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Characteristics of maize parental components according to yield structure and grain quality indicators

Vitalii Prudnikov
Postgraduate Student
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0009-0000-5712-5187

Hanna Kovalyshyna*
Doctor of Agricultural Sciences, Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-2715-7679

Abstract. The relevance of the study is determined by the need to select maize source material capable of combining high productivity with high grain quality. In breeding processes, it is important to conduct complex studies on the morphometric traits of the ear, elements of productivity, grain filling, and the content of the main storage substances in the parental components. This study aimed to study the characteristics of the maize parental components on the basis of the elements of ear structure, grain quality parameters, and to reveal the relationships between the economically valuable traits. Field experiments were conducted during 2024-2025 in the Kyiv Region on typical low-humus chernozem soil. The experiment was arranged according to a randomised design with three replications. The studied characteristics are: weight of the ear with and without the cob, diameter and length of the ear, number of kernel rows, number of kernels per row, grain yield, 1,000-grain weight, test weight, content of proteins, starch, and oil in it. Statistical processing of the results was performed using analysis of variance and correlation analysis. Considerable phenotypic variability of the studied material was established. Ear weight with cob ranged from 30.06 g to 148.34 g, ear weight without cob from 18.48 g to 130.72 g, grain yield from 60.86% to 88.12%, and 1,000-grain weight from 174.2 g to 360.8 g. Genotype LLF 2983 was characterised by the highest values of ear weight, grain yield, and 1,000-grain weight. The highest content of proteins was revealed in LLN 2948, the highest starch content in LFH 1940 × LMH 3161, and the highest oil content in LGR 2038. Correlation analysis between the studied

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**Corresponding author (hkovalyshyna@gmail.com)*

traits showed the presence of high positive correlations between the weight of the ear, dimensions of the ear, number of kernels in the row, and grain yield. Simultaneously, multidirectional relationships were established between productivity and grain quality indicators. The practical significance of the study consists of the substantiation of promising genotypes and signs for their selection in the process of obtaining high-yield hybrids with high grain quality

Keywords: inbred lines, 1,000-grain weight, protein, starch, oil, correlation analysis

Introduction

Maize (*Zea mays* L.) ranks among the most important cereal crops in the world, playing a vital role in food, feed, industrial and breeding applications. The grain is used to obtain products, feed, food, starch, oil, bioethanol, and many other types of processing products. Currently, one of the main directions in the breeding of maize is not only the increase in yield potential, but also the improvement of grain quality and technological properties. In the conditions of increasing demand for grain production stability, the breeding of hybrids with high yield, adaptation to the changing environment, grain quality and technological properties of the grain is especially relevant.

Modern maize breeding development is based on a synthesis of traditional selection methods with molecular, genomic, and biotechnological approaches. B. He *et al*. (2024) noted that current trends in maize breeding encompass marker-assisted selection, genomic selection, haploid induction, genetic engineering, genome editing, and synthetic biology. Such approaches are aimed at improving yield potential, quality of grain, increasing resistance to biotic and abiotic factors, and improving the efficiency of nitrogen use. At the same time, in all approaches, the effectiveness of breeding largely depends on the quality of the source material, in particular, inbred lines and parental components with valuable characteristics for obtaining new hybrids. P. Kaushik & W. Grichar (2024) consider maize as one of the most important crops for ensuring food security and advancing innovation in the agricultural sector. The authors noted that the role of genetic and varietal diversity, genomics, and biotechnological approaches in the direction of new research on maize breeding, in particular for yield, and the grain nutritional quality improvement. Therefore, evaluation of parental components according to a set of productivity and quality traits remains an important stage in the development of competitive breeding material.

Maize displays an exceptional range of variability, both morphologically and in terms of productivity and quality indicators. High adaptability of the crop has led to the formation of huge genetic diversity and genetic resources with different usage, grain quality, adaptability and agronomic properties have emerged in the world according to P. Revilla *et al.* (2022). This is very important for breeding because different fields of maize usage require different target characteristics: for feed purposes, grain protein content and energy value are most important; for food purposes, nutritional value and technological properties are of particular importance; and in industry, starch, oil and the content of other components, as well as their composition, are of significant importance.

One of the trends of modern studies is the assessment of maize grain quality indicators (protein, starch, and oil content, amino acid composition, and the physical properties of the kernel). I.K. Amegbor *et al.* (2022b) established that hybrids developed using lines with enhanced grain quality may differ in tryptophan content and protein quality index. It has been shown that QPM lines crossed with non-QPM material can result in loss of quality protein advantages, while some QPM hybrids have good yield combined with improved nutritional value. Under Ukrainian conditions, the assessment of the source material of maize by grain quality indicators is also relevant. According to V.L. Jemeida *et al.* (2020), the creation of new hybrids is carried out on the basis of the formation of the necessary properties of the parental elements through the selection of those that serve as a source of improved biochemical and agronomically valuable traits. In their research, lines that were selfpollinated maize have been evaluated for protein, starch and oil content, which allowed the identification of lines that could be used in the tester-crossing scheme. Such an approach is close in methodological terms to the assessment of parental components by the set of yield structure and grain quality traits.

