PRODUCTION AND SOME QUALITY INDICES VARIATION IN MAIZE - CASE STUDY IN FARM CONDITIONS

Vasile-Daniel GRIGOR¹, Florin SALA²,*

¹University of Life Sciences "King Mihai I" from Timisoara, Timisoara, Calea Aradului, 300645, Romania
²Agricultural Research and Development Station Lovrin, Lovrin, 307250, Romania
*Corresponding author: florin_sala@usvt.ro

Abstract. The study comparatively analyzed the production results and the values of some quality indices for two corn hybrids, in the specific crop conditions of the Western Plain of Romania. Corn crops was carried out in the area of Grabat locality, Timis County, Romania. Maize hybrids P9889 and DKC5092 were cultivated, in a non-irrigated system, between 2021 and 2023. Adequate plant growth conditions were ensured through crop technology. In the case of the P9889 hybrid, the productions were 8500 kg/ha (2021), 5350 kg/ha (2022), and 11000 kg/ha (2023). In the case of the DKC5092 hybrid, the productions were 7900 kg/ha (2021), 5800 kg/ha (2022) and 10800 kg/ha (2023). Based on mean grains samples, the crude protein content (CP) showed values between 8.5% (year 2021) and 10.05% (year 2023); the starch content (ST) presented values between 54.09% (year 2021) and 59.04% (year 2023); the crude cellulose content (crude fibers, CF) presented values between 1.99% (year 2021) and 2.25% (year 2023); the proportion of broken grains (BG) showed values between 0.98 (year 2023) and 1.3% (year 2022), with an mean value BG = 1.10%. A very strong positive correlation was recorded between CP and M (r = 0.955), between ST and M (r = 0.900), and between ST and CP (r = 0.989). Very strong negative correlation was recorded between Y and BG (r = -0.926). A strong, positive correlation was recorded between CF and Y (r = 0.834), and between CF and M (r = 0.865). According to PCA, PC1 explained 60.307% of variance, and PC2 explained 39.693% of variance. The decrease in production in 2022 (extremely dry year), compared to the mean value, was ΔY = -2933.33 kg/ha for the P9889 hybrid, respectively ΔY = -2366.67 kg/ha for the DKC5092 hybrid. From the analysis of the obtained values, the hybrid P9889 recorded a greater decrease in production (difference of 566.66 kg/ha) compared to the hybrid DKC5092, under the conditions of 2022, specific to the study conditions.

Keywords: comparative analysis, maize, PCA, quality indices, yield

INTRODUCTION
Maize is one of the main crop plants, with a long and important present and future history for multiple ecological values, food resources, fodder, the biofuel industry, etc. (Garcia-Lara and Serna-Saldívar, 2019; Erenstein et al., 2022). As a result of the importance of maize, many studies are being carried out to improve germplasm in terms of productivity and quality indices, to perfect technologies and improve decisions at the farm level (Sandhu et al., 2020; Zystro et al., 2021).

The relationship of maize with environmental factors and technological factors was studied for the selection of adapted genotypes and the optimization of the production process (Rahme et al., 2020; Adham et al., 2022; Engida et al., 2024).

The relationship with fertilizers is of high importance, in order to optimize fertilization in relation to the purpose of the crops (food consumption, fodder, industrialization, etc.), the environmental conditions and the categories of farmers (Burke et al., 2019; Krimshawati and Sugiono, 2020; Adzawla et al., 2021; Agapie and Sala, 2022; Jiang et al., 2024).

The improvement of quality indices, based on valuable genotypes and appropriate agronomic practices, is of interest in order to obtain yields with high nutritional and fodder indices (Katsenios et al., 2021; Alvarado-Ramirez et al., 2023).

The maize cultivation experiment, under conditions of agricultural farms, is of great interest, because it takes place with technologies accessible to farmers, and represents technological benchmarks for farmers in the neighboring areas (Alesso et al., 2019; Azrai et al., 2022; Muenchrath et al., 2023).

