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DYNAMICS OF MORPHOPRODUCTIVE CHARACTERS IN *Phalaris arundinacea* UNDER THE CONDITIONS OF THE WESTERN PLAIN OF ROMANIA

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Abstract

Phalaris arundinacea, (reed canary grass), is suitable as an option for cultivating lands that are not ideal for other crops, numerous studies identify it in mild climates and humid environments but also drier areas, on various types of soil, with a pH between 4.0 and 7.5. The study aimed to identify the interdependence between morpho-productive characters in vegetation conditions in the Western plain of Romania, the biological material was represented by the Premier variety. Vegetative growth was investigated in 6 BBCH codes: 1.19; 2.21; 2.22; 2.29; 3.31; 3.37, and the measurements targeted the following characters: bush diameter, bush height, plant height, number of vegetative shoots, and the number of leaves of the main shoot. Statistical processing through descriptive statistics, Pearson correlation coefficient, and ANOVA analysis of variance illustrate a correct distribution of the experimental data and the existence of strong correlation relationships between the studied characters. This element is practically important because in the breeding process prioritizing positive and strong correlations can help to obtain faster results.

Key words*: reed canary grass, correlation, morpho-productive characters.*

INTRODUCTION

Reed canary grass (RCG) or *Phalaris arundinacea* L., Moench (Ţîţei, 2020), is a perennial, heterogamous, and stoloniferous species belonging to the family *Poaceae*, subfamily *Pooideae* (Strašil, 2012; Winterfeld et al., 2018). The species has a fast growth that follows the C3 photosynthetic pathway (Kinmonth-Schultz & Soo-Hyung, 2011), being native to regions of North America, Asia, and Europe (Kitczak et al., 2023).

The species reaches heights of up to 200 cm (Ţîţei, 2020), although it can sometimes grow up to 3 meters (Kitczak et al., 2023). The leaves are flat, smooth, and gradually narrow, measuring between 30-45 cm in length and 0.8-1.2 cm in width. The root system of RCG consists of broad rhizomes that are strong, long, and segmented, facilitating the spread of the plant underground to depths exceeding 3 meters (Zhang et al., 2013; Kitczak et al., 2023). Fresh rhizomes mainly arise below the soil surface from buds at the nodes of other rhizomes. The roots and rhizomes can create an almost impenetrable carpet. The lifespan of a RCG plant is commonly estimated to be about ten years (Von Cossel et al., 2019). In temperate regions of Europe, RCG usually flowers between May and July, lasting several weeks (Ustak & Muňoz, 2019). The inflorescence is in the form of branched panicles with lengths ranging from 7 to 40 cm (Linding-Cisneros & Zedler, 2001). The fruit consists of a caryopsis, measuring between 1.5- 4.0 mm in length and 0.7-1.5 mm in width, producing a relatively large number of seeds (Lavergne & Molofsky, 2004). The weight of 1000 seeds is on average 0.8 g (Ustak & Muňoz, 2019).

The germination process of RCG is dependent on adequate light exposure (Linding-Cisneros & Zedler, 2001) and well-drained soil. Optimal germination can occur even under water-saturated conditions (Lavergne & Molofsky, 2004). The ideal temperature for plant photosynthesis is typically between 20 and 25°C (Ge et al., 2012).

This versatile plant thrives in a variety of environments, making it a suitable option for cultivating lands that are not ideal for other crops (Ustak & Muňoz, 2019, Perdereau et al., 2017). Numerous studies show that RCG is most commonly found in mild climates and humid environments such as wet meadows, marshy areas, lake shores, river banks, and floodplains (Lavergne & Molofsky, 2004; Kieloch et al., 2015; Ustak & Muňoz, 2019; Kitczak et al., 2023) and humid forests (Perdereau et al., 2017). Although the species has a preference for humid conditions, the species also adapts to areas with reduced humidity even in mountainous areas (Lord, 2015).

