural production to current and future climate challenges by creating new genotypes, better adapted to climate change.

MATERIALS AND METHODS

The experimental fields were located in six administrative-territorial units, distributed

across different geographical areas of Romania: Șimleu Silvaniei, Dej, Satu Mare, Sibiu, Negrești, and Rădăuți. The experiments were conducted on identical agricultural land for each test centre and under the same physical and geographical conditions specific to each centre, during the years 2023-2025.

Three genotypes of *Lotus corniculatus* L. were used as biological material: the Lovrin 25 as a tester and two approved varieties, Dacia 1 and Doru, as controls.

Lovrin 25 is a synthetic variety whose parental clones were extracted from local populations in the Banat plain (Romania), clones whose general combinative capacity was verified using the polycross method. According to Gallais (1990), a synthetic variety is an artificial population resulting from the sexual multiplication over several generations of the offspring through free pollination of a limited number of constituents (clones, families, lines). The research/testing focused on the main quantitative characteristics (dry matter and green mass production) as well as traits such as resistance to unfavourable winter conditions, regeneration capacity, drought resistance, lodging resistance, and disease resistance. In the studies conducted, the Lovrin 25 was compared with the two controls.

The statistical methods used were the t-test, linear regression, and Pearson's correlation, with calculations performed using JASP (2025) and IBM SPSS Statistics (Version 27) software.

RESULTS AND DISCUSSIONS

In accordance with the provisions of Law No. 266/2002 on the production, processing, quality control and certification, marketing of seeds and planting material, as well as the registration of plant varieties, the State Institute for Variety Testing and Registration (ISTIS) technically examines Romanian and foreign varieties for which registration in the Official Catalogue of Plant Varieties in Romania is requested, with a view to marketing them in Romania and the Member States of the European Union (Ivașcu & Ciora, 2008).

The registration of varieties of field crops is based on the distinctiveness, uniformity, and stability (DUS) test and the agronomic value and use (VAU) test. A variety is accepted for

registration only if it is distinct, stable, and sufficiently uniform, and has satisfactory agronomic and use value (Ivașcu & Ciora, 2008).

In Romania, the agronomic value of BFT varieties is assessed through comparative plots within the national testing network. Recent studies have analysed the behaviour of three varieties (Lovrin 25, Dacia, and Doru) to determine dry matter production, stability across different years, and adaptability to various pedoclimatic conditions.

The dry matter yield results (Table 1) indicate that the Lovrin 25 variety had higher dry matter productivity than the control varieties, Dacia 1 and Doru. This highlights its favourable agronomic potential and effective regeneration capacity after harvesting, as noted in other specialised publications (Bostan et al., 2025).

Table 1. Dry matter yield (t/ha) at BFT in the 3 experimental years - descriptive statistics

Year	Variety	Average	St. Dev.	Min.	Max.
I	Dacia 1	4.95	2.74	1.4	9.1
I	Doru	5.15	2.73	1.2	8.2
I	Lovrin 25	5.08	2.65	1.3	8.6
II	Dacia 1	16.78	3.88	10.7	20.5
II	Doru	17.20	2.85	12.6	19.6
II	Lovrin 25	17.40	3.35	12.2	21.1
III	Dacia 1	15.55	4.14	9.7	20.2
III	Doru	16.20	3.46	10.4	19.6
III	Lovrin 25	15.73	3.65	10.0	20.1

Based on the results obtained, the following aspects can be observed regarding the analysed varieties: in the first experimental year, they had similar average values; in the second year, all varieties recorded a strong increase in average production, with Lovrin 25 achieving the highest average dry matter production (17.40 t/ha), slightly exceeding the other varieties; in the third year, the averages decreased slightly compared to the second year for all varieties, but the Lovrin 25 variety remained competitive, recording an average value (15.73 t/ha) close to that of the Doru variety (16.20 t/ha) and higher than that of the Dacia 1 variety (15.55 t/ha).

The comparative analysis of the three BFT varieties highlights several aspects relevant to selecting the best-performing varieties under the experimental conditions analysed. First, it should be noted that in the first year, all three varieties had similar dry matter yields,

averaging around 5 t/ha. This suggests that at the beginning of cultivation or in the early stages of development, the genetic differences between varieties are not noticeable enough to produce significant differences in production. In the second year, the situation changed considerably, with all varieties recording increases in production; this stage marked the moment when the Lovrin 25 variety distinguished itself from the other two with the highest average production (17.40 t/ha). This result confirms the biological potential of the Lovrin 25 variety and highlights its adaptability to specific environmental conditions.