Classical methods and methods based on teledetection, imaging analysis, were used to evaluate the relationship of plants with environmental conditions, crop dynamics and to estimate production and quality indices (Sala et al., 2020; Strenner et al., 2023).

The aim of the study was the comparative analysis of the production and some quality indices of corn, P9889 and DKC5092 hybrids, under crop conditions in non-irrigated system, 2021 - 2023 period.

MATERIAL AND METHODS
The study analyzed the variation of the production and some quality indices of the corn crop in the specific conditions of the area of the Grabat locality, Timis County, Romania, figure 1 (a).
Grabat locality (45.88°N, 20.74°E) is at an altitude of 84 m above sea level. The area is part of the Western Plain, Galațca-Bega Plain, with a horizontal distribution between 80 - 100 m above sea level. The region in which Grabat is located is in the steppe vegetation zone, on the border with the forest-steppe. The comparative corn crops was carried out within SC BARAGAN SRL.

The corn hybrids P9889 and DKC5092 were cultivated, and the study took place between 2021 and 2023. The corn crops was carried out in a non-irrigated system, with a technology that ensured adequate vegetation conditions.

The basic soil work was done by plowing in the fall, at a depth of 30 cm. Soil preparation for sowing was done with soil preparing combine machine. Fertilization was done with 200 kg/ha complex (16:16:16) and 180 kg/ha urea. Sowing was done at the optimal time (April 1, 2021; April 4, 2022; April 21, 2023), at an mean density of 76,000 plants/ha. The pre-emergence herbicide was done with Adengo (0.35 L/ha) and the post-emergence herbicide was done with Samson 0.75 L/ha + Temsa 1.2 L/ha (year 2021), Package Pixides + Arigo 0.350 g powder/ha (year 2022), respectively Henik 1 L/ha + Temsa 1 L/ha (year 2023). Aspect of the corn crop is presented in figure 1 (b).

At physiological maturity, BBCH 9 – Senescence (Meier, 2001), the mechanized harvesting of corn grain production was done. The production (Y, kg/ha) was evaluated every year, and for each corn hybrid. Corn grain production was together valorized on market, and quality indices were determined on mean corn grain samples, from the two hybrids. The determined quality indices were represented by moisture (M, %), crude protein (PC, %), starch (ST, %), crude fiber (CF, %), and broken grains (BG, %).

The production data and the quality indices were analyzed and statistically processed appropriately. The statistical calculation module in EXCEL, the PAST software (Hammer et al., 2001) and Mathematica (Wolfram Research, 2020) were used.

RESULTS AND DISCUSSIONS

The recorded values for corn yield (Y, kg/ha), Pioneer 9889 and DKC5092 hybrids, and the main quality indices of corn grain production (mean values) during the study period (2021 – 2023), are presented in table 1. In the case of the hybrid P9889, the yield recorded the value of 8500 kg/ha in the year 2021, 5350 kg/ha in the conditions of the year 2022, and 11000 kg/ha in the conditions of the year 2023. In the case of the hybrid DKC5092, the yield recorded the value of 7900 kg/ha ha in 2021, 5800 kg/ha in the conditions of 2022 and 10800 kg/ha in the conditions of 2023.

Corn grain quality indices were determined on mean grains samples, as a mixture. The moisture of the grains showed values between 11.32% (year 2021) and 13.33% (year 2023), with an mean value M = 12.37%. The crude protein content (CP) showed values between 8.5% (year 2021) and 10.05% (year 2023), with an mean value CP = 9.45%. The starch content (ST) presented values between 54.09% (year 2021) and 59.04% (year 2023), with an mean value ST = 57.39%. The crude cellulose content (crude fibers, CF) showed values between 1.99% (year 2021) and 2.25% (year 2023), with an mean value CF = 2.08%. The share of broken grains (BG)
showed values between 0.98 (year 2023) and 1.3% (year 2022), with an mean value \( BG = 1.10\% \). The ANOVA test confirmed the reliability of the experimental data, table 2.