The assessment of the source material of maize for its grain quality traits should also include other important indicators, in particular, ear structure traits and yield components – ear weight, ear length and diameter, number of kernel rows, number of kernels per row, grain yield, 1,000-grain weight, and test weight. According to L. Yang *et al.* (2021), ear structure traits are among the key factors in the formation of maize grain yield. It was revealed in their study that the ear length, ear diameter, number of kernel rows, number of kernels per ear row and number of kernels per ear have significant QTLs, and there are high genetic and phenotypic relations between these traits. Thus, this research supports the use of indicators of ear structure traits as important indicators in breeding evaluation. Ear structure traits and productivity components are of particular importance. N.S. Khalaf & W.A. Hassan (2022) evaluated the yield in the introduced and local maize varieties and their components depending on plant density. Plant density significantly influenced almost all of the examined traits, namely ear length, row number, kernel number per row, kernel number per ear, and grain weight. Introduced varieties surpassed local ones in some productivity traits, which underlines the necessity to conduct the comparative analysis of genotypes at specific locations. These findings confirm that the productive potential of maize is formed under the combined influence of genotype, agronomic factors, and their interaction.

V.V. Bagatchenko *et al.* (2020) also demonstrated that the formation of the fractional composition and sowing qualities of maize parental seed components depends on genetic characteristics and plant density. Different parental components were shown to respond differently to changes in plant density, which affected the yield of valuable seed fractions, 1,000-grain weight, germination energy, and germination capacity. Thus, the quality of seed material and the productivity of parental components are determined by the interaction between genotype and growing conditions. Hence, they should be assessed on the basis of a complex of morphometric traits, productivity and grain quality characteristics. In research by V. Babić *et al.* (2024), the quality of maize grain depends on the genotype and year of cultivation, agrotechnical factors, as well as the relationships between the individual traits of the structural and biochemical content. According to V. Babić *et al.*, among elite maize lines and hybrids, there is great variability of quality traits of grain, as well as the year of the study and the influence of the components of parents, which are manifested for almost all quality characteristics. According to the authors, simultaneous improvement of some complexes of traits is possible, for instance, protein and starch or protein and oil, while the joint increase in oil and starch content is due to some negative relationships associated with the structure of the kernel.

There is a huge number of studies on the issues of breeding, productivity, and grain quality of maize. However, this aspect of the complex evaluation of the components of parents according to a combination of productivity, physical and mechanical properties of grain and biochemical composition, and depending on the peculiarities of the combination of soil and climatic conditions, was not sufficiently investigated. Of particular relevance is the identification of relationships between valuable agronomic traits, which makes it possible to determine indicators suitable for use as selection criteria in breeding programmes.

This study aimed to evaluate maize parental components according to ear structure traits, productivity components, physical grain properties, and grain quality indicators, as well as to establish relationships between valuable agronomic traits in order to identify promising source material for further use in breeding programmes.

Materials and Methods

Field experiments were conducted during 2024-2025 on the experimental plots of the Experimental Field unit of the Department of Genetics, Breeding and Seed Production named after Professor M.O. Zelenskyi at the National University of Life and Environmental Sciences of Ukraine (Agronomic Research Station), located within the Bila Tserkva District of Kyiv Region. The soil cover of the experimental area was represented by typical low-humus chernozem.

The source material consisted of 12 genotypes of maize developed by MAS Seeds, representing two groups of parents. The first group included lines of self-pollination for the development of twocomponent hybrids (LOR 3696, LNR 3495, LLN 2948, LIN 2456, LLF 2983, LGR 2038, LSH 369), and the second group included hybrid combinations that are used as the components of parents to obtain three-component hybrids (LIR 2232 × LIR 2234, LFH 1940 × LMH 3161, LAR 1490 × LBR 1558, LLR 2961 × LMR 3185, LGR 2038 × LSH 369).

The accounting plot area was 9.8 m^2. The experiment was arranged according to a randomised design with three replications. Determination of protein, starch, and oil content in the grain of maize parental components, as well as analysis of ear structure elements, was carried out in accordance with the Methodology for Conducting Qualification Examination of Plant Varieties for Suitability for Dissemination in Ukraine (Kienko *et al.*, 2016). Biochemical grain quality indicators were determined using a FOSS Infratec 1241 Grain Analyzer (Denmark).

Weather conditions during the years of the study were characterised by considerable inter-annual variability in temperature regime and uneven moisture supply. Air temperatures in 2024 were, in general, higher than the corresponding mean values over long-term average data. Together with moisture deficiency in the second half of July, partial suppression of growth processes was found during the tasselling period. The year 2025 was more typical in air temperature conditions, except in the month of May, when it was cooler than normal. Moisture conditions in these years were characterised by a moisture supply at higher levels compared to long-term averages; however, the rain distribution during the growing season was not uniform. The most satisfactory conditions for the moisture supply were during the first half of the summer of 2024; periods of moisture deficiency were determined in the second half of the growing season for both years. It is clear that high temperature and irregular distribution of rainfall were among the key reasons why the productive potential of the crop could not be realised.

Statistical processing of the obtained results was performed using methods of variation statistics and analysis of variance (ANOVA) in order to assess the influence of the studied factors on ear structure traits and maize grain quality indicators. For each treatment, the arithmetic mean (M) and standard error of the mean (SE) were determined. The significance of differences between treatments was evaluated using post hoc multiple comparison tests (LSD/Tukey HSD) at a significance level of $p \leq 0.05$. The results of the statistical analysis are presented in tables using letter indices to indicate homogeneous groups. The study was conducted in accordance with the international ethical requirements set out in the Convention on Biological Diversity (1992) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973). During the research process, the principles of these documents aimed at preserving biodiversity and preventing negative impacts on the studied species were observed.

