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MORPHO-PRODUCTIVE AND NUTRITIONAL EVALUATION OF GREEN LEAVES IN FODDER BEET LINES OBTAINED THROUGH SELECTION

Christianna-Maria ISTRATE-SCHILLER[1], M.N. HORABLAGA[1,2], C. BOSTAN[2], Luminița COJOCARIU[1,2]

[1]University of Life Sciences "King Michael I" from Timisoara, 300645, 119, Calea Aradului, Timisoara, Romania
[2]Agricultural Research and Development Station Lovrin, 307250, 200, Principala, Lovrin, Romania
**Corresponding author: luminitacojocariu@yahoo.com*

Abstract. *Fodder beet (Beta vulgaris L. var. crassa) is a crop of great agricultural importance due to its ability to produce a significant amount of biomass with high nutritional value, widely used in animal feeding. The green leaves, often underestimated compared to the roots, represent a valuable source of crude protein, minerals, and bioactive pigments, contributing to the balance of forage rations. The aim of this study was to evaluate the morpho-productive performance and nutritional value of green leaves in four experimental fodder beet lines compared to the control cultivar C6/24, in order to identify genotypes with superior yield potential and forage quality. The experiment was conducted in 2024 at the Agricultural Research and Development Station (ARDS) Lovrin. The analyzed parameters included green leaf weight, number of leaves, dry matter content (%), and crude protein (%). The results showed values ranging from 12.98–16.17% for dry matter and 3.24–3.91% for crude protein, with superior performance recorded in lines V104/4/24 and V105/1/24. Green leaf weight varied between 0.73 and 1.33 kg, and the average number of leaves ranged from 36 to 84, confirming significant biological variability among genotypes. Correlation analysis revealed a strong association between the number and weight of green leaves (r = 0.82) and a positive correlation between dry matter and crude protein (r = 0.70). Principal Component Analysis (PCA) explained 88.3% of the total variability, highlighting the clear separation of lines V104/4/24 and V105/1/24 from the control. These findings confirm the potential of these genotypes for improving the productivity and nutritional value of fodder beet.*

Keywords: *fodder beet, green leaves, nutritional value, morpho-productive traits, multivariate analysis*

INTRODUCTION

Beta vulgaris var. crassa is a type of dicotyledonous plant that belongs to the *Amaranthaceae* family (OYEN, 2004) (former *Chenopodiaceae*). The plant is classified as a biennial, completing its life cycle in two years (AL JBAWI, 2020). During the first year, it develops a fleshy tuberous root and leaves, which are harvested for fodder (CONSTANTINESCU, CONSTANTINESCU, 2013). In the second year, after overwintering, it produces a floral stem and generates seeds. The root is substantial and can come in various colors, including yellow, orange, red, or white (COJOCARIU, 2005; AL JBAWI, 2014). Unlike the sugar beet, the root of the fodder beet primarily grows above the soil surface, allowing for easier harvesting due to its shallow submergence (HENRY, 2010).

This winter fodder is a highly valued source of nutrition in animal feed, particularly for ruminants such as dairy cows (DULPHY, DEMARQUILLY, 2000) fattening bulls, as well as for pigs and sheep. With a high energy value ranging from 0.12 to 0.15 Nutritive Units per kilogram, it owes its beneficial qualities to a significant content of easily digestible carbohydrates, particularly sucrose (WAGHORN ET AL, 2019), found in the roots (ROBERTS, SABRI,1988). Incorporating this fodder into the diets of dairy cows (WOODS ET AL, 2023).

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Beta vulgaris can enhance milk production (WAGHORN ET AL, 2018), demonstrating its galactogenic effect. Additionally, it is easily digestible and supports the overall health of the animal's digestive system (DULPHY, DEMARQUILLY, 2000). It is administered to animals in raw and chopped form, being an important component of the winter ration, partially replacing concentrated fodder. Usually, it is administered in controlled amounts (eg 15 - 30\ kg/day to a dairy cow), because in excess it can cause gastrointestinal issues. A surplus of dietary protein can be managed with the use of fodder beet (INRA, 2007). As dairy cows were given fodder beet, their urine's urea:creatinine ratio and milk urea concentration decreased (ERIKSSON ET AL, 2009) fodder beets are also more readily accepted.