Table 1. Values of yield and quality indices for corn, period 2021 - 2023

<table>
<thead>
<tr>
<th>Year</th>
<th>P9889 (kg/ha)</th>
<th>DKC5092 (kg/ha)</th>
<th>Mean (kg/ha)</th>
<th>M (Mean values, %)</th>
<th>CP (Mean values, %)</th>
<th>ST (Mean values, %)</th>
<th>CF (Mean values, %)</th>
<th>BG (Mean values, %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021</td>
<td>8500</td>
<td>7900</td>
<td>8200</td>
<td>11.32</td>
<td>8.5</td>
<td>54.09</td>
<td>1.99</td>
<td>1.03</td>
</tr>
<tr>
<td>2022</td>
<td>5350</td>
<td>5800</td>
<td>5575</td>
<td>12.45</td>
<td>9.8</td>
<td>59.03</td>
<td>2.01</td>
<td>1.3</td>
</tr>
<tr>
<td>2023</td>
<td>11000</td>
<td>10800</td>
<td>10900</td>
<td>13.33</td>
<td>10.05</td>
<td>59.04</td>
<td>2.25</td>
<td>0.98</td>
</tr>
<tr>
<td>Mean (2021 – 2023)</td>
<td>8283.33</td>
<td>8166.67</td>
<td>8225</td>
<td>12.37</td>
<td>9.45</td>
<td>57.39</td>
<td>2.08</td>
<td>1.10</td>
</tr>
</tbody>
</table>

Table 2. ANOVA test results

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F crit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>5.05E+8</td>
<td>7</td>
<td>72197815</td>
<td>40.46858</td>
<td>8.99E-12</td>
<td>5.234912</td>
</tr>
<tr>
<td>Within Groups</td>
<td>42817103</td>
<td>24</td>
<td>1784046</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5.48E+8</td>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The correlation analysis led to the diagram in figure 2. A very strong positive correlation was recorded between CP and M \( (r = 0.955) \), between ST and M \( (r = 0.900) \), and between ST and CP \( (r = 0.989) \). Very strong negative correlation was recorded between Y and BG \( (r = -0.926) \). A strong, positive correlation was recorded between CF and Y \( (r = 0.834) \), and between CF and M \( (r = 0.865) \). Weak correlation was recorded between CP and CF \( (r = 0.677) \), and between CF and ST \( (r = 0.560) \). Weak negative correlation was recorded between CF and BG \( (r = -0.565) \).

Figure 2. Correlation matrix plot at the level of yield and quality indices, corn crop, mean values of P9889 and DKC5092 corn hybrids

The variability recorded for yield presented values, according to Coefficient of variation, \( CV = 34.1798 \) in the case of the P9889 hybrid, \( CV = 30.7426 \) in the case of the DKC5092 hybrid, respectively \( CV = 32.3719 \) in the case of mean values.

The quality indices showed low variability, \( CV = 4.9750 \) in the case of ST, \( CV = 6.9448 \) in the case of CF, \( CV = 8.1476 \) in the case of M, \( CV = 8.8060 \) in the case of CP, \( CV = 15.6021 \) in the case of BG. The graphic
representation of the diversity profile for quality indices is presented in figure 3.

Figure 3. Diversity profile for corn grain quality indices (mean values), period 2021 - 2023

The multivariate analysis led to the PCA diagram, figure 4, in which the distribution and correlation between years (during the study period) and parameters considered in the evaluation of grain corn crop, in non-irrigated crop system, is represented. PC1 explained 60.307% of variance, and PC2 explained 39.693% of variance. The year 2021 presented an independent position in relation to the analyzed production and quality parameters. The year 2022 was associated with the broken grain index (BG). The year 2023 was associated with most of the considered parameters. Among these parameters, the CF index presented a direct orientation, and the other quality and production indices presented a close positioning.

