BIOMETRIC PARAMETERS IN THE CHARACTERIZATION OF EARS IN A COLLECTION OF CORN GENOTYPES

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Abstract. *The study evaluated morphological parameters and yield elements in corn ears to compare a collection of corn genotypes. The research took place in ARDS Lovrin, Romania. 80 maize genotypes were analyzed, and certain representative parameters were determined: corn ear weight (CEW, kg), corn grain weight (CGW, kg), corn cob weight (CCW, kg). Based on the recorded values, the kernels in corn ears was calculated (KCE, %). Several ratios were also calculated, CEW/CGW, CEW/CCW, and CGW/CCW. The data series showed normal distribution and statistical confidence. Very strong positive correlation was recorded between CGW and CEW (r = 0.963), and between the ratios CGW/CCW and CEW/CCW (r = 0.996). Very strong negative correlation was registered between the ratio CEW/CGW and KCE(%), r = -0.992. According to PCA, PC1 explained 69.055% of variance, and PC2 explained 29.108% of variance. The close correlation of the Lv_47 hybrid with the KCE parameter (%) was observed. According to the cluster analysis, the dendrogram for the classification of genotypes based on similarity, in relation to the KCE parameter resulted (Coph.corr. – 0.813). The variation of the KCE parameter (%) in relation to the CEW, CGW, and CCW parameters was analyzed by regression analysis. Mathematical models described the variation of KCE in relation to the considered morphological parameters, under statistical safety conditions (R^2 = 0.999 in relation to CEW and CGW; R^2 = 0.757 in relation to CEW and CCW; R^2 = 0.835 in relation to CGW and CCW; p <0.001 for all cases). Graphical models (3D, isoquants) represented the KCE variation (%) in relation to the considered morphological parameters. The divergent influence was recorded in the case of the CGW and CCW parameters on the KCE distribution.*

Keywords*: corn ear, corn kernels, model, PCA, variability*

INTRODUCTION

Traditional morphological traits, associated with corn ears, are important in corn breeding programs, for adapted genotypes, and for increasing yield (Wang et al., 2023). The authors analyzed 20 ears traits in over 400 inbred lines by phenotypic measurement methods.

Different biometric parameters and elements of identification and characterization were considered in the classification of corn ears in the breeding process, associated with neural networks and the automatic learning process (Ma et al., 2023).

The analysis of corn ears was done in the USA to identify symptoms associated with abnormal development and their elimination (Ortez et al., 2022a). The authors of the study communicated several symptoms identified in corn ears based on previous studies, and supplemented with other new symptoms from their own studies. The authors of the study concluded that elements of abnormality in the formation and development of corn ears represent "genetics x environment x technological practices" interactions. Different aspects of abnormal development of corn ears have been communicated and analyzed in relation to different causes that generated the anomalies (Ortez et al., 2022b). The authors also studied how ears deformation affected yield.

The ear size and the ear:plant ratio were analyzed as agronomic traits that express the efficiency of fertilizer use and corn yield (Wang et al., 2023). The position of the ears on the plant and biometric and morphological parameters were studied in relation to the corn harvest (Xing et al., 2024).

Imaging analysis was used in the evaluation of corn ears, with importance in the improvement process, the study of the genetic bases and the determination of the yield (Makanza et al., 2018). Imaging analysis was used to study and analyze corn ears and certain biometric (productivity) elements useful for the selection process and breeding programs (Gillette et al., 2023). Methods based on imaging analysis have been tested for the analysis and morphological characterization of corn ears (length, diameter, number of kernels, etc.), as alternative methods to classical methods (Dunderski et al., 2023). The authors communicated different equations that described the parameters considered in relation to fertilization, and the nitrogen requirements of the plants.

The study analyzed weight parameters in corn ears and kernel yield in order to characterize corn ears in a collection of corn genotypes within ARDS Lovrin.

MATERIAL AND METHODS

The study analyzed biometric parameters at the level of corn ears in order to characterize a collection of corn genotypes in cultivation within ARDS Lovrin. The agricultural year 2022 - 2023 was considered. Eighty maize genotypes were cultivated, in chernozem soil conditions, non-irrigated crop system.