In this context, detailed knowledge of the chemical composition (GRACE ET AL, 2010, GIBBS, 2014) and nutritional value of fodder beet leaves becomes essential for establishing balanced rations and optimizing mineral supplementation in animal feed. The leaves can be an important source of crude protein, fibre and macroelements, helping to improve the feed value of the crop (BORDEAN ET AL, 2013; AGAPIE ET AL, 2020; WOODS ET AL, 2023). Thus, the morphoproductive and nutritional evaluation of green leaves in different fodder beet lines obtained through selection provides essential information for improving feed quality and for efficient management of plant resources for animal husbandry (SINGH, GARG, 2013; DALLEY ET AL, 2020).

This species is a valuable resource in animal feed, but its inclusion in dairy cows' rations requires careful management to avoid negative effects on rumen health, in particular the occurrence of rumen acidosis (PACHECO ET AL, 2020). At the same time, it is essential to ensure a balanced nutrient intake that supports microbial protein synthesis and the productive performance of animals. In this regard, knowledge of the nutritional value and morphoproductive characteristics of fodder beet leaves contributes to the formulation of optimal rations and to the efficient exploitation of the forage potential of the selected species.

The results of studies conducted by Zöngür A (2024) shows *Beta vulgaris var. crassa* cytotoxic potential (KUMAR ET AL, 2024) on prostate and cervical cancer cells, while also showing significant antimicrobial and antifungal activities, especially at high concentrations. These pharmacological properties are attributed to the composition rich in essential oils, fatty acids and bioactive compounds. In the context of the present work, which aims at the morphoproductive and nutritional evaluation of green leaves in fodder beet lines obtained by selection, these findings support the importance of studying the biochemical composition (OLUMESE, OBOH, 2016) of leaves, considering their potential not only forage, but also phytotherapeutic, by capitalizing on natural active compounds (EL-BELTAGI ET AL, 2018).

The aim of the work was to evaluate the morphoproductive performance and nutritional value of the leaves in four fodder beet lines compared to the control C6/24, aiming to identify the genotypes with superior production potential and feed quality, which can be used in breeding and selection programs of valuable biological material.

MATERIALS AND METHODS

The experimental field was located within the Agricultural Research and Development Station Lovrin, situated in the eastern part of Lovrin locality (Figure 1), in an area that, from a physical-geographical point of view, is characterized by a low plain with altitudes not exceeding 100 m, uniform relief, and gentle slopes, typical of the Banat Plain region.

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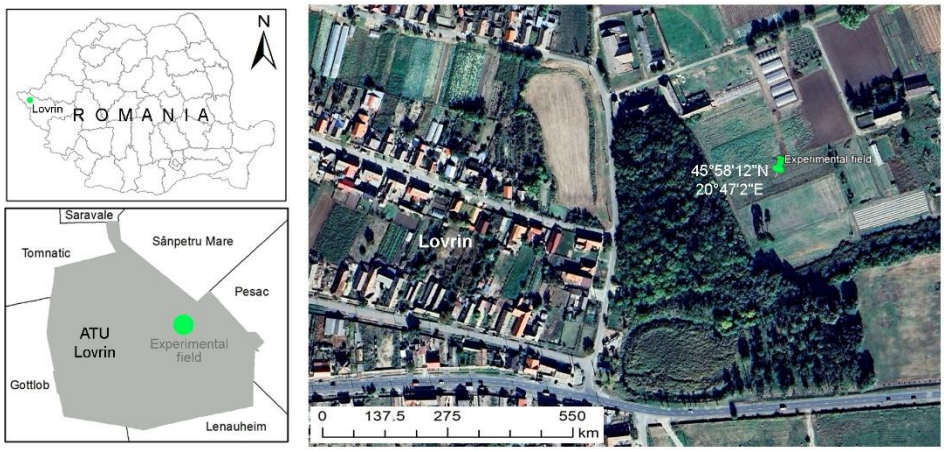

Figure 1. Field experiment location (processing after GEOSPATIAL, 2022)

In 2024, an experimental experiment was organized at SCDA Lovrin, with the objective of evaluating four fodder beet genotypes in the process of breeding (V102/1/24, V103/3/24, V104/4/24 and V105/1/24), compared to the control variety C6/24.

