EVALUATION OF THE AGRONOMIC POTENTIAL OF FODDER BEET GENOTYPES ACCORDING TO MORPHOLOGICAL TRAITS

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Abstract. *Fodder beet is an important crop for animal nutrition, and improving it can help achieve higher yields and genotypes that are better adapted to climate change. The aim of the research was to evaluate and compare the main agronomic traits of some fodder beet genotypes in the breeding process, in order to identify those with superior performance. The biological material included seven fodder beet genotypes and one control variety (CV), analyzed for four traits: root weight, leaf weight, maximum root length and maximum root diameter. The genotypes were followed in a comparative culture at SCDA Lovrin. Biometric measurements were statistically analyzed using boxplots, analysis of variance (ANOVA) and principal component analysis (PCA). The results indicate that genotypes V104, V106 and V108 showed higher root weights compared to the control, while the leaf weight was higher in V106 and V108. Genotype V106 stood out for its root length and diameter, having clear advantages to all the characteristics analyzed, suggesting a high agronomic potential. ANOVA analysis indicated significant differences between varieties for root weight ($p < 0.001$), leaf weight ($p = 0.035$) and maximum root diameter ($p < 0.001$), but not for root length ($p = 0.054$). Correlations between the analyzed traits indicate positive associations between root weight and leaf weight, as well as between root weight and length. The PCA analysis highlighted the differences and similarities between genotypes, highlighting groups of varieties with similar characteristics and outlining directions for genotype selection in breeding programs. Research has shown that there are differentiations between the genotypes of fodder beet analysed that can be exploited in breeding, and high-performance genotypes, such as V106, have a high potential for improving production. The results support the importance of detailed evaluation of morphological characteristics in the selection and breeding process.*

Keywords: *fodder beet, genotypes, comparisons, breeding, agronomic traits*

INTRODUCTION

Fodder beet is part of the *Amaranthaceae family,* it is a generally diploid, biennial species with a fleshy root (tuber) that is formed in the first year (vegetative) and in the second year (generative) the floral organs appear. The phenotypic characters are very varied (dark green-light green leaves, the root color found is red, yellow, orange and their variations) the variability is genetically determined (CIULCA, 2002; NEDELEA, MADOȘA, 2004; SAVATTI ET AL., 2004) but also influenced by climatic conditions, plant age, etc. (HENRY, 2010).

It is a crop that is grown in the temperate area for fodder in many places of the globe (NADAF ET AL., 1998; NIAZI ET AL., 2000). Fodder beet is attractive for livestock breeders because the whole plant, both the root and the leaves, is used as fodder feed (COJOCARIU, MOISUC, 2005). High digestibility (EDWARDS ET AL. 2014; WAGHORN ET AL., 2019) low nitrogen content (GIBBS, 2014) and high in sugar, characterizing it as a supplement appreciated for its energetic potential (DRAYCOTT ET AL., 2003) that it offers to animals.

Due to the long vegetation period, fodder beet is also characterized by high feed yields, i.e. 60-80 t ha^{-1} roots to which is added about 20% leaf production (COJOCARIU, 2005).

Under proper fertilization (TURK, 2010) and irrigation conditions, fodder beet feed yields can increase (KUN ET AL., 2022).

The aim of the research was to evaluate and compare the main agronomic traits of several fodder beet genotypes in order to identify the genotypes with superior performance in terms of root and leaf weight, as well as the characteristics that give the root shape (maximum root length and diameter). The results aim to provide useful information for the selection of the most promising genotypes for breeding programs.

MATERIALS AND METHODS

The experimental field is located at SCDA Lovrin, in the eastern part of Lovrin locality (Figure 1).

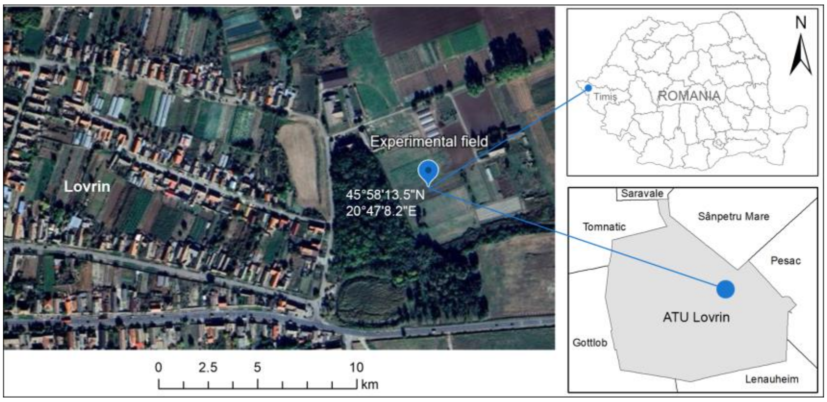

Figure 1 Location of the experimental field (GEOSPATIAL, 2022)

From a physical-geographical point of view, the locality of Lovrin is located in the lowland area, with altitudes below 100 m, in the conditions of a monotonous terrain, with low slopes.