Sowing was done in the optimal time, the first decade of April.

At physiological maturity, BBCH 9 - Senescence (Meier, 2001), samples of ears (5 ears) were collected for each genotype and repetitions.

The parameters considered were corn ear weight (CEW, kg, mean sample), corn grain weight (CGW, kg, mean sample), corn cob weight (CCW, kg, mean sample). Based on the recorded values, the kernels weight in ear was calculated (KCE, %, mean sample). Several ratios were also calculated, CEW/CGW, CEW/CCW, and CGW/CCW.

In order to characterize the data series, related to the recorded parameters, a descriptive statistical analysis was made. The correlation analysis was done to find out the interdependence relationships between the parameters considered in the corn ears. Multiparameter analysis (PCA, CA) was done to find out the association of the genotypes considered in the study with determined parameters, as well as to find out the grouping of the genotypes based on similarity in relation to the recorded values. The regression analysis was used to analyze the contribution relationship of the CEW, CGW, and CCW parameters to the formation and variation of the KCE(%) parameter. The calculation module in EXCEL, and dedicated software (Hammer et al., 2001; Wolfram, 2020; JASP, 2022), were used to analyze the experimental data in relation to the purpose of the study.

RESULTS AND DISCUSSIONS

The biometric determinations of the ears samples led to the data of the considered parameters, for the characterization of the 80 maize genotypes, in the comparative analysis. The CEW parameter presented values between 0.764 – 1.195±0.009 kg. The CGW parameter presented values between 0.663 – 1.018±0.007 kg. The CCW parameter presented values between 0.102 – 0.226±0.003 kg.

The kernels in corn ears (KCE, %) showed values between 80.350 – 90.610±0.204%. The results of the descriptive statistical analysis of the data series are presented in table 1. Based on the values of the considered parameters, the ratios CEW/CGW, CEW/CCW, and respectively CGW/CCW were calculated. The distribution of the data series, in histogram format, is presented in figure 1.

According to the ANOVA Test, the experimental data showed statistical reliability, table 2.

Table 1. Results of the descriptive statistical analysis

Statistical parameters	CEW	CGW	CCW	KCE(%)	CEW/CGW	CEW/CCW	CGW/CCW
Valid	80	80	80	80	80	80	80
Missing	0	0	0	0	0	0	0
Median	1.002	0.849	0.151	84.620	1.180	6.505	5.515
Mean	0.990	0.839	0.153	84.771	1.180	6.577	5.587
Std. Error of Mean	0.009	0.007	0.003	0.204	0.003	0.081	0.081
Std. Deviation	0.082	0.067	0.023	1.828	0.025	0.728	0.728
Coefficient of variation	0.083	0.079	0.154	0.022	0.021	0.111	0.130
Variance	0.007	0.004	5.513×10^{-4}	3.342	6.418×10^{-4}	0.530	0.531
Minimum	0.764	0.663	0.102	80.350	1.100	5.090	4.090
Maximum	1.195	1.018	0.226	90.610	1.240	9.490	8.500
25th percentile	0.934	0.787	0.139	83.648	1.160	6.123	5.130
50th percentile	1.002	0.849	0.151	84.620	1.180	6.505	5.515
75th percentile	1.041	0.876	0.168	85.907	1.200	7.052	6.043

Table 2. ANOVA Test

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	466597.7	6	77766.2776	123266.731	0	3.806017
Within Groups	348.8756	553	0.63087807			
Total	466946.5	559				

