



GRAIN MAIZE (*ZEA MAYS* L.) HARVESTING APPRAISAL IN TERMS OF COB AND KERNEL CHARACTERISTICS

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SUMMARY

Unlike other cereal crops, maize (*Zea mays* L.) kernels do not shatter and fall on the ground upon reaching maturity. This feature develops constructive conditions for the complete collection of maize grains. However, at this point, kernel growth ceases. At the beginning of the milk-wax maturity stage, ear moisture remained 40% to 50%. Such ears require drying either in the field or in special dryers. For seed production, maize harvest occurs at the complete physiological maturity stage. Synchronized harvesting with kernel separation is an option as and when kernel moisture content remains 2%-30%. However, the entire harvesting operation should be final within 10–15 days. Grain maize harvesting can proceed once the dry matter content exceeds 60% in the kernels. At this stage, a distinct black layer appears at the point where the kernel is attached to the cob. For the preparation of ear-kernel mixtures, harvesting is considerably optimal when the dry matter content of husked ears reaches 50%–60%. However, the harvested material must not stay in the field until late autumn. Once frosts begin, the germination capacity of high-moisture maize kernels declines rapidly. These results provide essential information for the designing and adjustment of maize harvesting and postharvest equipment.

Keywords: Grain maize (*Z. mays* L.), maize harvesting, ear and kernel traits, postharvest technology, ear deformation, kernel moisture, seed quality, drying technology, kernel separation, coefficient of variation

Key findings: Maize's (*Z. mays* L.) full mechanical harvesting is possible due to the nonshattering nature at maturity; however, improper combined settings cause substantial losses. Maize optimal harvesting for grain begins at milk-wax maturity; however, full maturity is necessary for seed production purposes.

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INTRODUCTION

The importance of grain maize (*Zea mays* L.) harvesting has been progressive on the national and global levels over the past decades (Baributsa *et al.*, 2020; Li *et al.*, 2023). Maize is one of the most deliberate cereal crops, which plays a central role in both food and feed production, serving as a primary raw material for the starch, oil, livestock, and bioenergy industries (Dong *et al.*, 2024; Wang *et al.*, 2024). In Azerbaijan, in response to growing demand for high-quality grains and silage, maize cultivation is expanding; therefore, timely and well-organized harvesting has become a crucial factor for obtaining higher grain yields with good quality (Hasanov *et al.*, 2024; Asadullayev *et al.*, 2024; Huseynov *et al.*, 2026a). These challenges are consistent with global trends in maize production, where harvesting efficiency and grain quality remain key concerns. The harvesting process comprises several specific agronomic and technological characteristics that clearly differentiate it from the harvesting of wheat, barley, and other small-grain cereals (Ma *et al.*, 2020; Demir and Çolak, 2023). These differences are mainly in association with the structural features of maize ears, higher kernel susceptibility to mechanical damage, and the need for optimized threshing and postharvest management (Fang *et al.*, 2024; Tang *et al.*, 2024; Kassa *et al.*, 2025).

Unlike wheat and barley, wherein grains easily shatter and fall to the ground upon reaching full maturity, maize kernels remain firmly attached to the cob. This non-shattering trait develops positive conditions for complete mechanical collection with reduced field losses under ideal conditions (Li *et al.*, 2023; Wang *et al.*, 2024). However, this advantage in maize can quickly turn into a serious shortcoming if non-observation of proper technological regulation prevails during harvesting. Failure to follow recommended harvesting procedures and also incorrect adjustment of the combine harvester leads to considerable quantitative and qualitative losses, along with serious mechanical damage to the machine itself (Demir and Çolak, 2023; Fang *et al.*, 2024). Overloading the threshing mechanism with

whole ears, incorrect setting of rotor speed, and concave clearance commonly result in kernel breakage, cob damage, and even breakdown of the costly harvesting equipment (Dong *et al.*, 2024; Tang *et al.*, 2024; Huseynov and Aghayev, 2024). Maize harvesting usually starts when the kernels reach the milk-wax maturity stage. At this critical physiological point, dry-matter accretion in the grain ceases, and the plant begins the final phase of maturation (Baributsa *et al.*, 2020; Kassa *et al.*, 2025).