RCG can grow in various soil types, such as poorly drained, heavy, compact, but also well-drained, dry soils (Lord, 2015), flooded (Ustak & Muňoz, 2019), clayey (Perdereau et al., 2017), artificial (Lord, 2015) or even soils contaminated by cattle urine (Maeda et al., 2006) with a pH between 4.0 and 7.5 (Ustak & Muňoz, 2019).

The ideal habitat for RCG consists of fertile, humus-rich soils (Kieloch et al., 2015) and with high concentrations of organic nitrogen, total phosphorus, and phosphate and low levels of dissolved oxygen (Perdereau et al., 2017).

Phalaris arundinacea has a high tolerance to flooding compared to other cool-season grasses and is known for its resistance to frost and drought. RCG thrives at temperatures between 5 and 30 degrees Celsius and can withstand extremely cold temperatures, even down to -20 degrees Celsius (Kitczak et al., 2023).

Its ability to survive prolonged periods of flooding is due to its rhizomes, which can withstand low oxygen conditions. In terms of productivity, environmental conditions play a crucial role in the growth and development of RCG.

Plants thrive in fertile soils with high humus content and neutral pH, which leads to increased height growth as well as larger leaves, which in turn leads to higher biomass production (Kieloch et al., 2015). Medvedev and Smetannikova, cited by Țîței (2020) reported that a green mass yield of 90 t/ha was obtained. The content of digestible nutrients was found as follows: 72% crude protein, 55% crude fat, 65% crude cellulose, and 72% nitrogen-free extract.

When grown in fertile soil and receiving adequate care, RCG can produce significant amounts ranging from 6 to 20 $Mg \cdot ha^{-1}$ DM (Kitczak et al., 2023). The multitude of specialized studies (Ustak & Muňoz, 2019), but also by other authors (Strašil, 2012; Piskier, 2017; Hesham et al., 2019; Kitczak et al., 2023) highlight the potential of RCG as an excellent energy source.

Apart from its energy applications, Ustak et al. (2019), as well as Wrobell et al. (2009), mention numerous uses of RCG, such as its use as a forage crop, as a long-term perennial cover for permanent grasslands, for the restoration of degraded soils and waters, for phytoextraction of soil contaminants, for revegetation and stabilization of banks, for the production of acidic suspension ponds, for the treatment of wastewater to remove ammonia and nitrates, for the mineralization of organic solutions, for bioenergy purposes and the production of pulp, paper, and fibers, as mentioned by Lavergne & Molofsky in 2004. Another potential bioenergy application for RCG is biogas production, which involves the decomposition of digestible organic material (Ustak et al., 2019).

Wrobel et al. (2009) mention that RCG can produce substantial quantities of high-quality hay under optimal crop management conditions.

MATERIALS AND METHODS

Biological material and the purpose of the work

The biological material was represented by the Premier variety produced by ICDPP Brasov, with this variety a collection field was established located at Lovrin Agricultural Research and Development Station. The soil on which the experience was carried out is a typical chernozem soil, weakly gleied, representative of the Low Banat Plain area. Regarding the properties of this type of soil, a pH value indicating a weakly alkaline reaction (7.3-8.4) in the range of 20-100 cm, to even strongly alkaline (9.1-9.4) at depths of up to 200 cm is evident (Bostan et al., 2024).

The purpose of the study

The study aimed to observe the externalization of productive characters in the conditions of the Low Banat Plain area so that reed canary grass, respectively the Premier variety, would constitute a viable alternative for the production of fodder in the plain area affected by limiting factors of production. Another objective of this study is to observe the behavior of the Premier variety in specific soil conditions, in terms of the presence of precipitation and temperatures as the most important growth factors.