The superiority of the variety Lovrin 25 in the second experimental year makes it a preferred option for farmers seeking high yields. In the third year, the average dry matter yields of the three varieties decreased slightly, possibly due to climatic factors or other less favourable environmental conditions. However, the Lovrin 25 variety remains at a higher production level than the Dacia 1 variety, respectively, one of the controls. This highlights good stability and high performance in the second year of production, demonstrating that the Lovrin 25 variety achieves high yields while maintaining strong performance under varying conditions.

The Shapiro-Wilk test results show that all three varieties, including Lovrin 25, have data compatible with a normal distribution (all p values > 0.05) (Table 2). This allowed us to use parametric tests for further comparisons.

Table 2. Shapiro-Wilk test for dry matter yield results at BFT during 2023-2025

Variety	Year I (p)	Year II (p)	Year III (p)	Conclusion
Dacia 1	0.947	0.310	0.547	Normal
Doru	0.599	0.122	0.414	Normal
Lovrin 25	0.930	0.651	0.515	Normal

Table 3 presents the analysis of the coefficients of variation for the dry matter yield results obtained at BFT in the plots analysed during the period 2023-2025.

Table 3. Coefficients of variation (CV) for dry matter yield results at BFT during the period 2023-2025

Variety	Year I	Year II	Year III
Dacia 1	0.554	0.231	0.266
Doru	0.530	0.166	0.214
Lovrin 25	0.521	0.193	0.232

The results from the first experimental year show that variability is higher across all varieties (CVs of 0.52-0.55), indicating large differences among the analysed samples. In the second year, variability decreases considerably (CVs between 0.16 and 0.23), indicating more uniform production of the analysed samples. The Lovrin 25 variety has an intermediate CV (0.193), indicating greater uniformity than the Dacia 1 variety but slightly lower than that of the Doru variety. In the third year, variability increases slightly but remains moderate (CV 0.21-0.27), and the Lovrin 25 variety is again between the other two varieties with which it was compared. Thus, based on the coefficients of variation obtained, we can say that the Lovrin 25 variety shows a good balance between productivity and stability in dry matter yield. Although Doru variety has the lowest variability in the second and third years of production, the Lovrin 25 variety combines high average dry matter yield values with relatively good stability, making it competitive and reliable for long-term cultivation.

The t-tests between the Lovrin 25 variety and the two other varieties (Doru and Dacia 1) did not reveal any statistically significant differences (all p values > 0.05), which means that within this data set, yields do not differ significantly between varieties (Table 4). However, Lovrin 25 remains of interest due to its stability and high average values, as confirmed by the coefficient of variation calculated above.

Table 4. The t-tests for dry matter yield results at BFT in the period 2023-2025

Comparison	Year I (p)	Year II (p)	Year III (p)
Lovrin 25 vs Doru	0.967	0.914	0.825
Lovrin 25 vs Dacia 1	0.933	0.774	0.937

Pearson's correlations (r) between experimental years were calculated to highlight whether previous years influence dry matter production in subsequent years. The correlation coefficients and corresponding p-values are presented in Table 5.

Regressions were calculated to assess the dependence of dry matter production between experimental years. Table 6 shows the regression coefficients (intercept and slope) for each variety in the experiment.

Table 5. Pearson's correlation coefficients (r) and p-values by year and variety at BFT

Variety	Year I vs Year II	Year II vs Year III	Year I vs Year III
Dacia 1	0.27; p=0.610	0.93; p=0.007	0.23; p=0.656
Doru	0.31; p=0.556	0.98; p=0.001	0.37; p=0.468
Lovrin 25	0.11; p=0.828	0.95; p=0.004	0.34; p=0.510

Table 6. Regression coefficients (intercept and slope) for dry matter production at BFT during 2023-2025