Results and Discussion

As a result of the experimental studies, ear structure indicators in maize were evaluated depending on genotype. Analysis of the obtained data made it possible to determine the level of variation in the main ear structure traits and to identify statistically significant differences among the studied variants. Ear weight with cob ranged from 30.06 g to 148.34 g, whereas ear weight without cob ranged from 18.48 g to 130.72 g (Table 1). Significantly high values for both indicators were recorded in genotype LLF 2983 (148.34 g and 130.72 g, respectively), while the minimum values were observed in LLN 2948 (30.06 g and 18.48 g). Differences among the samples for these indicators were statistically significant ($p \leq 0.05$).

Table 1. *Morphometric parameters of maize ear structure depending on genotype (M ± SE)*

Maize sample	Ear weight with cob, g	Ear weight without cob, g	Ear diameter, cm	Ear length, cm	Number of rows, no.	Number of kernels per row, no.
LOR 3696	122.02 ± 17.12^{bc}	97.72 ± 16.63^{bc}	3.58 ± 0.38^{b}	14.60 ± 2.16^{cd}	14.40 ± 0.89^{b}	24.00 ± 2.35^{c}
LNR 3495	94.76 ± 15.57^{d}	77.78 ± 13.79^{c}	3.34 ± 0.48^{bc}	13.20 ± 1.10^{def}	16.40 ± 4.77^{a}	22.00 ± 3.16^{c}
LLN 2948	30.06 ± 7.86^{e}	18.48 ± 6.58^{d}	2.80 ± 0.27^{de}	12.00 ± 1.41^{fg}	11.60 ± 2.19^{d}	8.80 ± 2.28^{e}
LIN 2456	49.80 ± 14.63^{e}	35.12 ± 12.57^{d}	3.10 ± 0.22^{cd}	13.00 ± 1.22^{ef}	14.00 ± 0.00^{b}	16.80 ± 1.79^{d}
LLF 2983	148.34 ± 19.50^{a}	130.72 ± 19.40^{a}	3.82 ± 0.19^{a}	18.14 ± 1.14^{a}	14.40 ± 0.89^{b}	29.00 ± 3.32^{ab}
LGR 2038	51.66 ± 15.38^{e}	31.44 ± 10.17^{d}	2.43 ± 0.15^{f}	13.76 ± 2.16^{cde}	12.40 ± 0.89^{cd}	16.20 ± 2.59^{d}
LSH 369	53.42 ± 15.58^{e}	38.02 ± 10.88^{d}	2.50 ± 0.35^{ef}	11.40 ± 0.96^{g}	8.00 ± 0.00^{e}	16.4 ± 1.52^{d}
LIR 2232 × × LIR 2234	116.70 ± 25.90^{bcd}	93.52 ± 20.80^{bc}	3.12 ± 0.47^{c}	14.58 ± 1.79^{cd}	12.00 ± 1.41^{cd}	30.80 ± 3.77^{a}
LFH 1940 × × LMH 3161	127.20 ± 22.14^{abc}	106.66 ± 20.16^{b}	3.34 ± 0.22^{bc}	15.10 ± 0.55^{bc}	16.80 ± 3.35^{a}	30.40 ± 6.39^{ab}
LAR 1490 × × LBR 1558	138.70 ± 11.31^{ab}	95.92 ± 45.00^{bc}	3.30 ± 0.27^{bc}	18.4 ± 1.67^{a}	14.40 ± 0.89^{b}	32.80 ± 3.63^{a}
LLR 2961 × × LMR 3185	109.34 ± 22.64^{cd}	81.34 ± 22.05^{c}	3.38 ± 0.30^{bc}	16.14 ± 1.02^{b}	12.40 ± 1.67^{cd}	25.80 ± 1.64^{bc}
LGR 2038 × × LSH 369	103.00 ± 29.13^{cd}	76.86 ± 21.30^{c}	3.40 ± 0.86^{bc}	15.04 ± 2.22^{bc}	13.20 ± 2.28^{bc}	26.00 ± 1.87^{bc}
$\bar{x}$	95.42 ± 39.46	73.63 ± 35.01	3.18 ± 0.42	14.61 ± 2.17	13.33 ± 2.34	23.25 ± 7.36

Note: values are presented as arithmetic mean (M) ± standard error (SE). Different letters (a, b, c, d, e, f, g) within a single indicator denote statistically significant differences between genotypes according to the multiple comparison test at $p \leq 0.05$

Source: developed by the authors on the basis of their own research

The ear diameter varied within 2.43-3.82 cm, and the ear length varied from 11.40 to 18.40 cm. Genotypes LLF 2983 and LAR 1490 × LBR 1558 had the largest ear diameter and length (3.82 cm and 18.14-18.40 cm, respectively), which were statistically reliably greater than others. The number of kernel rows was in the range of 8.0-16.8, and the number of kernels per row ranged from 8.8 to 32.8. The largest numbers of kernel rows were detected in genotypes LFH 1940 × LMH 3161 and LNR 3495 (16.8 and 16.4, respectively), the maximum number of kernels per row (30.4-32.8) was in genotypes LAR 1490 × LBR 1558, LIR 2232 × LIR 2234 and LFH 1940 × LMH 3161, and minimum values of these indicators were determined for genotypes LLN 2948 and LSH 369.