Regarding the biological growth of the Premier variety, the vegetative growth was investigated in 6 BBCH codes (1.19; 2.21; 2.22; 2.29; 3.31; and 3.37). The measurements targeted the following characters: bush diameter, bush height, plant height, number of vegetative shoots, and the number of leaves of the main shoot. Regarding the expression of these characters, a statistical analysis was carried out, evaluating the correlation between these characters.

Climatic conditions

In the studied area, the expression of the climatic regime for the period 2023-2024 showed abiotic conditions for the growth of RCG atypical with precipitation amounts located well below the multiannual monthly limit. For the Low Banat Plain area, the total precipitation amounts in the growth period 2023-2024 was 417.4 mm. A negative deviation of 104 mm from the multiannual average is observed.

The most important is, however, the growth period (April - August) when the amount of precipitation was 121.6 mm, highlighting a negative deviation of 134.6 mm from the MMA.

Statistical processing

The graphical representations were made with JASP version 0.18.3 and presented aspects such: the distribution of variables, regression curves, confidence intervals, and prediction intervals for the pairs of variables analyzed. Also, in the JASP program, the test was used to identify the existence of significant differences between the means of the investigated morpho-productive characters.

A correlation matrix was created and graphically represented in the form of a heatmap, using the "corrplot" package in R. The p-value shows that significant correlations are marked with: *p < .05 if the correlation is significant at the alpha level =.05; **p < .01 if the correlation is significant at the alpha =.01 level; and ***p < .001 if the correlation is significant at the alpha =.001 level.

In the analysis of the strength of association between productive traits in reed canary grass, the Chi-squared Test was also used because it is desirable in the analysis of small samples with fidelity (Bandalos & Finney, 2018; Dinno, 2014; Golino et al., 2020).

The dendrogram-type cluster analysis of the characters was performed by cluster analysis by the program MiniTab 17.1.

RESULTS AND DISCUSSIONS

Descriptive statistics were used to analyze the distribution of the values of the analyzed characters: bush diameter, bush height, plant height, number of vegetative shoots, and the number of leaves of the main shoot (Table 1).

Table 1. Normality dynamics of the distribution of the analyzed characters at reed canary grass

	95% Confidence Interval Mean				
	Mean	Upper	Lower	Std. Deviation	MAD
Bush diameter (cm^2)	690.33	1058.38	322.28	740.11	205.50
Bush height (cm)	26.16	32.88	19.44	13.51	6.00
Plant height	22.95	29.68	16.23	13.51	6.35
Number of vegetative shoots	13.72	15.86	11.58	4.30	4.00
Number of leaves of the main shoot	2.72	3.09	2.34	0.75	1.00

Depending on the number of variables determining characters, the number of layers displayed is also displayed, for the five productive characters their average on the 95% confidence interval, the standard deviation and the coefficient of variation were determined. The distribution of the experimental data highlights normal values of enrollment compared to the average of the analyzed character on a high degree of confidence which led us to conclude that the experimental data were correctly sampled and statistically interpreted (Moore et al., 2012; Whitlock & Schluter, 2015).

During its biological development cycle, RCG along with the growth in height, develops compound leaves and stems, practically the plant preparing for the flowering process. It is considered that this stage of development is important for photosynthesis, which provides the energy necessary for the subsequent stages of development. The biological growth dynamics of reed canary grass were assessed by investigating the main characteristics of the species, namely: bush diameter, bush height, plant height, number of vegetative shoots, and the number of leaves of the main shoot Thus, the degree of linear association between normally distributed quantitative variables in our study is expressed by the Pearson's correlation matrix (Table 2). Also, to have the smallest possible statistical error, we used the common means of the exteriorization of the characters in expressing the correlations between them. In the present study, the Pearson correlation coefficient is obtained by calculating the covariance of the two variables divided by the product of their standard deviations (Sellke et al., 2001; Caruso & Cliff, 1997; Xu et al., 2013).