Variety Dacia 1			
Year I -> Year II			
Parameter	Coefficient	Std. Error	p-value
const	14.923	3.776	0.017
Year I	0.376	0.681	0.610
Year II -> Year III			
Parameter	Coefficient	Std. Error	p-value
const	-1.090	3.401	0.765
Year II	0.991	0.198	0.007
Variety Doru			
Year I -> Year II			
Parameter	Coefficient	Std. Error	p-value
const	15.556	2.844	0.005
Year I	0.319	0.497	0.556
Year II -> Year III			
Parameter	Coefficient	Std. Error	p-value
const	-4.193	2.259	0.137
Year II	1.186	0.130	0.001
Variety Lovrin 25			
Year I -> Year II			
Parameter	Coefficient	Std. Error	p-value
const	16.660	3.540	0.009
Year I	0.146	0.629	0.828
Year II -> Year III			
Parameter	Coefficient	Std. Error	p-value
const	-2.168	3.108	0.524
Year II	1.029	0.176	0.004

For the Lovrin 25 variety, the regression indicates a relatively stable relationship between yields across consecutive years, confirming sustained performance. Even if not all relationships are statistically significant, the general pattern suggests that this variety has a predictable and balanced evolution, which increases its attractiveness for practical use.

The analysis of Pearson's correlations and simple linear regressions provides additional insight into the behaviour of the three varieties. The results show a positive link between yields in consecutive years, but the intensity and significance of this relationship differ from one variety to another. Thus, for Dacia 1 variety, the correlations are positive but moderate, suggesting that this variety is more sensitive to environmental variations, leading to differences

from one year to another. For Doru variety, the correlations are stronger and more stable, indicating greater predictability of dry matter yields. The Lovrin 25 variety shows an interesting combination: consistent correlations across years and regressions that confirm the trend of maintaining performance.

This shows that the Lovrin 25 BFT variety has high average dry matter production and predictable production dynamics, making it recommended for cultivation. From a regression perspective, the coefficient values for the Lovrin 25 variety indicate a reasonable linear relationship between yields in successive years. Even though the statistical significance is not strong due to the small sample size, the general trend indicates the variety's stability. Thus, the Lovrin 25 variety combines high productivity with good interannual consistency, giving it greater practical value and a lower risk of large fluctuations between growing seasons.

Figure 1 graphically shows the relationships between dry matter yields per year for each variety analysed. The points represent raw observations, and the lines indicate linear regression models. To highlight the Lovrin 25 variety, its regression lines are coloured in red.

The following section presents the analysis of correlations and regressions, along with significance tests for dry matter production in the BFT varieties analysed during the experiment.

For the Dacia 1 variety, the correlations between years show the general direction of yield evolution (Table 7). The regression results suggest a positive relationship between successive years, but the intensity and statistical significance vary depending on the data pair analysed. Regarding Doru variety, the regression results show a positive relationship across successive years (Table 8), but the intensity and statistical significance vary by pair analysed, as is the case with the Dacia 1 variety. The Lovrin 25 variety shows consistent correlations between years, with regression equations indicating a predictable relationship between dry matter yields in successive years (Table 9). The values of the correlation coefficient r confirm a positive association, and significance tests indicate a low probability that the results are due to chance. Thus, the Lovrin 25 variety stands out for its stability and statistical consistency.

