

Aspects of Yield, Productivity and Corn Seeds Parameters in the Context of Mineral Fertilization

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Abstract. The applied research, under farm conditions, evaluated the yield, productivity and some seeds parameters in two corn hybrids in relation to mineral fertilization. The study was conducted over three agricultural years (2022 – 2024) in the area of ATU Racovița, Timis County, Romania. Pioneer 9911 and KWS Kashmir corn hybrids were cultivated. Fertilization was done with complex fertilizers (20/20/0) at a dose of 150 kg/ha and CAN (27% N a.c. – active substance) at a dose of 300 kg/ha. The mean yield value for the Pioneer 9911 hybrid was $\bar{Y}_{(P)} = 8106.70$ kg/ha, and for the KWS Kashmir hybrid it was $\bar{Y}_{(KWS)} = 7650.00$ kg/ha. In 2023, both hybrids provided yields with positive differences ($p < 0.05$, *), and in 2024 they provided yields with negative differences ($p < 0.01$, oo) compared to the means values. The mean yield value at the experiment level was $\bar{Y}_{(Exp)} = 7878.30$ kg/ha. Compared to the experiment mean, the Pioneer 9911 hybrid generated higher yield values in 2022 ($p < 0.01$, **) and in 2023 ($p < 0.001$, ***), and the KWS Kashmir hybrid generated higher yield values in 2023 ($p < 0.05$, *). In 2024, for both hybrids, the yield was below to the mean value, with statistically significant differences ($p < 0.001$, ooo). The variation of broken grains (BG, %) in relation to foreign bodies (FB, %) was described by a polynomial equation of degree 2, under conditions of $R^2 = 0.981$, $p = 0.0026$. The Partial Factor Productivity (PFP) index in relation to nitrogen provided by mineral fertilization recorded values between $PFP = 80.991 \pm 6.694$ for the Pioneer 9911 hybrid (year 2023), and $PFP = 57.658 \pm 5.674$ for the KWS Kashmir hybrid (year 2024).

Keywords: corn hybrids, mineral fertilizers, models, nitrogen, PFP

INTRODUCTION

The appropriate application of fertilizers, in terms of the type of fertilizer, the applied rate, the split applications of simple fertilizers, associated or not with complex fertilizers, have been the subject of recent studies to optimize corn yield (Ojeniyi et al., 2024).

The influence of variable rate fertilization on corn crops was studied in order to optimize the technology for certain deficient climatic conditions (Wang et al., 2023). Variable fertilizer rates have been studied in relation to agronomic parameters, physiological indices and yield in maize, with the aim of agronomic efficiency of crops, sustainable soil use and environmental protection (Zou et al., 2024). The influence of organic and mineral fertilizer resources, in variable doses, has been analyzed in relation to soil and yield and quality elements in corn crop (Mhoro et al., 2025).

Managing fertilizers and nutrients in a site-specific manner is important for sustainable soil use and yield optimization (Ojeniyi et al., 2024). The use of appropriate nitrogen fertilizers, and their rational application in relation to specific crop conditions, is important for optimal crop yields (Boldea and Sala, 2010; Wang et al., 2025). Testing different fertilizer combinations was useful to find out the fertilization variant that ensured the optimal yield in relation to the maize genotype, environmental conditions and crop technology (Wang et al., 2025).

Under certain conditions, low fertilization rates over a long period of time have led to soil nutrient depletion and stagnant corn crop yields (Pasley et al., 2019). Under experimental conditions, high nitrogen rates led to negative effects in the soil-plant balance for certain mineral elements (Pasley et al., 2019). The use of nitrogen in high doses, in unilateral fertilizations, inadequate in relation to soil conditions, has led to low nitrogen efficiency, a fact reported in various studies (Quan et al., 2020). The application of nitrogen fertilizers at increasing rates has contributed to sustaining grain yields, but associated with reduced nitrogen use efficiency has increased the negative impact on soil, groundwater and the environment in general (Quan et al., 2021). Adequate nutrient management through fertilization, based on field studies, on different fertilizer utilization efficiency indices, associated with economic efficiency indices, has become increasingly necessary (Quan et al., 2021). Different productivity and economic efficiency indices in maize cultivation have been studied in relation to fertilization, yield and sustainability of farmers (Adzawla et al., 2024).