Table 2. Expressing the degree of linear association of productive characters in reed canary grass in Pearson's correlation matrix

Variable		Bush diameter (cm2)	Bush height (cm)	Plant height	Number of Vegetative shoot	Number of leaves Of the main shoots
Bush diameter (cm2)	Pearson's r	-				
	p-value	-				
Bush height (cm)	Pearson's r	0.986***	-			
	p-value	<.001	-			
Plant height	Pearson's r	0.988***	1.000***	-		
	p-value	<.001	<.001	-		
Number of vegetative shoots	Pearson's r	0.731***	0.729***	0.734***	-	
	p-value	<.001	<.001	<.001	-	
Number of leaves of the main shoots	Pearson's r	0.328	0.387	0.366	0.356	-
	p-value	0.184	0.113	0.135	0.147	-

*p < .05, ** p < .01, *** p < .001

From the analysis of the power of association between the five productive characters, we can state that there are positive associations, or even the lack of a linear correlation, between these characters. Considering bush diameter as a determined and positively correlated character in specialized studies with productive properties such as bush, plant height, and the number of vegetative shoots, we measured and described the degree of linear association between this character and the other quantitative variables. As a result of these considerations, the presence of statistically significant correlation relationships is observed between bush diameter and bush and plant height as well as the number of vegetative shoots. Thus, between the bush diameter character and the bush height and plant height characters, close Pearson correlation values of 0.986 and 0.988 are observed, which corresponds to p values considered as a very significant correlation. The same degree of significance is also observed between bush diameter and the number of vegetative shoots (Pearson correlation 0.731), and the p-value is considered a very significant correlation. The same degree of association is obtained between plant height and number of vegetative shoots, the value of the Pearson coefficient being 0.734, which ensures from a statistical point of view by the value of p as a very significant correlation. These results demonstrate the hypothesis that the increase in height in the case of the Premier reed canary grass variety is accompanied by a positive proportional increase in bush diameter, number of vegetative shoots, and number of leaves of the main shoot.

The graphical representation of correlation relationships provided with statistical significance by the Pearson correlation can be found in Figure 1. The graphical representation shows two elements, the first is given by the expression of the correlation between the characters, and the second shows the testing of the null hypothesis according to which the correlation between pairs of variables is equal to zero (there is no significant connection between the two characters).