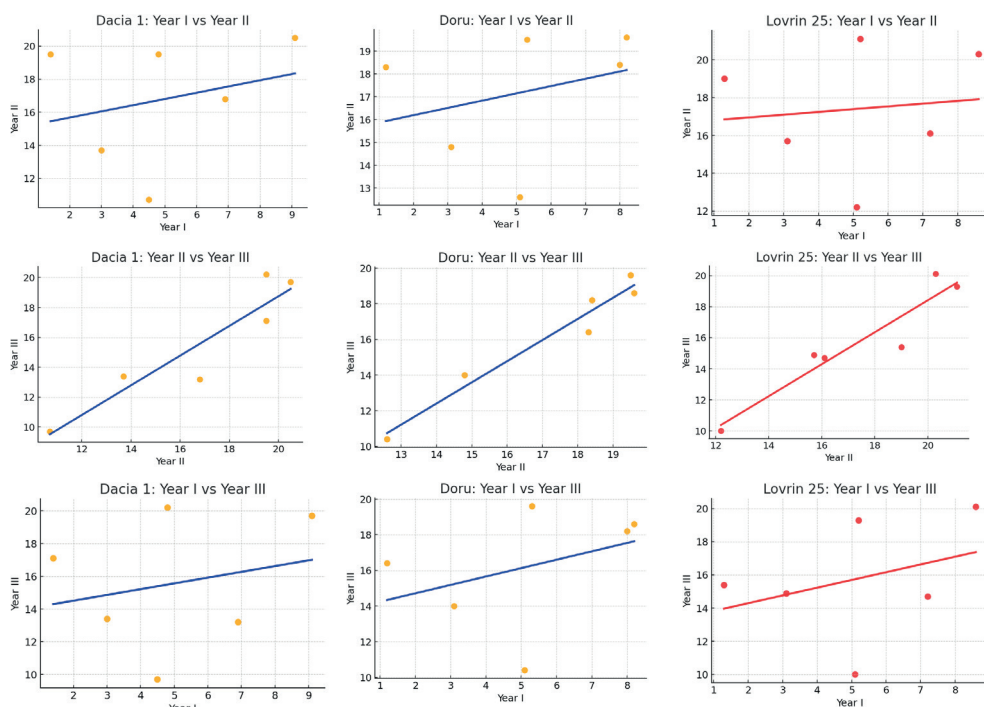


Figure 1. Regression lines of the dry matter yield compared among varieties and pairs of vegetation years

Table 7. Correlation and regression analysis along with significance tests for dry matter production in the Dacia 1 variety of BFT during the period 2023-2025

Relationship	Regression equation	r	p (r)	slope (b)	p (b)
Year I -> Year II	$y = 14.92 + 0.38 \cdot x$	0.27	0.610	0.38	0.610
Year II -> Year III	$y = -1.09 + 0.99 \cdot x$	0.93	0.007	0.99	0.007
Year I -> Year III	$y = 13.81 + 0.35 \cdot x$	0.23	0.656	0.35	0.656

Table 8. Correlation and regression analysis along with significance tests for dry matter production in the Doru variety of BFT during the period 2023-2025

Relationship	Regression equation	r	p (r)	slope (b)	p (b)
Year I -> Year II	$y = 15.56 + 0.32 \cdot x$	0.31	0.556	0.32	0.556
Year II -> Year III	$y = -4.19 + 1.19 \cdot x$	0.98	0.001	1.19	0.001
Year I -> Year III	$y = 13.78 + 0.47 \cdot x$	0.37	0.468	0.47	0.468

Table 9. Correlation and regression analysis along with significance tests for dry matter production in the Lovrin 25 variety of BFT during the period 2023-2025

Relationship	Regression equation	r	p (r)	slope (b)	p (b)
Year I -> Year II	$y = 16.66 + 0.15 \cdot x$	0.11	0.828	0.15	0.828
Year II -> Year III	$y = -2.17 + 1.03 \cdot x$	0.95	0.004	1.03	0.004
Year I -> Year III	$y = 13.36 + 0.47 \cdot x$	0.34	0.510	0.47	0.510

Pearson's correlation analysis shows that Lovrin 25 has positive associations between yields across successive years, confirming consistent performance. Linear regression equations highlight direct relationships between successive yields (Year I–II and Year II–III),

and the correlation coefficients (r) indicate that the data align with a predictable model. Even though some p-values do not indicate strong significance (due to the small sample size), the general direction is clear; the Lovrin 25 variety is stable, predictable, and high-performing.

Summarizing the results obtained for the new BFT Lovrin 25 variety, it stands out for: the highest yield in the second year, confirming its biological potential; good statistical stability, low CV, and consistent correlations between years; resistance to environmental variations, demonstrated by high values even in the third year of production, when yields generally decreased; and predictability proven by regression equations and correlation coefficient values. Considering the above-mentioned aspects, the Lovrin 25 variety ranks first in direct comparison and demonstrates a combination of high dry matter yields, stability, and statistical consistency, providing farmers with a new promising variety option for cultivation. It is a semi-late to traditional variety, characterized by good resistance to diseases, wintering and drought. It has very good resistance to falling and a very good regeneration capacity.

CONCLUSIONS

The results confirm that all BFT varieties analysed show a positive trend in dry matter production over successive years. Among them the Lovrin 25 variety stands out due to its balance high yields and consistent performance, distinguishing it from Dacia 1 and Doru varieties. Lovrin 25 demonstrates both productivity and stability making it a reliable and valuable option for cultivation. Its performance remains relatively consistent across years, even where the statistical differences are not always significant. Overall, Lovrin 25 emerges as the most promising variety analysed. Its combination of yield and stability supports its recommendation for expanding cultivated areas and highlights its suitability for farmers under current agricultural conditions.

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