Reduced nitrogen and phosphorus efficiency was recorded associated with increased fertilization rates in maize crops under semi-arid growing conditions (Wang et al., 2023). The variable rate of increase in corn yields, sometimes only marginal, has been recorded in relation to considerable increases in fertilization rates (Adzawla et al., 2024). Long-term studies have reported variations in the economically optimal nitrogen fertilization rate

for corn, associated with grain yield and nitrogen losses, under U.S. crop conditions (Baum et al., 2025). The study authors considered that better methods of evaluating and estimating nitrogen rates are needed in order to sustain yields and to reduce nitrogen losses (Baum et al., 2025).

Differentiated relationships of direct influence and interaction of experimental factors (e.g. genotype, fertilizers) were recorded in corn crop for yield and quality indices, which showed the importance of field experiments for optimizing technological interventions (Sihombing et al., 2021; Agapie and Sala, 2022).

Nitrogen use efficiency in relation to timing and variable nitrogen application rates was analyzed in corn crop (Gheith et al., 2022). The authors of the study recorded the positive variation of some morphological parameters of corn plants in relation to the increase in the nitrogen rate, as well as the variation of some parameters in relation to the timing of nitrogen application. The interdependent analysis of the experimental factors facilitated the formulation of corn fertilization recipes for the study conditions.

Variable rates of nitrogen use efficiency have been reported for agricultural crops, in relation to biological, environmental and technological factors that have characterized different growing conditions (Govindasamy et al., 2023). Increasing the efficiency of nitrogen use in agricultural crops is a permanent concern, of high interest from an agricultural, ecological and economic perspective (Govindasamy et al., 2023).

Nitrogen is a mineral element, with an important role in plant nutrition, an element that has a major contribution in the formation of agricultural yields (Rawal et al., 2024). The use of nitrogen at variable rates has been studied in corn in relation to yield, economic efficiency and other indicators of ecological interest (Rawal et al., 2024). Balancing fertilizer doses, especially nitrogen, in relation to soil conditions (e.g. texture, nutrient retention capacity), rainfall regime, relief conditions and other environmental factors that influence fertilizer utilization, is important for crop yield and soil health (Abrol et al., 2024). The sustainability of agricultural land has been recorded in relation to fertilizer use in different categories of agricultural holdings, with implications for potential crop yields (Mhoro et al., 2025).

This study comparatively analyzed two corn hybrids (Pioneer 9911, KWS Kashmir) over three agricultural years, 2022 - 2024, in terms of yield, partial productivity of factors, in relation to nitrogen, and some seed quality parameters in relation to mineral fertilization.

MATERIAL AND METHODS

The study was conducted on corn crops, located in the agricultural area of ATU Racovița, Timis County, Romania, figure 1. The aim of the study was to evaluate the yield, grain quality indices, and productivity in relation to the amount of nitrogen applied through fertilization to two corn hybrids under the study conditions. The corn hybrids were cultivated over three agricultural years, from 2022 to 2024. The agricultural area is located in the Timis Plain, with Aluviosol soils. The climatic conditions during the study period are presented in figure 2.

Pioneer 9911 and KWS Kashmir corn hybrids were cultivated. The area cultivated with the Pioneer 9911 hybrid was 4.2 ha (year 2022), 5.12 ha (year 2023) and 4.8 ha (year 2024). The area cultivated with the KWS Kashmir hybrid was 3.4 ha (year 2022), 3.85 ha (year 2023) and 5.12 ha (year 2024). Within each plot and corn hybrid there were observation modules.