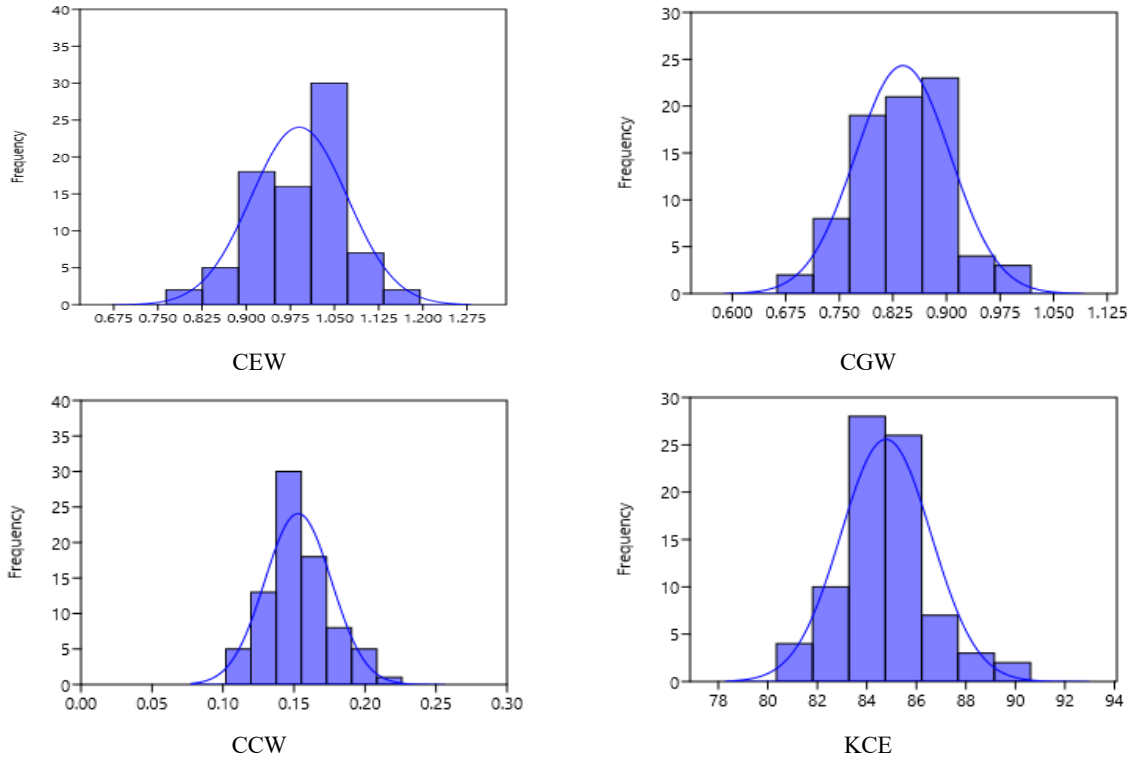


Figure 1. Distribution histograms of the data series for the parameters considered in corn

The correlation analysis led to the diagram in figure 2, in which the values of the correlation coefficient between the parameters considered and the ratios calculated for the characterization of the ears in corn hybrids are presented. A very strong positive correlation was recorded between CGW and CEW (r = 0.963) and between the ratios CGW/CCW and CEW/CCW (r = 0.996). Very strong negative correlation was registered between the ratio CEW/CGW and KCE(%), r = -0.992.

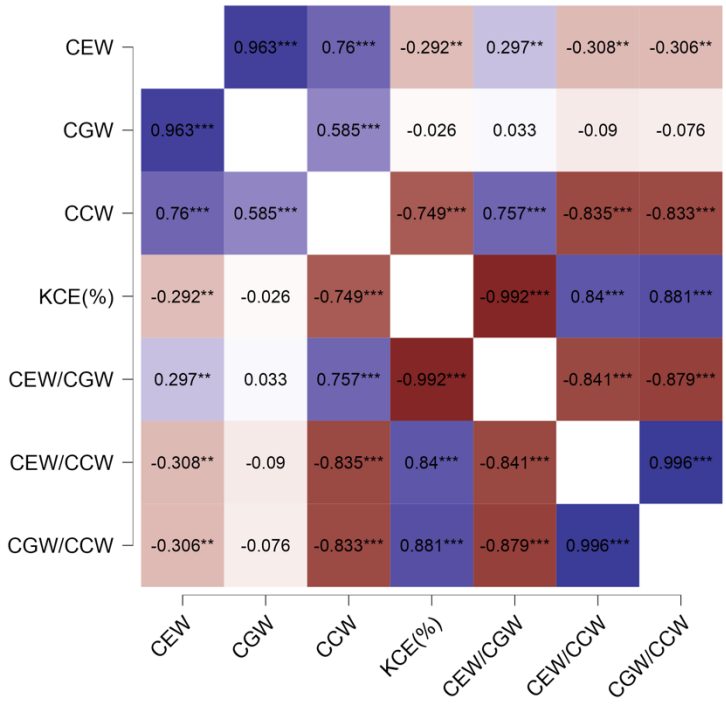


Figure 3. Diagram of the correlation coefficient values between parameters and ratios in corn ears

According to PCA, the diagram in figure 3 resulted, in which the maize genotypes were distributed in relation to the considered parameters. PC1 explained 69.055% of variance, and PC2 explained 29.108% of variance. The close correlation of the Lv_47 hybrid with the KCE (%) parameter was observed.