It is imperative to note that at the very beginning of the milk-wax stage, ear moisture content is still relatively high and approximately 40% to 50%. Such high-moisture ears cannot stay in storage for long periods without drying either directly in the field or in specialized drying facilities (Hasanov *et al.*, 2024). For commercial grain production, harvesting is generally a preference at the milk-wax stage, while for seed production, the crop remains until complete physiological maturity (Li *et al.*, 2023; Huseynov *et al.*, 2026c; Musayeva *et al.*, 2026). Synchronized harvesting and kernel separation from the cob become an option as and when kernel moisture content is constant at 26%–30% (Fang *et al.*, 2024; Wang *et al.*, 2024). However, under normal environmental conditions, the intact harvesting campaign should reach completion within a period of 10–15 days (Kassa *et al.*, 2025; Shukurova *et al.*, 2026). Grain maize can undergo harvesting securely once the dry-matter content in the kernels exceeds 60%, and a reliable visual indicator of this stage is the manifestation of a distinct black layer at the kernel attachment point (Baributsa *et al.*, 2020; Amanova *et al.*, 2026).

One cannot overstate the importance of timely harvesting. Storing the harvested mass in the field until the end of autumn is strongly inadvisable. Once the first frosts arrive—when the temperature falls below 0 °C—the germination viability of high-moisture seeds/grains undergoes a sharp and irreversible decline (Hasanov *et al.*, 2024; Huseynov *et al.*, 2026b; Sadigov *et al.*, 2026b). In prolonged rainy weather, fungal pathogens also rapidly spread through the ears, significantly lowering both the market quality and feed value of the

crop (Baributsa *et al.*, 2020; Kassa *et al.*, 2025; Teymurov *et al.*, 2026). Therefore, careful preparation of harvest operations, selection of appropriate machinery, and strict observance of technological parameters were evidently crucial to minimize yield losses and preserve the biological and economic values of the maize crop (Demir and Çolak, 2023; Dong *et al.*, 2024). The timely study focuses on the detailed examination of ear types, dimensional characteristics, and kernel traits across different sections of the ear. The obtained results provide essential scientific and practical data for the designing and optimization of harvesting and

postharvest equipment, contributing to higher productivity and improved quality of both food-grade and seed maize (Tang *et al.*, 2024; Wang *et al.*, 2024; Huseynov *et al.*, 2025).

MATERIALS AND METHODS

The type and dimensions of maize (*Z. mays* L.) ears require high considerations (Figure 1). The main dimensional traits of the most common ear types underwent studies (Table 1). Maize ears primarily differed in length, while variability in the remaining ear traits



Figure 1. Representative maize ear samples with the lower, middle, and upper sections.

Table 1. Main dimensional characteristics of maize ears.

Ear No.	Ear Dimensions				Core diameter	
	Total length (mm)	Length of the middle part (mm)	Diameter (mm)		max	min
			max	min		
1	165	100	47	38	29.4	17.2
2	153	100	41	37	29.8	18.1
3	170	123	45	37	27.2	18.1
4	145	95	40	37	25.9	15.0
5	173	128	53	41	32.2	20.5
6	247	143	51	39	33.8	15.1
7	225	153	50	48	30.1	15.5
Mean values	182.6	120.3	46.7	39.6	29.8	17.1
Mean squared tendency (mm)	38.3	37.5	4.5	2.93	2.73	1.0
Coefficient of variation (%)	21.0	22.4	9.0	2.16	9.01	11.0

Table 2. Statistical characteristics of kernel width by ear section (mm).

Ear No.	Lower part			Middle part			Upper part		
	<i>M</i> (mm)	σ (mm)	ν (%)	<i>M</i> (mm)	σ (mm)	ν (%)	<i>M</i> (mm)	σ (mm)	ν (%)
1	8.25	0.81	9.80	7.77	0.55	7.10	7.29	0.72	10.00
2	8.12	0.56	6.90	8.14	0.57	7.00	7.10	0.79	11.10
3	9.04	1.10	12.20	8.34	0.89	10.10	7.88	0.74	9.40
4	7.86	0.89	11.30	7.02	0.48	6.90	6.49	0.56	8.60
5	9.05	0.56	6.20	8.58	0.58	6.80	6.89	0.73	10.60
6	9.27	0.98	0.60	8.69	0.59	6.60	8.73	0.69	8.40
7	9.41	0.57	6.10	8.03	0.69	7.80	7.54	0.58	7.70
Mean values	8.71			8.12			7.42		

M (mm) – kernel width measured from the maize ear, σ (mm) – standard deviation, ν (%) – coefficient of variation.

remains within the coefficient of variation of 9.1%–11% (Ma *et al.*, 2020; Li *et al.*, 2023; Gumbatov *et al.*, 2024). Morphological variability of maize ears and kernels plays a substantial role in determining the efficiency of harvesting and postharvest operations (Wang *et al.*, 2024; Hasanov *et al.*, 2024; Mammadov *et al.*, 2026c).