Figure 1. Agricultural area for experimental corn crop, ATU Racovița, Timis County, Romania

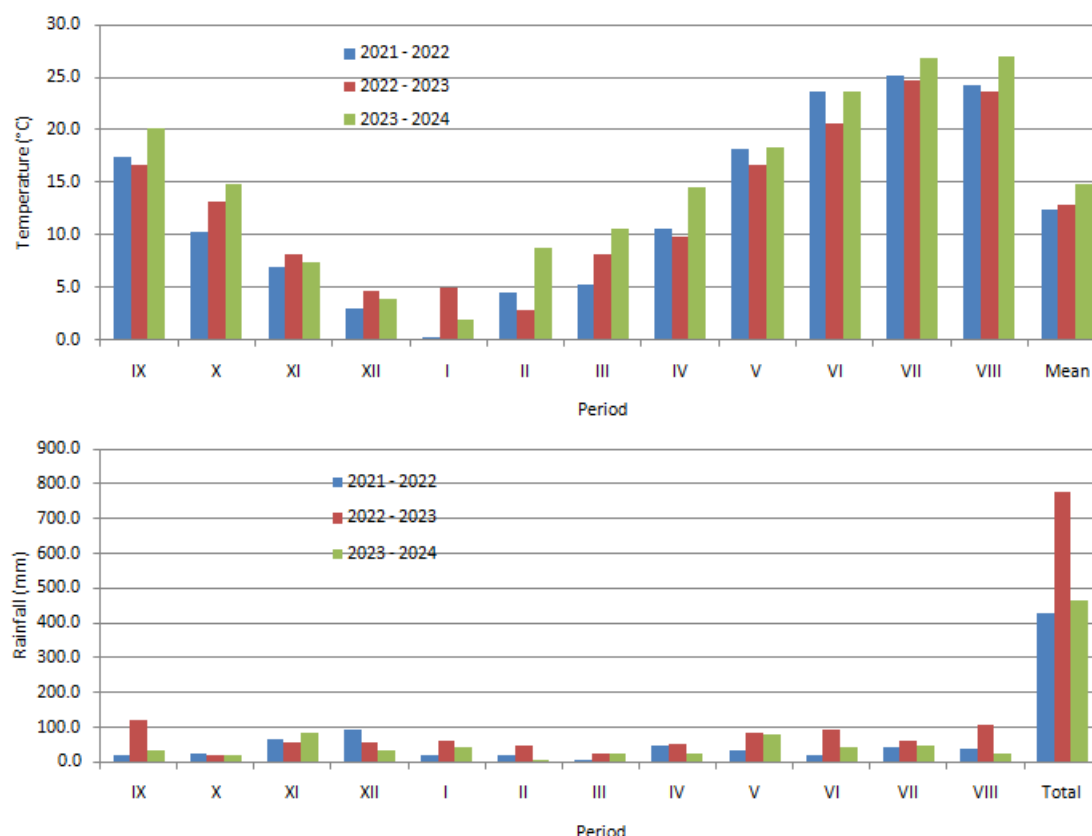


Figure 2. Climatic conditions during the study period

The agricultural land was prepared by plowing and subsequent soil preparation works for sowing. Complex fertilization (20/20/0) was applied at a dose of 150 kg/ha, and CAN at a dose of 300 kg/ha (27% N active substance, a.s.). Sowing was done at the optimal time, the first decade of April. The sowing density was for 68,000 plants/ha.

At harvest maturity, 99 BBCH code (Meier, 2001) production was harvested mechanized with a combine. The yield (Y, kg/ha) was determined for each hybrid. From grain samples, determinations were made regarding the marketable quality of the grain production, namely moisture (Moist, %), Foreign bodies (FB, %), and Broken grains (BG, %). The determination of corn seed quality indices was done with the Granomat Plus device. The Partial Factor Productivity (PFP) index (Dobermann, 2005; Fixen et al., 2015) was calculated for each hybrid and crop year, during the study period, in relation to the nitrogen provided by fertilization.

The general analysis of the data regarding the presence of variance and data reliability was done by ANOVA Test. The yield of maize hybrids and experimental years was analyzed comparatively by t-Test. Cluster analysis was used to obtain the grouping of hybrids in the experimental years based on similarity in relation to yield and seed quality parameters. Regression analysis was applied to describe the variation of some seed quality indices.

The calculation module in EXCEL and the PAST software (Hammer et al., 2001) were used for calculations and to generate diagrams and graphs.

RESULTS AND DISCUSSIONS

The cultivated corn hybrids (Pioneer 9911, KWS Kashmir) generated different results during the study period, with higher values in 2023 and lower in 2024.