In 2024, a comparative culture was organized with seven genotypes of fodder beets, in the process of improvement (V102, V103, V104, V105, V106, V108, V109), along with the control variety (CV) - C4 (Red Eckendorf).

It was sown at a distance of 50 cm between rows and 20 cm between plants per row; ensuring a minimum of 10 m^2 harvestable per plot / three rehearsals.

During the vegetation period, observations were made and 10 biometric measurements were made at harvest, both at the leaves (leaf weight) and at the root (root weight, maximum length and diameter).

The soil on which the experiment was organized is of the typical chernozem type, weakly gleized and epicalcareous, with a medium clay texture, specific to the Galaţca Plain (Pesac-Lovrin-Teremia area) and representative for a large part of the Low Plain of Banat.

The analysis of rainfall data indicates an atypical year as a whole (Figure 2), with precipitation amounts well below the multiannual monthly average in most months. Rainfall was unevenly distributed over decades, months and year, negatively influencing the development of fodder crops. In the 2023-2024 agricultural year, the total amount of precipitation was 417.4 mm, registering a negative deviation of 104 mm compared to the multiannual average. During the crop vegetation period (April – August), 121.6 mm of precipitation accumulated, with a negative deviation of 134.6 mm compared to MMA. Of the

153 days of this period, in 123 days there was no precipitation, in 12 days the daily quantities were between 0-1 mm, in 26 days between 1-10 mm, and in only 2 days the precipitation exceeded 10 mm.

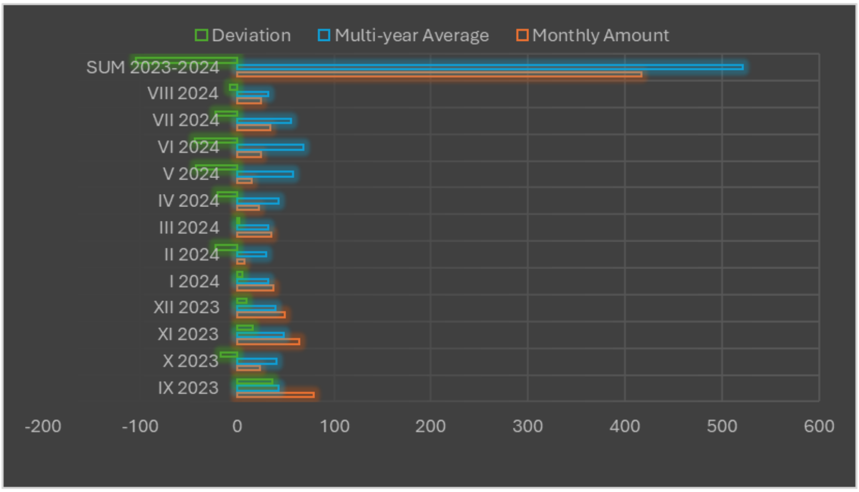

Figure 2. Precipitation regime at SCDA Lovrin, 2023-2024

For the analysis of the statistical data, the following were used: PAST, version 4.17 (HAMMER, 2001; HAMMER, 2024), IBM SPSS Statistics 26 (IBM SPSS) and Excel (Data Analysis module).

RESULTS AND DISCUSSION

The paper presents the main production traits, namely root weight and leaf weight, which represent plant production in fodder beet, and root traits, maximum length and diameter, which give root shape (MOISUC ET AL, 1994; KERTEN, J.L., 2003; COJOCARIU, 2005; MOISUC ET AL, 2010).

The results regarding the analyzed traits of the seven fodder beet stalks, which are in the process of improvement, together with the control variety C4 (CV) are presented comparatively in the four boxplot diagrams (Figure 3).

The diagrams in Figure 3 help identify genotypes that perform higher or lower depending on the characteristics measured and provide a basis for selecting the most promising genotypes for breeding.