Depending on the genotype, the grain yield ranged within 60.86%-88.12%, and the 1,000-grain weight ranged from 174.2 to 360.8 g (Table 2). The highest grain yield was recorded in genotype LLF 2983 at 88.12%, which was also characterised by the maximum 1,000-grain weight of 360.8 g. This indicates that the genotype combines a high proportion of grain in the ear structure with the formation of large kernels, which is an important characteristic of its productive potential. A similar tendency was observed in the self-pollinated lines LNR 3495 and LOR 3696, in which high grain yield values of 82.08% and 80.09%, respectively, were combined with relatively high 1,000-grain weights of 312.0 g and 311.2 g. This may indicate a more balanced formation of ear productivity components in these genotypes.

Table 2. *Productivity parameters of the ear and physical grain properties of maize depending on genotype (M ± SE)*

Maize sample	Grain yield, %	1,000-grain weight, g
LOR 3696	80.09 ± 2.66[b]	311.20 ± 24.16[b]
LNR 3495	82.08 ± 2.29[b]	312.00 ± 37.97[b]
LLN 2948	61.48 ± 7.24[e]	258.00 ± 16.28[d]
LIN 2456	70.52 ± 9.18[cd]	174.20 ± 50.36[h]
LLF 2983	88.12 ± 10.98[a]	360.80 ± 56.02[a]
LGR 2038	60.86 ± 6.11[e]	205.00 ± 69.20[gh]
LSH 369	71.17 ± 1.174[cd]	222.00 ± 44.50[fg]
LIR 2232 × LIR 2234	80.14 ± 1.30[b]	267.60 ± 50.22[cd]
LFH 1940 × LMH 3161	83.85 ± 1.678[ab]	208.20 ± 43.41[fgh]
LAR 1490 × LBR 1558	69.16 ± 31.88[d]	275.00 ± 22.92[cd]
LLR 2961 × LMR 3185	74.39 ± 5.13[cd]	301.4 ± 15.65[bc]
LGR 2038 × LSH 369	74.62 ± 0.80[c]	240.00 ± 68.56[ef]
$\bar{x}$	74.71 ± 8.55	261.28 ± 54.26

Note: values are presented as arithmetic mean (M) ± standard error (SE). Different letters (a, b, c, d, e, f, g) within a single indicator denote statistically significant differences between genotypes according to the multiple comparison test at $p \leq 0.05$

Source: developed by the authors on the basis of their own research

At the same time, the samples did not display a direct correlation between grain yield and 1,000-grain weight. For example, for LFH 1940 × LMH 3161, one of the high grain yield values was observed (83.85%), yet the 1,000-grain weight was low (208.2 g). This suggests that in this genotype, such high values for grain yield were determined not by the kernel size, but probably by the greater number of kernels or less content of cob tissue in the ear mass. For LIR 2232 × LIR 2234, a similar pattern was also observed. Despite the high grain yield of this combination (80.14%), 1000-grain weight was only average (267.6 g), while 1,000-grain weight of LAR 1490 × LBR 1558 was relatively large (275.0 g); however, it was characterised by a relatively lower grain yield (69.16%). As for the samples with the lowest grain yield values – LGR 2038 (60.86%) and LLN 2948 (61.48 %), they also differed from each other by the indicator of 1,000-grain weight. In LGR 2038, it reached 205.0 g, and in LLN 2948, 258.0 g, which confirms that low grain yield does not always go together with the lowest grain weight and may depend on the morphological structure of the ear and the relationship between the grain mass and the cob. The lowest 1,000-grain weight was recorded in LIN 2456 at 174.2 g; however, the grain yield of this genotype was 70.52%, which was higher than that of LGR 2038 and LLN 2948.

Test weight of maize grain varied widely depending on genotype, ranging from 390 to 754 g/L, indicating substantial genotypic differentiation in physical grain properties (Fig. 1). The best results in test weight were shown by

LIN 2456 – 754 g/L, LLR 2961 × LMR 3185 – 752 g/L, LSH 369 – 750 g/L, and LGR 2038 × LSH 369 – 743 g/L; they formed group "a". This indicates that there are no statistically significant differences between them in this respect. High test weight of these genotypes is evidence of better kernel filling, higher grain density, and potentially greater technological value. For food-grade maize, this indicator is particularly relevant, as a higher test weight implies a more uniform kernel, its density and better suitability for processing.

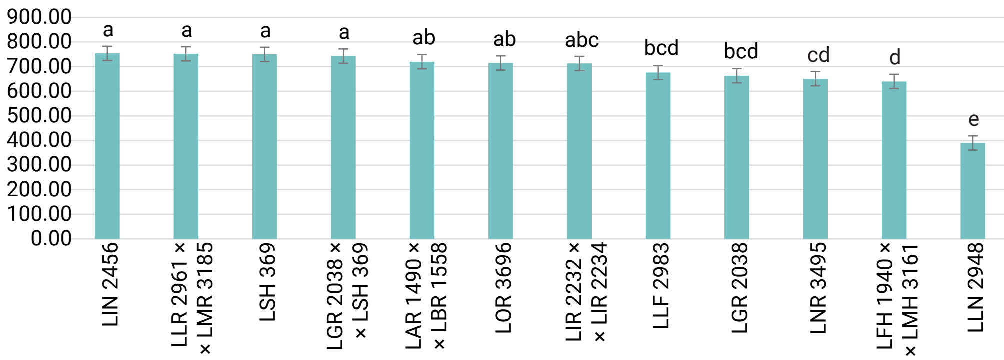

Figure 1. *Test weight of maize grain depending on genotype*

Note: different letters above the bars (a, b, c, d, e) indicate statistically significant differences between genotypes at $p \leqslant 0.05$