The data recorded for yield (Y, kg/ha) and seed quality parameters, important for the commercial market of corn production (Moist, FB, BG), are presented in Table 1. According to the ANOVA Test (Alpha = 0.001), the experimental data presented statistical reliability, and the presence of variance was confirmed in the data set, Table 2.

The comparative analysis was performed for yield values during the study period, both within each hybrid and at the experiment level.

Table 1. Yield values and some seed quality indices for corn hybrids during the study period (2022 - 2024)

Corn hybrid	Year	Yield (Y, kg/ha)	Moisture (Moist, %)	Foreign bodies (FB, %)	Broken grains (BG, %)
Pioneer 9911	2022	8700	14.7	1.6	2.0
	2023	8990	15.1	1.8	1.8
	2024	6630	13.9	1.4	2.0
	SE ($\pm$)	± 743.06	± 0.35	± 0.12	± 0.07
KWS Kashmir	2022	8140	15.1	1.5	2.0
	2023	8410	14.9	1.7	1.9
	2024	6400	13.8	1.5	2.0
	SE ($\pm$)	± 629.84	± 0.40	± 0.07	± 0.03

Table 2. ANOVA Test results

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.37E+08	3	2.79E+08	1052.511	6.78E-57	6.076
Within Groups	18017656	68	264965.50			
Total	8.55E+08	71				

In the case of the Pioneer 9911 hybrid, the mean value calculated over the three experimental years was $\bar{Y}_{(P)} = 8106.70$ kg/ha. Compared to the mean value calculated ($\bar{Y}_{(P)}$), a positive difference was recorded in 2023, at the $p < 0.05$ level (*), and a negative difference in 2024 at the $p < 0.01$ level (oo), table 3.

In the case of the KWS Kashmir hybrid, the mean value calculated over the study period was $\bar{Y}_{(KWS)} = 7650.00$ kg/ha. Compared to the calculated mean value ($\bar{Y}_{(KWS)}$), a positive difference was recorded in 2023, at the $p < 0.05$ level (*) and a negative difference in 2024, at the $p < 0.01$ level (oo), table 3.

The calculated mean values for each hybrid, the differences and the values of the statistical safety parameters are presented in table 3, and in figure 3 respectively.

Table 3. Yield differences and values of statistical safety parameters by hybrid groups during the study period (2022 – 2024)

Statistical parameters	Pioneer 9911			KWS Kashmir		
	2022	2023	2024	2022	2023	2024
Given mean:	8700.00	8990.00	6630.00	8140.00	8410.00	6400.00
Sample mean: (hybrid)	8106.70	8106.70	8106.70	7650.00	7650.00	7650.00
95% conf. interval:	(7249.9 8963.4)	(7249.9 8963.4)	(7249.9 8963.4)	(6923.8 8376.2)	(6923.8 8376.2)	(6923.8 8376.2)
Difference:	593.33	883.33	-1476.70	490.00	760.00	-1250.00
95% conf. interval:	(-263.41 1450.1)	(26.588 1740.1)	(619.92 2333.4)	(-236.2 1216.2)	(33.8 1486.2)	(523.8 1976.2)
t :	-1.5970	-2.3775	3.9745	-1.5559	-2.4133	3.9693
p (same mean):	0.1489	0.0447	0.0041	0.1583	0.0423	0.0041
Singnificance of differences	ns	*	oo	ns	*	oo

The Pioneer 9911 hybrid generated higher yields compared to the KWS Kashmir hybrid under the study conditions. The mean value of the Pioneer 9911 hybrid was higher compared to the mean value of the KWS Kashmir hybrid, figure 3.

Also, under the conditions of each experimental year, the yield of the Pioneer 9911 hybrid was higher compared to the yield of the KWS Kashmir hybrid, figure 3.