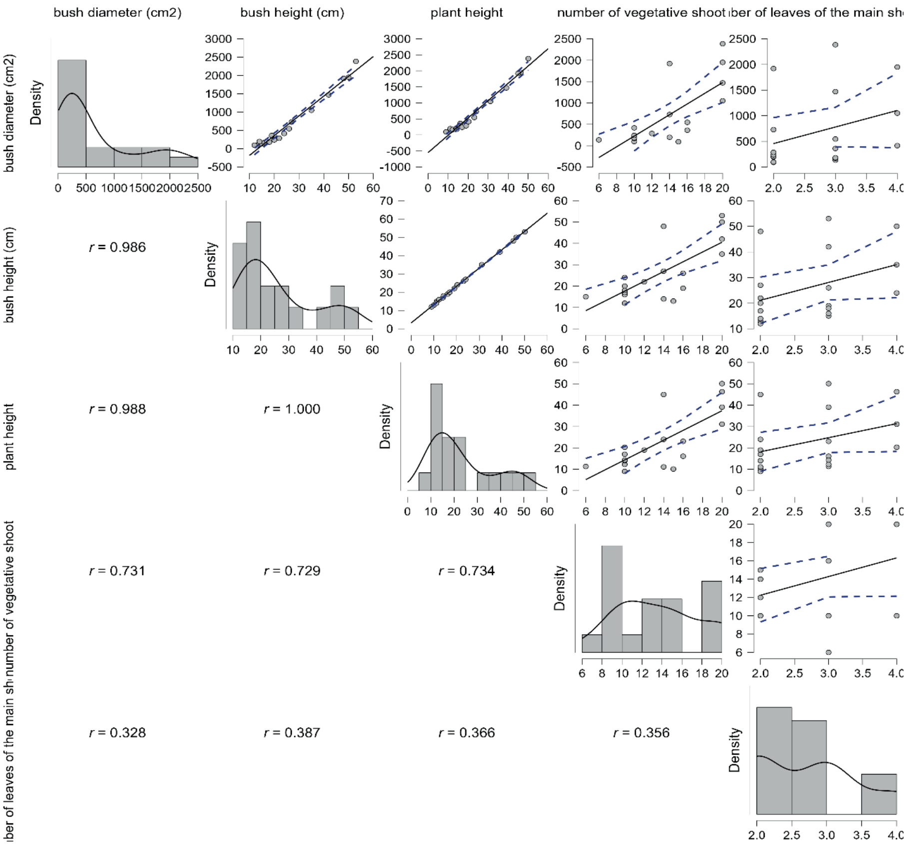

Figure 1. The graphical representation of the Pearson correlation at reed canary grass

From the experimental data illustrating the biological growth of the Premier variety under the specific experimental conditions of the Low Banat Plain area, it is evident in the previous graph that an increase in the scale of observations leads to a coarser table, while a decrease in the scale leads to a smoother table (Samfira et al., 2024).

Specifically, the distribution graphs presented show that for continuous variables, a histogram determined by the dynamics of bush diameter, plant height, and number of vegetative shoots is displayed, where the experimental data are correctly distributed in a Gaussian model.

Also, from the analysis of the nominal and ordinal variable values, a continuous frequency distribution is displayed as follows: in the case of correlation links between characters, the distribution of the experimental data is grouped, and if they are positively correlated, it is ascending.

The analysis of the power of association of productive characters in RCG by Chi-squared Test took into account the expression of df: Degrees of freedom cat and p: P-value when constructing the Principal Component Analysis (PCA) model (Hayton al., 2004; James et al., 2013). The analysis of the degree of uniqueness using Chi-squared Test confirms the close relationship between the studied productive characters (Table 3).

Table 3. The proportion of variance included in PCA

Component Loadings		
RC1		Uniqueness
bush height (cm)	0.980	0.040
plant height	0.979	0.042
bush diameter (cm^2)	0.970	0.060
number of vegetative shoots	0.831	0.309
number of leaves of the main shoots	0.485	0.764

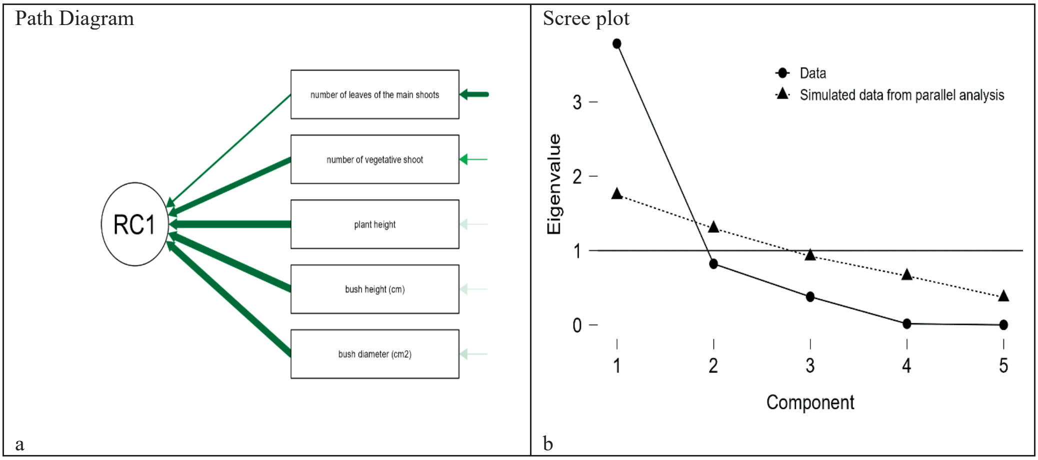

Figure 2. Analysis of the association strength of productive traits in reed canary grass by Principal Component Analysis (PCA): a) the degree of uniqueness of characters in biological development; b) the disposition of experimental data towards simulated analysis of the growth model

The graphical representation of Principal Component Analysis (PCA) gives us an image of the degree of uniqueness of the characters in biological development. In other words, the influence of each character in the biological growth of the reed canary grass species is analyzed according to df: and P-value (Osborne et al., 2008; Saris et al., 2009; Shlens, 2014).