Source: developed by the authors on the basis of their own research

Another group was made up of genotypes with relatively high, although slightly lower values, of test weight: LAR 1490 × LBR 1558 – 720 g/L, LOR 3696 – 715 g/L, LIR 2232 × LIR 2234 – 713 g/L. These fell into transitional statistical groups "ab" and "abc", indicating that their values were close to those of the maximum test weight group. In other words, this suggests that these genotypes may also be considered promising for this quality feature, as values in this group exceeded 700 g/L. This is sufficiently high for the formation of high-quality grain mass, especially in conjunction with other good agronomic features such as the 1,000-grain weight, grain yield per ear and yield stability. An intermediate group for test weight was formed by LLF 2983 – 676 g/L, LGR 2038 – 663 g/L, LNR 3495 – 651 g/L, and LFH 1940 × LMH 3161 – 640 g/L. Their values were much lower than those of the leading genotypes, yet remained within a range that may be acceptable for grain utilisation. In addition, comparing these indicators with other characteristics of productivity, it is possible to see that the highest 1,000-grain weight and the best grain yield did not necessarily indicate the greatest test weight values. For example, LLF 2983 had the highest 1,000-grain weight, and also showed the greatest grain yield, but the test weight for this genotype was within the intermediate range. In turn, LFH 1940 × LMH 3161 had the high grain yield and low values of test weight (640 g/L), which indicates that test weight depends not only on the size and weight of an individual kernel but also on its density, morphology and degree of filling.

The lowest test weight was shown by the genotype LLN 2948 – 390 g/L, and it considerably differed from the others. These values are very low, and they cannot be considered an indicator of high-quality grain for technological use, which can be evidenced by poor filling of grain, lower kernel density or other features of the grain morphology of this genotype. Additionally, it is worth noting that LLN 2948 showed one of the lowest grain yield values, confirming its comparative modesty in productive and technological potential among the tested samples.

The content of grain protein in maize ranged from 9.0% to 11.7% (Table 3). The highest indicator was obtained for the LLN 2948 genotype (11.7%), which significantly surpassed other variants. High values were also identified for the LGR 2038 (11.5%) and LNR 3495 (11.0%) genotypes. The lowest results were noted for LLF 2983 and LAR 1490 × LBR 1558 genotypes (9.0% each) and for the LIN 2456 genotype (9.2%).

Table 3. *Maize grain quality indicators depending on genotype (M ± SE)*

Maize sample	Protein content, %	Starch content, %	Oil content, %
LIR 2232 × LIR 2234	10.1 ± 0.2[de]	69.8 ± 0.2[c]	3.9 ± 0.0[ef]
LFH 1940 × LMH 3161	9.3 ± 0.3[fg]	72.1 ± 0.2[a]	3.8 ± 0.0[fg]
LAR 1490 × LBR 1558	9.0 ± 0.2[g]	68.2 ± 0.2[fg]	4.0 ± 0.0[de]
LLR 2961 × LMR 3185	10.7 ± 0.1[cd]	68.8 ± 0.2[def]	4.1 ± 0.0[d]
LGR 2038 × LSH 369	9.6 ± 0.1[efg]	69.8 ± 0.3[c]	4.1 ± 0.0[d]
LOR 3696	10.2 ± 0.2[de]	68.5 ± 0.3[efg]	4.3 ± 0.0[bc]
LNR 3495	11.0 ± 0.3[bc]	69.1 ± 0.2[cde]	3.7 ± 0.0[gh]
LLN 2948	11.7 ± 0.1[a]	67.8 ± 0.3[g]	4.4 ± 0.0[ab]
LIN 2456	9.2 ± 0.1[g]	70.6 ± 0.3[b]	3.8 ± 0.0[fg]
LLF 2983	9.0 ± 0.1[g]	69.2 ± 0.14[cde]	3.6 ± 0.0[h]
LGR 2038	11.5 ± 0.13[ab]	68.3 ± 0.16[fg]	4.5 ± 0.0[a]
LSH 369	9.8 ± 0.2[ef]	69.4 ± 0.42[cd]	4.1 ± 0.1[cd]
$\bar{x}$	10.1 ± 0.2	69.3 ± 0.3	4.0 ± 0.0

Source: developed by the authors on the basis of their own research

Starch content fluctuated from 67.8% to 72.1%. The highest value was recorded in the LFH 1940 × LMH 3161 genotype (72.1%), which significantly surpassed other variants. High values were also identified for the LIN 2456 (70.6%) and LIR 2232 × LIR 2234 (69.8%). The lowest value for this indicator was established for the LLN 2948 genotype (67.8%). The oil content of grain ranged from 3.6% to 4.5%. The highest value was recorded in the LGR 2038 genotype (4.5%), as well as in the LLN 2948 (4.4%) and LOR 3696 (4.3%) genotypes, which significantly surpassed other variants. The lowest result was recorded for LLF 2983 (3.6%) and LNR 3495 (3.7%) genotypes.