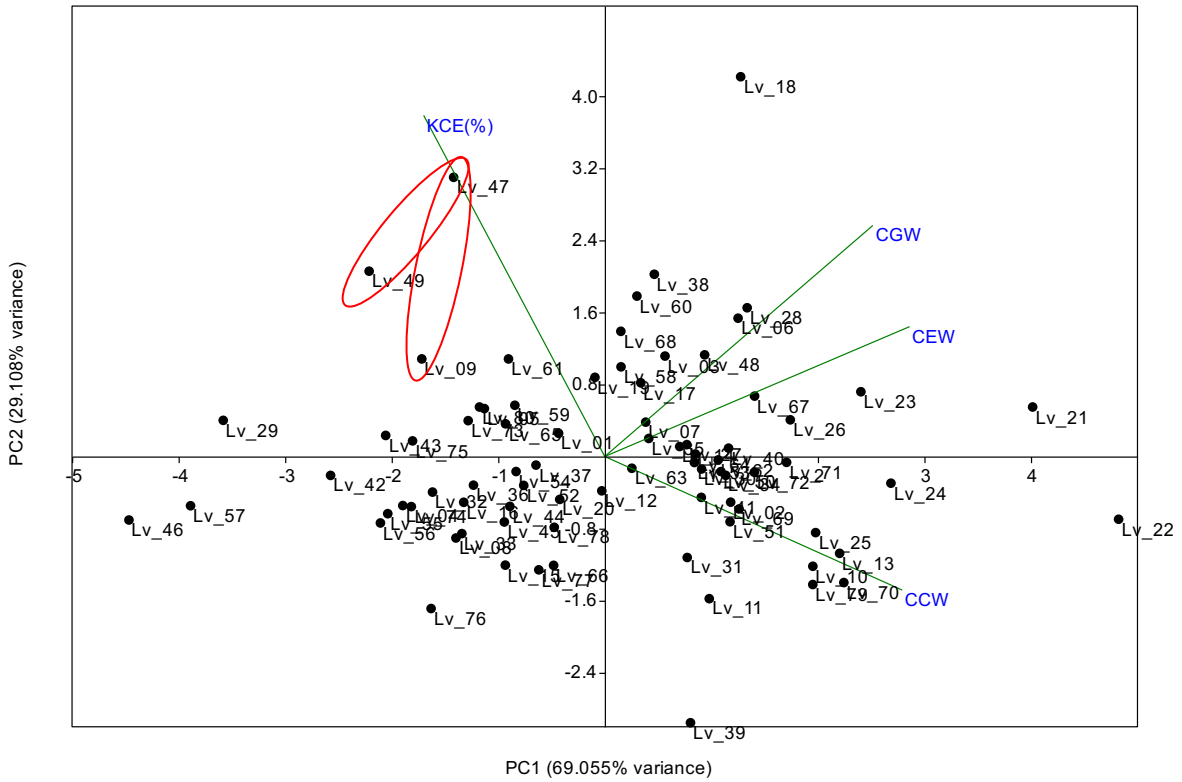


Figure 3. **PCA diagram, with the representation of maize genotypes in relation to considered parameters, as biplot**

The cluster analysis, based on the kernels in corn ears (KCE, %) facilitated obtaining the dendrogram in figure 4 (Coph.corr = 0.813). The formation of two clusters was found, with several subclusters in relation to the grouping of genotypes. The red mark indicates the subcluster with genotypes with high values for the KCE(%) parameter.