The arrangement of productive characters in reed canary grass strengthens the value expression through the Pearson correlation of the association between characters. It can thus be seen from Figure 2 that the main role in biological growth is attributed to the character's bush diameter, bush height, and plant height.

The graphical representation of the PCA arranges the studied productive characters compared to a simulated growth model. In this case, the arrangement of the experimental data that make up the biological growth model of reed canary grass is under the influence of the specific growing conditions of the Low Banat Plain area.

Also, the dendrogram-type cluster analysis of the characters was performed by cluster analysis. The dendrogram cluster analysis was performed the distance between clusters is measured as a correlation. The OY axis shows the degree of similarity and the OX axis shows the biological growth periods and the BBCH code. In the case of the reed canary grass variety Premier, following the cluster analysis, three clusters were obtained in Figure 3.

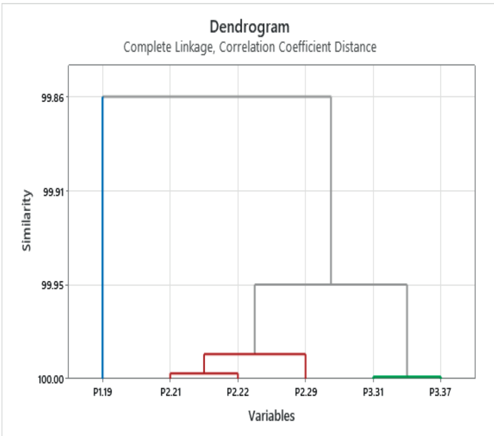

Figure 3. Graphic representation of the dendrogram regarding the externalization of productive characters in reed canary grass

The three clusters determine the grouping of the biological growth stages expressed in BBCH according to the five productive characters studied. The values of the productive characters were obtained on averages of the measurements of several plants within the same BBCH growth period. The intermediate biological growth periods (2.21, 2.22, and 2.29) are grouped in cluster number 2. Towards physiological maturity and the end of the vegetative growth period of the reed canary grass species, cluster 3 groups these stages 3.31 and 3.37.

CONCLUSIONS

Knowledge of the interrelationships between the productive characters is important because these relations ensure not only the productivity of the species but are essential for its regeneration and expansion within the different natural ecosystems where it is present or in the case of agroecosystems where it is cultivated.

In the experimental conditions of the Low Banat Plain area on a gleied chernozem soil, the biological growth of the reed canary grass species is influenced by humidity and temperature conditions. The continuous water regime below the multiannual average of precipitation is noted as an influencing factor.

The calculation of the power of association between the five productive characters by determining the Pearson Correlation highlighted the bush diameter character as a determining character in the biological growth of RCG. The strengthening of the statistical significance of the results obtained were also analyzed by the Chi-squared test. Thus, the power of association of the studied characters is also confirmed by Principal Component Analysis (PCA) where the degree of uniqueness of each character involved in the biological growth corresponds to the significance obtained by the Pearson correlation. The different arrangement of the experimental data compared to a predicted model validates the importance of abiotic growth factors in the biological development of RCG. The biological growth model obtained by following six BBCH stages and read by cluster analysis validates the normal distribution of the growth stages in the life cycle of RCG. In conclusion, RCG has demonstrated a high capacity to adapt to global changes in life factors and we can predict an increase in the cultivation area of the species.

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