Figure 4. PCA diagram regarding the correlation between evaluated parameters and years of study, corn crop

The yield variation was analyzed in relation to the crude protein (CP) and starch content (ST). The
regression analysis led to equation (1), under conditions of $R^2 = 0.998$, $p < 0.001$. The graphic representation is presented in figure 5, in 3D format (a) and isoquants (b).

\[
Y = -1358.18 + 121.454y^2 + 821.667xy + 8394.23
\]

(1)

where: $Y$ – mean corn yield (2021 – 2023); $x$ – crude protein content (CP); $y$ – starch content (ST).

![Figure 5. Graphic representation of the yield variation ($Y$) in relation to the crude protein content (CP, x-axis) and the starch content (ST, y-axis)](image)

The differences between the corn yield for each year, and the mean yield over the three years of the study, for each corn hybrid, were calculated. In the case of the P9889 hybrid, in 2021 there was a yield increase compared to the mean value of $\Delta Y = 216.67$ kg/ha. Under the conditions of 2022, a lower yield than the mean value was registered, with a negative increase, $\Delta Y = -2933.33$ kg/ha. In the conditions of the year 2023, a higher yield was recorded compared to mean value, with an increase $\Delta Y = 2716.67$ kg/ha. The graphic representation is presented in figure 6.

![Figure 6. Yield differences in the P9889 corn hybrid compared to the mean value, period 2021 - 2023](image)
In the case of the hybrid DKC5092, in 2021 a lower yield was recorded compared to the mean value, with a negative increase, \( \Delta Y = -266.67 \) kg/ha. Under the conditions of 2022, a lower yield than the mean value was recorded, with a negative increase, \( \Delta Y = -2366.67 \) kg/ha. Under the conditions of 2023, a higher yield than the mean value was recorded, with an increase \( \Delta Y = 2633.33 \) kg/ha. The graphic representation is presented in figure 7.

![Figure 7. Yield differences in the DKC5092 corn hybrid compared to the mean value, period 2021 - 2023](image)

The comparative analysis of the yields of the two hybrids, in the study conditions, period 2021 - 2023, led to differences in the mean values that did not show statistical certainty (p >0.05).

This showed that both hybrids found good growth conditions under the conditions of applied technology, non-irrigated system, and presented a similar behavior. The differences between the yields achieved, each year, were within the limits of standard errors (SE). In the year 2022, a year with excessive drought conditions, a significant reduction in yield was recorded, for both hybrids, compared to the years 2021, 2023, and their mean value. The decrease in yield, compared to the mean value, was \( \Delta Y = -2933.33 \) kg/ha for the P9889 hybrid, respectively \( \Delta Y = -2366.67 \) kg/ha for the DKC5092 hybrid. Analyzing the two values, a difference of 566.66 kg/ha was found. This shows that the P9889 hybrid registered a greater decrease in yield compared to the DKC5092 hybrid, under the conditions of 2022, specific to the study area.

The decrease in corn yield in conditions of water stress, or the total compromise of corn crops in those conditions, have been recently reported in numerous studies (Dhaliwal and Williams, 2022; Ortez et al., 2023; Yang and Wang, 2023).

Based on the PCA, it was found that associated with the year 2022 there was a higher share of broken grains (BG, %), with the depreciation of production for commercial purposes.

Based on the results of the regression analysis, a model was obtained to describe the yield variation (Y) in relation to corn grains quality indices (CP, ST).

The results recorded in the present study show the variation of corn yield in farm conditions, and can represent benchmarks and comparative analysis for the area of influence, with similar conditions.

**CONCLUSIONS**

The two corn hybrids, P9889 and DKC5092, presented similar yield values in the conditions of 2021 and 2023. In the conditions of 2022, with the accentuated drought and water and termite stress, a more pronounced decrease in yield was recorded in the hybrid P9889, in the study conditions.

Very strong and strong correlation, under statistical safety conditions, was recorded between yield and quality indices of corn kernels (e.g. \( r = 0.989 \) between ST and CP).

In the study conditions, the BG index showed high variability, with high deviation values in the year
2022, compared to the years 2021 and 2023 (CV = 15.6021).

The yield variation (Y) in relation to the main quality indices (CP, ST) was described by mathematical models, and represented by graphical models (3D, isoquants) in conditions of statistical safety.

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