Regarding the average root weight (Root Weight), the genotypes V104 (415.72 g), V106 (234.00 g) and V108 (489.85 g) have a higher average weight compared to the control (228.22 g). On the other hand, it has a higher variability of this character. Genotype V105 has a smaller median with a tighter data distribution, suggesting little variation.

The average weight of green leaves at harvest (Leaf Weight) at genotypes V106 (46.69 g) and V108 (53.31 g) is higher than at the control (19.86 g). V104 and V105 have very low values for leaf weight. The variation in leaf weight is evident in the case of varieties V102 and V106.

Regarding the root length, it was found that the V106 genotype has a longer root length, being visible compared to the medians of the other varieties, which suggests a specific characteristic of this variety. The control and genotype V105 show shorter lengths and less variation of this characteristic.

Regarding the Maximum Root Diameter, genotypes V106 and V104 have a higher root thickness compared to the other genotypes; they have a different root shape and can be taken into account in the breeding process. In genotype V109 this trait shows a high variability. CVs, V105s, and V108s have smaller medians, with less variation in data.

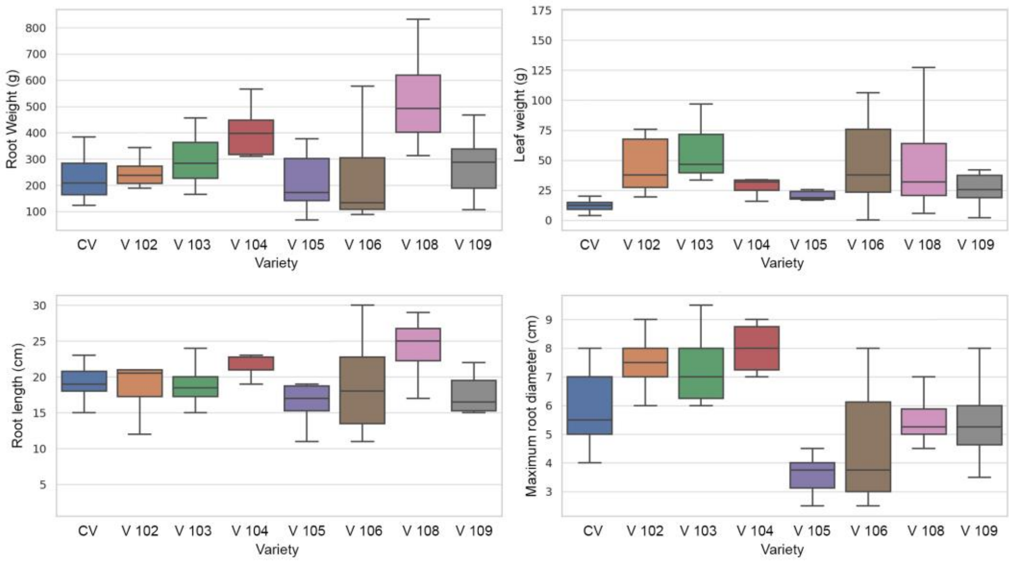

Figure 3. Comparison of morphological characteristics of fodder beet varieties

Clear advantages for all four traits present genotype V106, suggesting superior performance compared to all genotypes analyzed.

The results presented in the "boxplot" diagrams highlight the general variations and trends between varieties for each trait, providing a preliminary picture of the differences, which are rigorously confirmed and quantified by the ANOVA analysis described below.

Regarding the root weight, there are significant differences between the varieties, confirmed by the value, $p < 0.001$ and $F = 5.25$ (Table 1).

Table 1

ANOVA for Root Weight

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	688666.5	7	98380.92414	5.251448	< 0.001	2.139656
Within Groups	1348852	72	18734.05647			
Total	2037519	79				

There are significant differences between varieties in terms of leaf weight, F value = 2.31 and p = 0.035 (Table 2).

Table 2

ANOVA for leaf weight

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14527.19	7	2075.313	2.3088	0.035069	2.139656
Within Groups	64716.6	72	898.8416			
Total	79243.79	79				

There are no significant differences at a significance level of 0.05, the p-value being 0.054 (Table 3).

Table 3

ANOVA for root lenght

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	357.6	7	51.08571	2.104699	0.0537	2.139656
Within Groups	1747.6	72	24.27222			
Total	2105.2	79				

There are significant differences between varieties in terms of the maximum root diameter. The F value = 13.09, and the p-value < 0.001 (Table 4).