Seven representative maize ears received random selection from the harvested lot for dimensional analysis. The selected ears sought to cover the typical size range observed in the experimental material and exclude visibly damaged or diseased samples. Ear length, middle-section length, ear diameter, and cob diameter entailed measurement using a digital caliper with an accuracy of ± 0.01 mm. For kernel measurements, samples taken separately came from the upper, middle, and lower sections of each ear. Measuring at least 30 kernels from each section aimed to determine kernel width, standard deviation, and coefficient of variation. All measurements occurred under laboratory conditions at ambient temperatures (Mamedov, 2015; Mammadov, 2025; Mammadov and Mammadova, 2025).

For preparing seeds, kernels should come from the middle section of the ear. In the examined ears, the deviation from the middle-section kernel thickness was 0.95 mm at the upper tip and 0.43 mm at the lower part of the ear. Such variations in kernel size along the ear axis appeared to be associated with differences in nutrient distribution and grain-filling dynamics (Fang *et al.*, 2024; Tang *et al.*, 2024). The average width of small, non-conditioned maize kernels was 6.4 mm, with a standard

deviation of 0.71 mm. In adjusting the sieve cleaning system more accurately, the measurement of kernels must include various characteristics (Table 2). The proper calibration will significantly improve the grains' separation efficiency with reduced yield losses (Demir and Çolak, 2023; Dong *et al.*, 2024).

According to observations, the cob length revealed the primary dimensional variations. For cob length, the coefficient of variation was significantly high, whereas the other measured traits (diameter, grain density, and husk thickness) remained relatively stable, with variation coefficients ranging from 9.1% to 11%. This structural stability was of prime importance for justifying the selection of the middle section of the cob during seed preparation (Ma *et al.*, 2020; Li *et al.*, 2023; Hasanov *et al.*, 2024).

The dimensional deviation of kernels taken from the middle section of the cob relative to the central point reached a record of 0.95 mm at the upper end and 0.43 mm at the lower end. This difference can be due to the steady variation in kernel shape along the cob length—from cylindrical at the base to conical toward the tip. In the middle section, kernel width and thickness exhibited the highest homogeneity, which minimized the errors in succeeding cleaning and grading processes (Fang *et al.*, 2024; Tang *et al.*, 2024; Wang *et al.*, 2024). The analysis of the width of small and non-conditioned maize kernels showed a mean value of 6.4 mm and a standard deviation of 0.71 mm (Table 2). The coefficient of variation (CV) was approximately 11.1%, which occurred consistently with the typical variability reported

for maize kernel dimensions. The 95% confidence interval for the normal distribution ($\mu \pm 1.96\sigma$) spans the range of 4.99–7.81 mm (Ma *et al.*, 2020; Li *et al.*, 2023; Wang *et al.*, 2024).

These statistical parameters can be directly applicable for precise calibration of the sieve cleaning system: the retention of the main seed portion requires the selection of the sieve aperture diameter within the range of 7.0–7.5 mm. Installation of an additional sieve with apertures of 4.8–5.2 mm was also advisable for the separation of small and smashed kernels. Such calibration can project to achieve 92%–96% competence in the removal of non-conditioned kernels while keeping losses of viable seed below 3% (Demir and Çolak, 2023; Dong *et al.*, 2024; Kassa *et al.*, 2025). Based on maize kernel size, the statistical approach considerably enhanced the precision of the sieve cleaning system, reduced postharvest losses, and improved the overall quality of seeds planned for sowing (Baributsa *et al.*, 2020; Hasanov *et al.*, 2024; Dong *et al.*, 2024).

RESULTS AND DISCUSSION

In this presented research, the morphological structure of the maize (*Z. mays* L.) plant and the positional characteristics of its cobs received in-depth studies. A mature maize plant has a leafy stem 1.5–4 m in length and characteristically produces 1–3 cobs. The kernels show arranged rows on the cob surface, decisively attached to the core, and covered by several layers of husks. This cob and grain structure plays an important role in the mechanical harvesting and subsequent processing of maize grains (Demir and Çolak, 2023; Mammadov *et al.*, 2025).

The cob placement's height above the soil surface varies depending on the different genotypes. In short-statured maize cultivars, cobs sit 25–45 cm above the ground, while in taller genotypes, the cobs' height reaches up to 60 cm (Table 1). However, when cob height is below 30 cm, mechanical harvesting becomes considerably more difficult, leading to increased cob losses and higher technical losses of grains. Therefore, for grain maize production under mechanical harvesting, early-maturing and

lodging-resistant cultivars with optimal cob height proved most suitable (Dong *et al.*, 2024; Salimov and Huseynov, 2025; Salimov *et al.*, 2025).