A set of very high and strong positive correlations was identified between the traits related to ear structure (Table 4). Thus, a very high correlation coefficient (r = 0.98) was obtained for the relationship between the weight of the ear with cob and the weight of the ear without cob. In this case, the weight of the ear with cob also showed strong positive correlations with the number of kernels in rows (r = 0.94), length of the ear (r = 0.86), and diameter of the ear (r = 0.82), as well as a good correlation with grain yield (r = 0.76). Almost the same picture was observed with the weight of the ear without cob, which shows a good correlation with the number of kernels in rows (r = 0.90), the diameter of the ear (r = 0.85), and grain yield (r = 0.85). Grain yield showed strong positive correlations with the diameter of the ear (r = 0.78) and the number of kernels in rows (r = 0.67), as well as a moderate correlation with 1,000-grain weight (r = 0.54). At the same time, a strong negative correlation was identified for the grain yield and oil content (r = -0.77), which indicates a contrasting nature of formation of these traits. Statistically significant relationships were also found between some structural traits of the ear: the diameter of the ear was in correlation with its length (r = 0.69), the number of rows with kernels (r = 0.66), as well as with the number of kernels in rows (r = 0.67). Ear length had a high correlation with the number of kernels per row (r = 0.81) and a medium correlation with the number of kernel rows (r = 0.45). The 1,000-grain weight was mainly associated with moderate positive correlations with ear structure traits (r = 0.52-0.66), a weak one with the number of kernel rows (r = 0.22) and almost zero with test weight (r = -0.05). The test weight was correlated in a majority of cases weakly to moderately with the examined traits, including moderately positive with the number of kernels per row (r = 0.51), and weakly with ear mass traits (r = 0.33-0.39). Protein content showed medium negative correlations with ear structure traits (r = -0.49...-0.57) and with test weight (r = -0.57), while a medium positive correlation was found with oil content (r = 0.63). Starch content was characterised by a medium positive correlation with grain yield (r = 0.50), medium negative with 1,000-grain weight (r = -0.43) and medium negative with oil content (r = -0.57). The results obtained show large genotypic diversity among parental components of maize regarding main ear structure traits, productivity and grain quality traits. Significant variation was established in the weight of the ear with and without the cob, ear diameter and length, number of rows, and number of kernels per row, which confirms the broad range of morphological variability among the genotypes studied.

Table 4. *Correlation matrix of relationships between agronomically valuable traits of maize*

	Ear weight with cob, g	Ear weight without cob, g	Grain yield, %	Ear diameter, cm	Ear length, cm	Number of rows, no.	Number of kernels per row, no.	1,000-grain weight, g	Test weight, g/L	Protein content, %	Starch content, %	Oil content, %
Ear weight with cob, g	1.00											
Ear weight without cob, g	0.98	1.00										
Grain yield, %	0.76	0.85	1.00									
Ear diameter, cm	0.82	0.85	0.78	1.00								
Ear length, cm	0.86	0.79	0.41	0.69	1.00							
Number of rows, no.	0.54	0.56	0.52	0.66	0.45	1.00						
Number of kernels per row, no.	0.94	0.90	0.67	0.67	0.81	0.47	1.00					
1,000-grain weight, g	0.61	0.64	0.54	0.66	0.52	0.22	0.38	1.00				
Test weight, g/L	0.39	0.33	0.32	0.22	0.30	-0.03	0.51	-0.05	1.00			
Protein content, %	-0.57	-0.56	-0.50	-0.49	-0.52	-0.24	-0.63	0.02	-0.57	1.00		
Starch content, %	0.20	0.27	0.50	0.19	-0.04	0.35	0.33	-0.43	0.30	-0.55	1.00	
Oil content, %	-0.52	-0.59	-0.77	-0.59	-0.36	-0.51	-0.54	-0.27	-0.30	0.63	-0.57	1.00

Source: developed by the authors on the basis of their own research

Similar patterns were reported by L. Yadesa *et al.* (2022), who, in their evaluation of maize inbred lines with high-quality traits, established significant differences between genotypes for almost all traits studied. The authors noted that traits such as kernel number per ear, ear diameter, and 1,000-grain weight are of considerable breeding importance, as they combine moderate to high heritability with a positive effect on grain productivity. The variability for ear structure traits also corresponds to the results of B.T. Magar *et al.* (2021), who reported high genetic variability in maize genotypes for growth and yield traits. In that study, the highest values for heritability and genetic gain were recorded for grain yield and 1,000-grain weight, providing the authors with grounds to consider these indicators as effective selection criteria. In this regard, genotypes with higher values for ear weight, grain yield and 1,000-grain weight could be used as promising germplasm for breeding programmes.

The efficiency of maize hybrid production depends on high-value inbred lines and the mode of inheritance of traits, according to R.M.M. Habiba *et al.* (2022). In their study, for the majority of yield and yield component traits, the variance of general combining ability exceeded the variance of specific combining ability, suggesting a significant role for additive genetic variability. This suggests that the significant differences identified among the studied genotypes may be utilised in further selection of parental forms. An important component in assessing productive potential is grain yield and 1,000-grain weight. B.T. Magar *et al.* (2021) noted that 1,000-grain weight is one of the most indicative traits for assessing maize productivity due to its high heritability and correlation with yield. In a similar vein, L. Yadesa *et al.* (2022) reported on the importance of 1,000-grain weight, ear diameter and kernel number to grain yield determination in maize inbred lines.