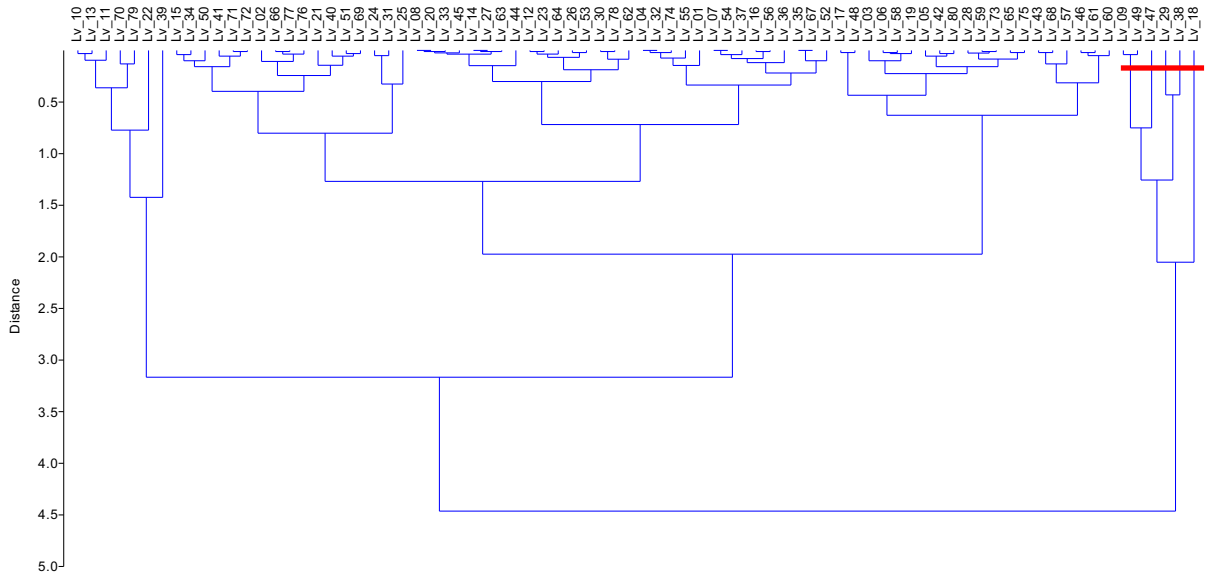


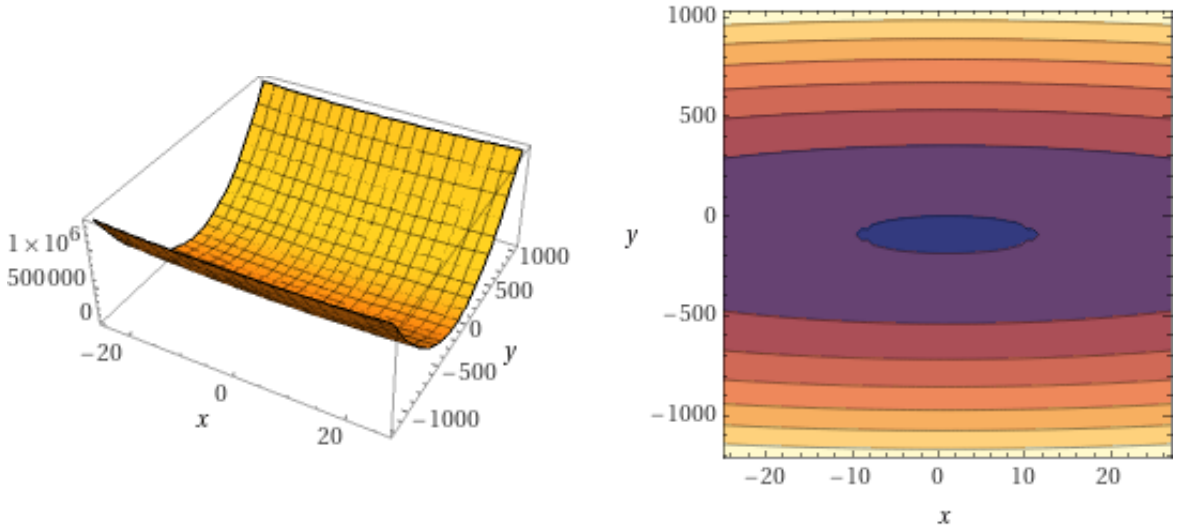
Figure 4. Dendrogram of grouping of maize genotypes based on KCE(%) parameter values

The kernels in corn ears (KCE, %) is an important parameter regarding grain production in corn crops. Based on this considerent, regression analysis was used to analyze the variation of the KCE parameter in relation to the CEW, CGW, and CCW parameters.