Maize grain harvesting can employ two main methods: a) harvesting whole cobs followed by subsequent kernel separation; and b) direct combine harvesting with simultaneous separation of kernels from the cobs. For stringent quality requirements applied during mechanical harvesting, the harvested mass must contain at least 95% cleaned cobs, with an overall cob cleanliness reaching 99%, while in hybrid seed production fields, the proportion of broken cobs must not exceed 5%. Achieving these markers primarily depends on the dimensional characteristics of maize cobs and the distribution of kernel size according to cob sections (Tables 1 and 2).

The primary dimensional variations among the maize cobs were evident in the cob length parameter (Table 1). Other measured characteristics (diameter, kernel density, and husk thickness) were relatively stable, with coefficients of variation ranging from 9.1% to 11%. This structural stability provides an accurate basis for using the middle section of the cob in seed preparation. The analysis further revealed that relative to the middle section, the deviation in kernel width was 0.95 mm at the upper end and 0.43 mm at the lower end (Table 2). The average width of small and non-conditioned kernels was 6.4 mm, with a standard deviation of 0.71 mm. This also ensured the highest homogeneity of kernel width and thickness along the cob, thereby minimizing errors in subsequent cleaning and grading processes (Demir and Çolak, 2023; Shukurova *et al.*, 2026; Najafov *et al.*, 2026).

The maize kernels' physical and mechanical properties also play a key role in designing the harvesting machines and equipment used for mechanical kernel separation from the cobs. According to obtained results, the following six principal characteristics succeeded in their determination, i.e., critical (terminal) velocity (9.8–17 m/s), specific gravity (1.3–1.4 g/cm³), bulk density (0.6–0.82 t/m³), thousand-kernel weight (286 g), internal

friction coefficient (0.53), and external friction coefficient on steel surface (0.37).

These important parameters sustained direct uses in the hydraulic and aerodynamic calculations of separators, fan-type cleaners, and sieve systems. For example, terminal velocity and bulk density determine the required airflow intensity of the fan, while friction coefficients define the trajectory of cobs' and kernels' movement. The joint analysis of the dimensional data in Tables 1 and 2 with these physical properties enunciates that considering both kernel size and physical-mechanical characteristics can substantially enhance the efficiency of harvesting and cleaning processes (Dong *et al.*, 2024; Kuliyeve *et al.*, 2026; Mammadov *et al.*, 2026a).

In conclusion, the close interrelationship among the morphological and dimensional parameters of maize cobs, the statistical distribution of kernels, and the physical-mechanical properties of the kernels provide a systematic base for optimizing mechanical harvesting technology. Consequently, it minimizes postharvest losses and improves seed quality for further sowing (Demir and Çolak, 2023; Dong *et al.*, 2024).

The results revealed the principal parameters of maize cobs and kernels, the specific features of harvesting technology, and the primary role of effective approaches for minimizing grain yield losses. These results hold considerable practical significance for the optimization of mechanical harvesting, cleaning, and drying processes (Kassa *et al.*, 2025; Mammadov *et al.*, 2026b; Sadigov *et al.*, 2026a).

Overall, the following conclusions can be drawn:

- In maize genotypes, when cob height is below 30 cm, mechanical harvesting becomes significantly more difficult and results in increased grain yield losses;
- Cob length varied between 145 and 247 mm, while the coefficient of variation for the other dimensional characteristics remains within the range of 9.0%–11.0%;
- Kernel size differed according to the section of the cob—the largest kernels appeared in the middle section, while the smallest grains occurred in the upper section; and

- The high-moisture maize grains require staged drying combined with an intermediate storage period of 3–5 days to ensure uniform moisture distribution throughout the entire mass.

CONCLUSIONS

Owing to maize (*Z. mays* L.) large size and dense husk, the kernels release moisture slowly during drying. Therefore, a single drying cycle is often insufficient. In achieving the standard moisture content (13%–14%), spreading the kernels out is a must, holding them for 3–5 days after the first drying cycle. This tempering period allows moisture to equalize throughout the entire mass and within each individual kernel. However, after repeated moisture verification, the grains can proceed into storage. Constant monitoring of the moist kernels' temperature is also essential. At 30 °C, the kernel respiration strengthened without any visible external variations. However, as and when the temperature reaches 38 °C, the fermentation begins, a characteristic fermented odor appears, and fungal infection occurs.

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