The correlation analysis conducted in this study revealed a close relationship between the main ear structure traits and maize productivity. A high positive correlation was found between ear weight with cob and ear weight without cob. In addition, ear weight had close correlations with the number of kernels per row, ear length and ear diameter. Grain yield also showed a positive correlation with ear diameter, number of kernels per row and 1,000-grain weight. This agrees with the research of B.T. Magar *et al.* (2021), who found that grain yield was positively and significantly directly associated with test weight, ear length, ear diameter and number of kernel rows per ear. These results suggest that ear structure traits can be used as a valuable indirect indicator for the selection of productive maize forms. Similar results have been reported by A. Khatibi *et al.* (2023), who studied the relationships between maize yield and its components under different levels of drought stress. They found that under optimal growing conditions, grain yield directly depends on plant height, ear length and number of kernels per row. Under conditions of stress, the type of correlation changes as well as its strength. These findings are of special importance for the interpretation of the results of the current study, as the weather in 2024-2025 was characterised by uneven distribution of precipitation and periods of moisture deficit, which could affect the manifestation of the yield potential of maize. Hence, the differences observed between genotypes can be caused both by different genetic backgrounds and by different abilities to form the ear under changing environmental conditions.

Of particular concern is the physical properties of grain, especially test weight. Test weight is an important indicator of kernel filling and technological quality. C. Dorsey-Redding *et al.* (1991) reported that significant relationships between individual grain quality traits of maize are also possible. Among them: a positive relationship was found between protein content, ash content and test weight, and a negative relationship between starch and protein. This implies that test weight should be interpreted not just as a physical characteristic, but also as another trait indicating the quality of grain. S. Chander *et al.* (2008) also investigated genotypic differences in protein, starch, and oil. They concluded that genotypes significantly differed in the biochemical composition of grain. The authors also demonstrated a high level of heritability for most quality indicators, indicating the potential for their effective improvement within breeding programmes. S. Cao *et al.* (2024) revealed that in cereals, a trade-off is frequently noted between yield and quality due to the interaction of storage proteins and starch biosynthesis with a complicated system. D.P. Chaudhary *et al.* (2012) also identified complicated connections between some nutritional components of maize grain. As a result, the inverse association between starch and oil suggests a likely competition between different storage compounds within the kernel.

The data presented by I.K. Amegbor *et al.* (2022a) for QPM and non-QPM maize hybrids also verify that there may be complicated relationships between yield and quality traits. In particular, their study found positive links between grain yield and protein and between tryptophan and oil and negative associations between yield and tryptophan as well as protein and tryptophan. This suggests that the improvement of one quality trait is not always accompanied by the improvement of others; therefore, selection assessment should be carried out using a complex of productive and biochemical parameters. Q. Ying *et al*. (2025) confirmed the relevance of breeding high-protein maize forms for improvement in the nutritional value of maize grain. However, an increase in protein and essential amino acid content in grain was observed to cause problems with obtaining high yield and other agronomic characteristics, which limit their breeding. In this context, genotypes with increased protein or oil content should be considered as potential sources of quality traits, while highly productive forms with greater ear weight, higher grain yield, and 1,000-grain weight may be utilised as sources of productivity.

Research by H. Wang *et al*. (2023) indicates that the quality of maize grain can vary significantly not only under the influence of genotype but also depending on mineral nutrition. It was revealed that the introduction of sulphur improved the yield due to the increase in the number of kernels in the ear and weight of grain, as well as improved the nutritional quality of the grain due to the regulation of amino acid composition. These findings are crucial for interpreting the results because the accumulation of proteins, oils, and starches is governed by the interplay of genetic potential, growing environments, and plant nutrition. This conclusion is corroborated by general breeding patterns found in other cereal crops: an integrated evaluation of both yield and quality is essential. As I. Havryliuk & H. Kovalyshyna (2024) have shown, the traits that constitute a crop's yield structure, its grain quality, and its 1,000-grain weight are all significantly affected by the genotype itself, the specific year's environmental conditions, and the interaction between the two.

The results of B. Mazurenko *et al*. (2025) and M. Voitovyk *et al*. (2023) further confirm the broader agrobiological context of crop productivity formation. In particular, B. Mazurenko *et al*. (2025) showed that the application of biostimulants in mixed cropping systems increased yield and certain productivity components, which were associated with anti-stress effects and stimulation of rhizosphere processes. M. Voitovyk *et al*. (2023) found that fertilisation systems and tillage practices influence the content and composition of humic substances in typical chernozem soils, thereby indirectly determining soil fertility and the conditions for realising crop yield potential. Taken together, these data confirm that effective breeding and agronomic evaluation of crops should take into account genotype, environmental conditions, adaptability, and product quality.

It has, therefore, been demonstrated that the parental maize lines used in this investigation exhibit pronounced differences in ear structure, yield capacity, physical grain characteristics, and grain quality. The most valuable traits for breeding high-yielding lines are the weight of the ear, diameter and length of the ear, number of kernels per row, grain yield, and 1,000-grain weight. Simultaneously, the concentrations of proteins, starch, and oils retain independent breeding significance, as they are primary determinants of the grain's nutritive, feeding, and technological value. Negative relationships between a number of yield indicators and grain quality components detected in this study underline the importance of comprehensive breeding strategies targeting the aggregation of these traits.