The variation of KCE in relation to CEW and CGW was described by equation (1), $R^2 = 0.999$, $p<0.001$, with graphic representation in figure 5.

$$KCE(\%) = 82.1005x^2 + 1.0472y^2 - 167.347x + 195.786y - 96.999xy + 85.521 \quad (1)$$

where: KCE(%) – kernels in corn ears (%); x – CEW parameter; y – CGW parameter



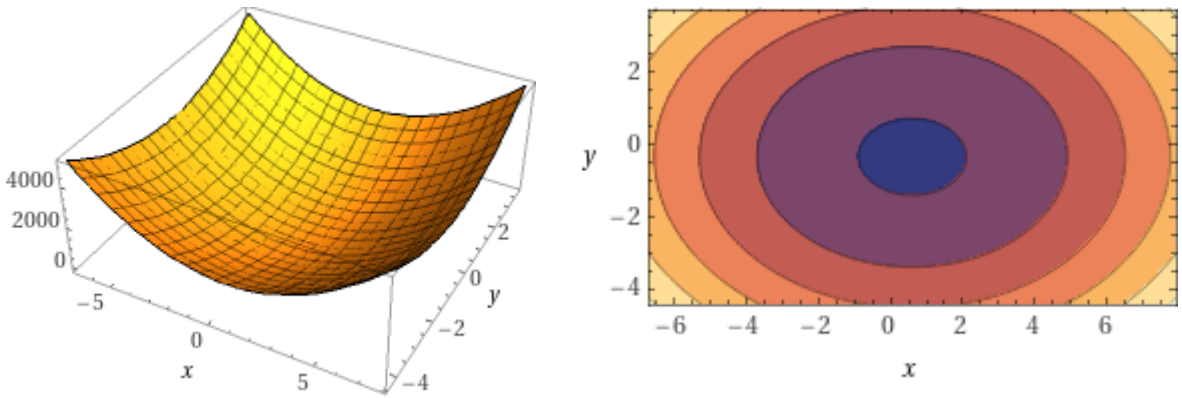
(a) (b)

Figure 5. Graphic representation of KCE variation in relation to CEW (x – axis) and CGW (y – axis)

The variation of KCE in relation to CEW and CCW was described by equation (2), $R^2 = 0.757$, $p<0.001$, with graphic representation in figure 6.

$$KCE(\%) = 61.443x^2 + 122.377y^2 - 74.689x + 83.250y - 215.865xy + 115.395 \quad (2)$$

where: KCE(%) – kernels in corn ears (%); x – CEW parameter; y – CCW parameter



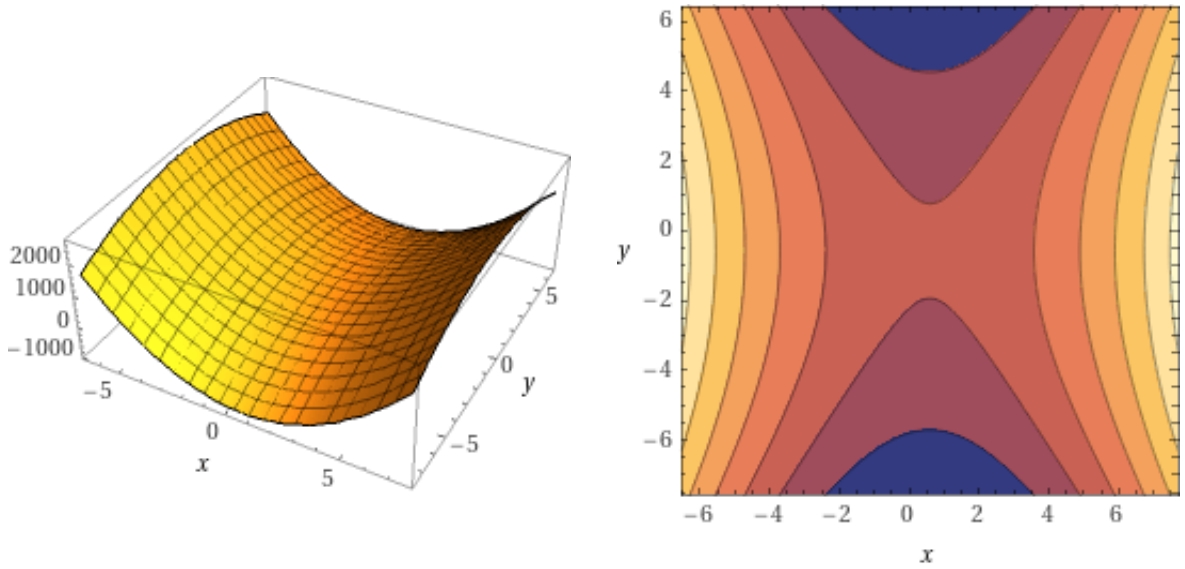
(a) (b)