Sowing was carried out at a distance of 50 cm between rows and 20 cm between plants per row, ensuring a harvestable area of at least 10 m² per plot, in three repetitions.

At the harvest, 10 biometric determinations were made for each variant, targeting the weight of the green leaves and the number of leaves per plant.

The determination of crude protein content was carried out in the laboratory of the Agricultural Research and Development Station Lovrin (ARDS Lovrin), using the Kjeldahl method, in accordance with standard feed analysis procedures. The sample was subjected to acid digestion to convert organic nitrogen into ammonium ions, followed by distillation and titration steps. The crude protein content was calculated by multiplying the total nitrogen content by the factor 6.25.

For data processing and statistical analysis, the software packages PAST, version 4.17 (HAMMER, 2001; HAMMER, 2024), IBM SPSS Statistics 26 (IBM SPSS, 2025), and Microsoft Excel (Data Analysis module) were used.

RESULTS AND DISCUSSION

The objective of the analysis was to evaluate the morphoproductive and nutritional performance of experimental fodder beet lines, compared to a commercial control. In the context of increasing selection for productivity and nutritional value, it is essential to identify genotypes that combine vigorous vegetative development with balanced chemical composition. The data obtained provide useful information for the improvement of varieties intended for direct feed and for optimizing the forage value of green leaves at harvest.

The mean values of the dry matter content (Figure 2) ranged from 12.98% at the control C6/24 to 16.17% at line V105/1/24. A general trend of increasing dry matter content is observed at the selected lines, especially at V104/4/24 (14,69%) and V105/1/24, which indicates a higher dry matter accumulation capacity in the plant organs. These results may suggest a higher potential for achieving more concentrated energy production.

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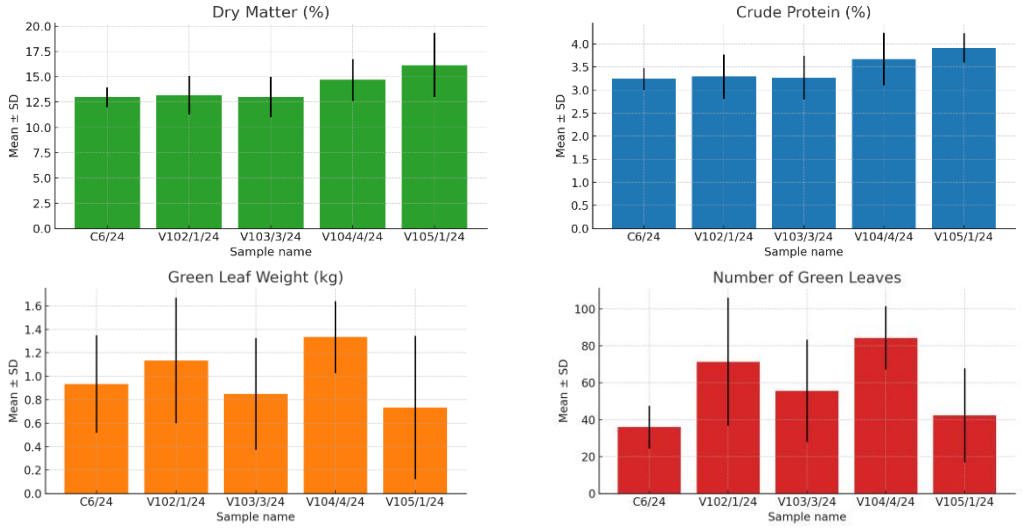

Figure 2. Comparative analysis of morphoproductive and nutritional traits in four fodder beet lines compared to control (C6/24)

The mean crude protein content (Figure 2) ranged from 3.24% at control C6/24 to 3.91% at line V105/1/24. The higher values of crude protein, observed at lines V104/4/24 (3.67%) and V105/1/24, suggest an improvement in the nutritional value of the biomass resulting from the selection. These lines can be considered potential gene donors for the improvement of the protein content in the biological material of feed beets.