Table 4

ANOVA for maximum root diameter

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	166.5469	7	23.79241	13.09424	< 0.001	2.139656
Within Groups	130.825	72	1.817014			
Total	297.3719	79				

The heatmap in Figure 4 illustrates the correlations between the four production characters taken into consideration, namely RW, LW, RL and RD. Linear correlation was applied, measured by the Pearson correlation coefficient which evaluates the degree of linear association between two variables (characters) and can take values between -1 and 1.

Figure 4 shows a positive correlation between root weight and root length (r = 0.39), suggesting that an increase in root weight is accompanied by an increase in root length.

There is also a positive correlation between leaf weight and root weight (r = 0.39), indicating that heavier roots are generally associated with heavier leaves.

The maximum root diameter shows variable correlations with the other production traits, which suggests that its relationship with weight (r = 0.49) and root length (r = 0.22), as well as with leaf weight (r = 0.17) is weaker (Figure 4).

The correlations in Figure 4 provide insight into how the traits measured in the analyzed feed beet genotypes are interconnected and can help identify patterns in the analyzed data.

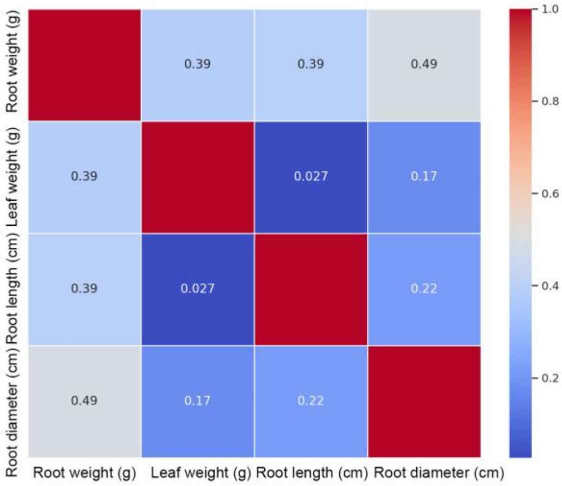

Figure 4. Linear correlation between production traits in feed beet genotypes

Figure 5 highlights the differences and similarities between the varieties (genotypes) of feed beet analysed and provides clues about their distinctive characters, depending on how they are distributed in the four quadrants of the PCA graph. The contoured areas indicate the groups of genotypes with similar characteristics. Thus, the genotypes S5-104 and S7-102 are in the first quadrant (upper right), suggesting similar characteristics, while S3-106 and S6-103 are grouped in the third quadrant (lower left), indicating another direction of variation. The varieties in different quadrants (e.g. S2-108 in the upper left vs. S4-105 in the lower right) show differences in the main production characters analyzed.

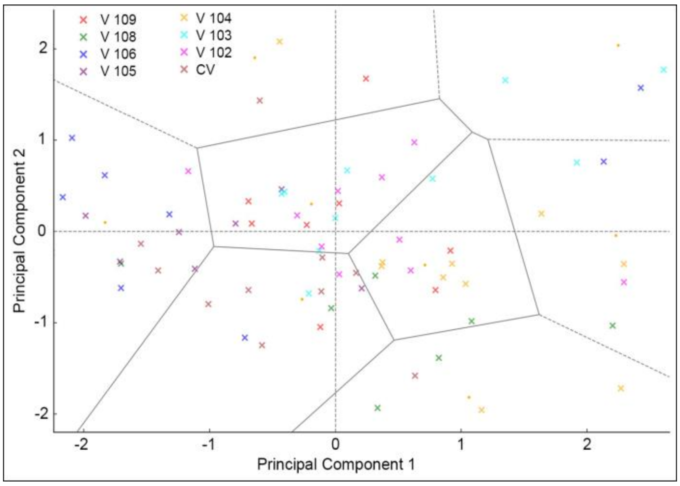

Figure 5. PCA representation of feed beet genotypes with marked grouping areas

If certain genotypes are grouped in the same region, it is possible that they are similar in terms of all the characteristics analyzed. They could have a common origin, a similar type of response to the environment, or similar agronomic characteristics.

Varieties that occur in different groups can be considered significantly different and could represent distinct categories or different genetic lines.

CONCLUSIONS

The results of the research indicate that the morphological variability observed between fodder beet genotypes provides a solid basis for the selection of valuable genotypes in breeding programmes.

Genotypes such as V106, which showed superior performance at all the characteristics analyzed, demonstrate a high agronomic potential and can be used to improve crop yield and adaptability.

The results obtained support the importance of the detailed evaluation of the morphological characteristics in identifying promising variants for the selection and genetic improvement of fodder beet.

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