Conclusions

The genetic variability of the maize genotypes under study showed a significant distinction in indicators of ear structure, yield capacity and quality of grain. Ear weight with the cob ranged from 30.06 g to 148.34 g, ear weight without the cob from 18.48 g to 130.72 g, ear diameter from 2.43 cm to 3.82 cm, ear length from 11.40 cm to 18.40 cm, number of kernel rows from 8.0 to 16.8, and number of kernels per row from 8.8 to 32.8. The LLF 2983 genotype was characterised by the highest values for most morphometric parameters, while the lowest values for certain traits were established for LLN 2948 and LSH 369.

Regarding productivity indicators, the LLF 2983 genotype was identified as having the highest grain yield and the maximum 1,000-grain weight. High values of specific yield indicators were observed in LNR 3495, LAR 1490 × LBR 1558, LFH 1940 × LMH 3161, and LIR 2232 × LIR 2234. Significant differences between genotypes were established for test weight. A group of genotypes was identified that were similar in this trait – LIN 2456, LLR 2961 × LMR 3185, LSH 369 and LGR 2038 × LSH 369 – with high test weight values that indicated better physical grain quality.

Regarding the biochemical composition of the grain, protein content ranged from 9.0% to 11.7%, starch from 67.8% to 72.1%, and oil from 3.6% to 4.5%. Maximum protein content was observed in LLN 2948, with similar indicators of LGR 2038 and LNR 3495. The starch content reached maximum values in LFH 1940 × LMH 3161, and the percentage of oil in LGR 2038. These parental genotypes can be considered the most appropriate for breeding with specific grain quality.

Analysis of correlation relationships proved a positive relationship between the structural parameters of ears and productivity. Ear weight with cob showed a very strong correlation with ear weight without cob, number of kernels per row, ear length, and ear diameter. The grain yield was associated with the parameters of ear diameter, number of kernels per row and 1,000-grain weight. Consequently, the weight of the ear, diameter and length of the ear, number of kernels per row, and 1,000-grain weight are informative criteria for selecting productive maize parental components. The relationship between the productivity indicators and grain quality indices turned out to be divergent. For the protein content, it was negative in relation to the ear structure, whereas the percentage of oil was inversely proportional to the grain yield. A positive relationship existed between protein and oil content. In this respect, balanced breeding for maize is desirable as an increase in yield, and maintaining its desirable biochemical composition and quality of the product is required.

Further research should focus on a multi-year study of the identified genotypes in various soil and climatic conditions, determination of their combining ability, as well as the assessment of the stability of productivity and quality of grain. Further investigation of the heredity of protein, starch and oil content, test weight and 1,000-grain weight in the grain of hybrids is recommended.

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Conflict of Interest

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Характеристика батьківських компонентів кукурудзи за показниками структури врожаю та якості зерна

Віталій Прудніков
Аспірант
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0009-0000-5712-5187
Ганна Ковалишина
Доктор сільськогосподарських наук, професор
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0002-2715-7679

Анотація. Актуальність дослідження зумовлена необхідністю добору вихідного матеріалу кукурудзи, здатного поєднувати високу продуктивність із високими показниками якості зерна. Для селекційної роботи важливим є комплексне оцінювання батьківських компонентів за морфометричними ознаками качана, елементами продуктивності, виповненістю зерна та вмістом основних запасних речовин. Метою дослідження було оцінити батьківські компоненти кукурудзи за показниками структури качана, продуктивності, показниками якості зерна, а також встановити взаємозв'язки між господарсько-цінними ознаками. Польові дослідження проводили протягом 2024-2025 рр. у Київській області на чорноземі малогумусному типовому. Дослід закладали за рандомізованою схемою з триразовою повторністю. Визначали масу качана зі стержнем і без стержня, діаметр і довжину качана, кількість рядів зерен, кількість зерен у ряді, вихід зерна, масу тисячі зерен, натуру зерна, вміст білка, крохмалю та олії. Статистичну обробку результатів здійснювали із застосуванням дисперсійного та кореляційного аналізу. Встановлено істотну фенотипову мінливість досліджуваного матеріалу. Маса качана зі стержнем варіювала від 30,06 до 148,34 г, маса качана без стержня – від 18,48 до 130,72 г, вихід зерна – від 60,86 до 88,12 %, маса тисячі зерен – від 174,2 до 360,8 г. Генотип LLF 2983 вирізнявся найвищими значеннями маси качана, виходу зерна та маси тисячі зерен. Найвищий вміст білка встановлено у LLN 2948, крохмалю – у LFH 1940 × LMH 3161, олії – у LGR 2038. Кореляційний аналіз підтвердив тісні прямі зв'язки між масою качана, його розмірами, кількістю зерен у ряді та виходом зерна. Водночас виявлено різноспрямовані зв'язки між показниками продуктивності та якості зерна. Практичне значення роботи полягає у виділенні перспективних генотипів і критеріїв добору для подальшого створення гібридів із поєднанням високої продуктивності та якості зерна

Ключові слова: інбредні лінії; маса тисячі зерен; білок; крохмаль; олія; кореляційний аналіз