Figure 6. Graphic representation of KCE variation in relation to CEW (x – axis) and CCW (y – axis)

The variation of KCE in relation to CGW and CCW was described by equation (3), $R^2 = 0.835$, $p<0.001$, with graphic representation in figure 7. From the analysis of the coefficient values of equation (3), as well as from the analysis of the graphic distribution, figure 7 (a), (b), the divergent behavior of the two parameters (CGW, CCW) in the KCE variation was found.

$$KCE(\%) = 52.047x^2 - 20.449y^2 - 61.623x - 23.931y - 63.006xy + 111.88 \quad (3)$$

where: KCE(%) – kernels in corn ears; x – CGW parameter; y – CCW parameter



(a) (b)

Figure 7. **Reprezentarea grafica a variatiei KCE in relatie cu CGW (x – axis) and CCW (y – axis)**

The morphology of corn ears plays a very important role in the improvement process and the increase in yield. The collection of maize genotypes cultivated within ARDS Lovrin was analyzed and characterized based on some important parameters of the ears, in order to identify genotypes with productivity parameters, mainly in terms of grain yield per ear.

The multiparameter analysis led to the PCA diagram and the CA dendrograna, according to which the genotypes associated with the analyzed parameters were identified. Groups of genotypes (clusters) with similar characteristics were also obtained. They are important in the selection of valuable genotypes in relation to the considered parameters.

Wang et al. (2023) reported significant correlations between certain morphological traits in corn ears and the number of kernels per row, or the number of kernels per ear. The authors of the study analyzed the data recorded in relation to different inbred corn lines, in terms of the number of rows, the number of kernels per row and their phenotypic variation.

Other studies have analyzed the yield in relation to fertilization (Ma et al., 2022; Dawar et al., 2024), in relation to environmental conditions (Ortez et al., 2022b; Liu et al., 2023) or to other factors of influence. Mathematical models have been communicated to describe the variation of some morphological parameters and the yield of agricultural crops in relation to technological factors or environmental factors (Boldea and Sala, 2011; Bassu et al., 2021; Gheith et al., 2022).

Variable levels of correlations were recorded between parameters considered in corn ears, and the regression analysis facilitated the obtaining of equations and graphic models in the description of the KCE parameter (%) in relation to ear weight parameters.

CONCLUSIONS

Morphological parameters considered for the comparative analysis of maize genotypes recorded values that presented a normal distribution, under statistical safety conditions. Variable levels of correlation were recorded between morphological parameters in corn ears.

The multiparameter analysis led to the PCA diagram, PC1 explained 69.055% of variance, and PC2

explained 29.108% of variance. The distribution of genotypes was recorded in relation to morphological parameters, considered as biplot in the PCA diagram. The genotype Lv_47 presented the highest value for the KCE(%) parameter, and the genotypes Lv_09 and Lv-49 presented similar values. Cluster analysis facilitated the grouping of genotypes into clusters based on similarity (Coph.corr. = 0.813).

Based on the regression analysis, mathematical models in the form of equations, and graphic models that described the variation of the KCE(%) parameter in relation to the weight parameters of the ears, under the condition of statistical certainty ($p<0.001$), resulted.

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