The average green leaf weight (figure 2) per plant ranged from 0.73 kg (V105/1/24) to 1.33 kg (V104/4/24). Line V104/4/24 stood out for the highest average value, which indicates good vegetative development and high production potential of green mass. Control C6/24 had an intermediate value (0.93 kg), while lines V103/3/24 and V105/1/24 showed lower leaf development.

The average number of green leaves (Figure 2) ranged from 36 for the control C6/24 to 84 for the V104/4/24 line. The lines V104/4/24 and V102/1/24 (71 leaves) stood out for a high vegetative capacity, a character that can contribute to a more intense photosynthesis and a higher total production. The values obtained reflect biological differences between genotypes in terms of growth potential and leaf formation.

Overall, lines V104/4/24 and V105/1/24 have the best biological performance, both in terms of dry matter and crude protein content and morphoproductive traits (number and weight of green leaves).

These results highlight valuable potential for the selection and breeding of fodder and nutritional beet varieties.

Figure 3 highlights the relationships between the main morphoproductive and nutritional parameters analyzed in the feed beet lines.

The analysis of correlations shows the existence of positive links between certain characteristics, reflecting the biological coherence of the data and the potential for association between traits.

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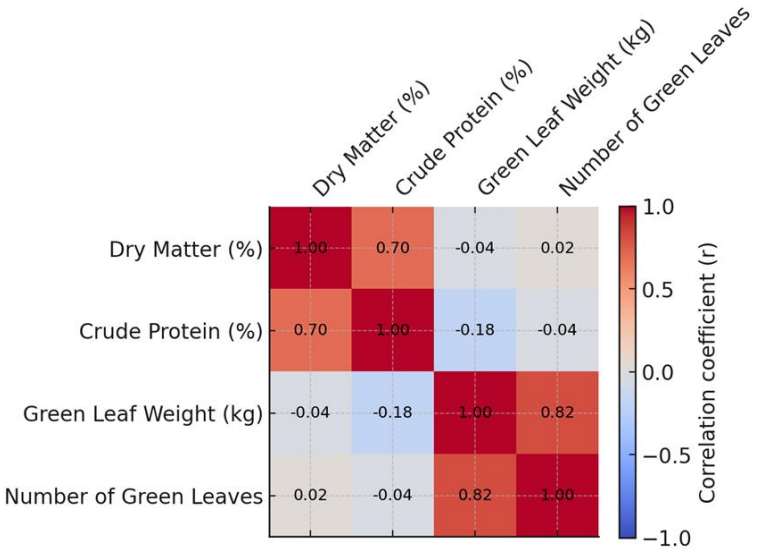

Figure 3. Pearson correlation matrix highlighting the relationships between dry matter content, crude protein, weight and number of green leaves in the analyzed feed beet lines. High positive values (in shades of red) indicate a direct correlation between variables, while negative values (in shades of blue) reflect inverse relationships

Figure 3 shows that the strongest relationship was observed between the number of green leaves and the weight of green leaves (r = 0.82), indicating that plants with a more developed leaf apparatus naturally have a higher total leaf mass. This association confirms that intense vegetative development contributes directly to increasing biomass production.

A moderate positive correlation was found between dry matter content and crude protein (r = 0.70), suggesting that lines with a higher dry matter density also tend to accumulate a higher amount of protein. This relationship is of interest in improving nutritional quality, as it indicates the possibility of simultaneously selecting lines with higher productivity and nutritional value.

In contrast, the relationships between morphological and chemical parameters (e.g., between leaf weight and crude protein, r = - 0.18) were very weak, which shows that these traits vary independently. This independence is advantageous in breeding programs, as it allows the improvement of nutrient content without compromising vegetative development.

Overall, the figure highlights two major axes of variation: a morphological one, associated with leaf development (number and weight of leaves) and a nutritional one, associated with dry matter and crude protein.

These relationships will be analyzed in detail through the principal component analysis (PCA), in order to visualize the grouping of the lines and the contribution of each parameter to the total variability. FP1 (Major Component 1) explains 47.4% of the total data change and FP2 (Major Component 2) explains 40.9% (Figure 4).

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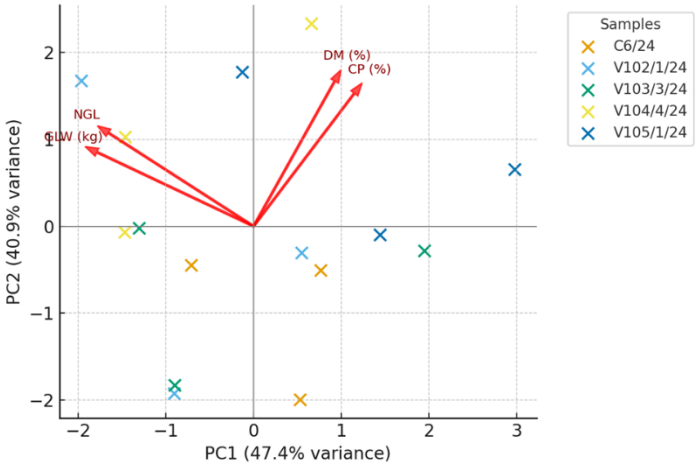

Figura 4. Principal Component Analysis (PCA) - Biplot showing the relationships among fodder beet lines and main traits: DM - Dry Matter, CP - Crude Protein, GLW - Green Leaf Weight, NGL - Number of Green Leaves

Figure 4 shows the distribution of feed beet lines in the plan defined by the first two main components, which together explain 88.3% of the total variability. Two major directions of variation can be distinguished: one associated with morphoproductive traits (number and weight of green leaves) and another related to nutritional parameters (dry matter and crude protein).

The lines V104/4/24 and V105/1/24 separate from the rest of the genotypes, suggesting a clear phenotypic differentiation.

Line V104/4/24 is associated with high values for morphological traits (number of green leaves and leaf weight), indicating a higher productive potential, while V105/1/24 is correlated with quality parameters (dry matter and protein content), highlighting a higher nutritional value.

Control C6/24 and lines V102/1/24 and V103/3/24 are grouped close to origin, reflecting low variability and close phenotypic behaviour for the parameters analysed.

The correlation of morphological and nutritional results highlights the fact that lines with a more intense vegetative development (V104/4/24 and V102/1/24) tend to accumulate a higher amount of biomass, but not necessarily a higher protein content. On the other hand, lines V105/1/24 and V104/4/24 show a favourable balance between productivity and nutrient quality, which recommends them for further testing in the field or under conditions of moderate water stress, to assess the stability of these traits.

Overall, the data obtained show that the selected lines show a valuable genetic variability for the traits analyzed. The lines V104/4/24 and V105/1/24 are distinguished by the favorable combination of productive potential and nutritional value, constituting a promising genetic material for feed beet breeding programs. Multivariate statistical analyses confirm the consistency of these results and the potential for using PCA and Pearson correlations as useful tools in the selection of performing lines.

The correlations and differences observed among the lines are consistent with trends reported in the scientific literature and confirm current selection directions focused on achieving a balance between productivity and nutritional value, while also providing a solid

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basis for further research aimed at assessing the stability of these traits under various agro-ecological conditions (MOISUC ET AL. 1994; COJOCARIU, MOISUC, 2005; TURK, 2010; MOISUC ET AL, 2010: ISTRATE-SCHILLER ET AL, 2024).

CONCLUSIONS

The study highlighted notable differences between the feed beet lines analyzed, both in terms of morphoproduction and nutrition. The dry matter content ranged from 12,98% to 16,17% at the V105/1/24 line, and the crude protein between 3,24% and 3,91%, the highest values being recorded at the V104/4/24 and V105/1/24 lines.

From a morphological point of view, the V104/4/24 line stood out for an average weight of green leaves of 1.33 kg and an average number of 84 leaves, which indicates a superior vegetative development. Pearson's correlation analysis confirmed a strong association (r = 0.82) between the number and weight of green leaves, as well as a moderate positive correlation (r = 0.70) between dry matter and crude protein.

Principal Component Analysis (PCA) explained 88.3% of the total variability, clearly delineating lines V104/4/24 and V105/1/24 from the control. These two lines combine high productive potential with superior nutritional value, and are recommended for further testing and inclusion in feed beet breeding programs.

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