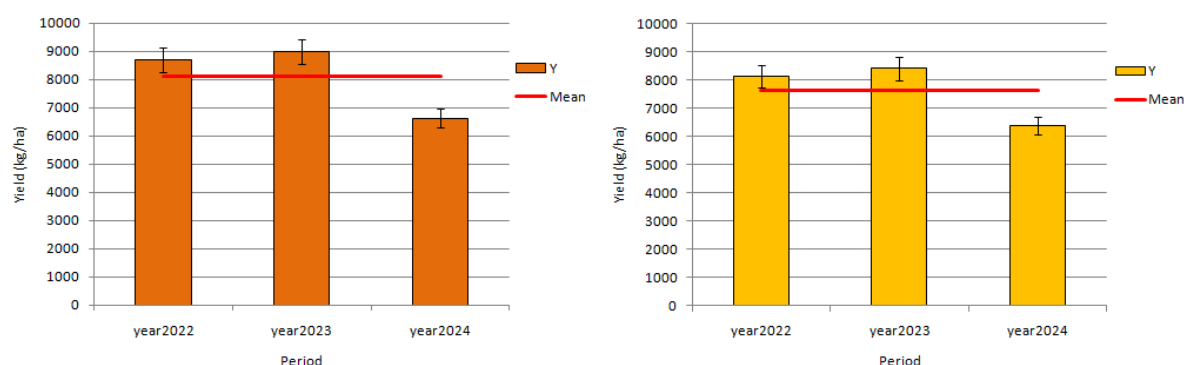


Figure 3. Graphical representation of annual yield values compared to the mean for each corn hybrid (left: Pioneer 9911 hybrid; right: KWS Kashmir hybrid)

The comparative analysis of the yield values for each hybrid and crop year, during the study period, was made in comparison with the mean value calculated at the experiment level ($\bar{Y}_{(Exp)}$). The analysis led to the results presented in table 4 and figure 4. The mean yield value at the experiment level was $\bar{Y}_{(Exp)} = 7878.30$ kg/ha (Table 4).

Compared to the calculated mean value ($\bar{Y}_{(Exp)}$), in the case of the Pioneer 9911 hybrid, a positive difference was recorded in 2022, at the $p < 0.01$ level (**), and in 2023 at the $p < 0.001$ level (***). In 2024, a negative difference was recorded, at the $p < 0.001$ level (ooo).

In the case of the KWS Kashmir hybrid, a positive difference was recorded in 2023 at the $p < 0.01$ level (*) and a negative difference in 2024 at the $p < 0.001$ level (ooo). In 2022, the difference in yield compared to the mean value calculated at the experiment level ($\bar{Y}_{(Exp)}$) did not present statistical certainty (Table 4).

Table 4. Yield differences in corn hybrids and statistical safety parameter values during the study period (2022 – 2024)

Statistical parameters	Pioneer 9911			KWS Kashmir		
	2022	2023	2024	2022	2023	2024
Given mean:	8700.00	8990.00	6630.00	8140.00	8410.00	6400.00
Sample mean: (Experiment	7878.30	7878.30	7878.30	7878.30	7878.30	7878.30
95% conf. interval:	(7366.4 8390.3)	(7366.4 8390.3)	(7366.4 8390.3)	(7366.4 8390.3)	(7366.4 8390.3)	(7366.4 8390.3)
Difference:	821.67	1111.70	-1248.30	261.67	531.67	-1478.30
95% conf. interval:	(309.71 1333.6)	(599.71 1623.6)	(736.38 1760.3)	(-250.29 773.62)	(19.711 1043.6)	(966.38 1990.3)
t :	-3.3862	-4.5813	5.1445	-1.0784	-2.1910	6.0923
p (same mean):	0.0035	0.0003	8.11E-05	0.2959	0.0427	1.20E-05
Singnificance of differences	**	***	ooo	ns	*	ooo

Cluster analysis facilitated the grouping of corn hybrids, associated with the crop year, in relation to the yield and grain quality indices (Coph.corr. = 0.949), figure 5. Two clusters resulted, with three subclusters, each with two elements, given by hybrid and crop year.

Based on similarity in relation to the elements considered in the analysis, a cluster included the hybrid P9911 year 2024 and the hybrid KWS Kashmir year 2024, with the lowest results for yield. A subcluster included the hybrids KWS Kashmir, crop years 2022 and 2023.

In the central position of the dendrogram, the hybrids P 9911 years 2022 and 2023 were positioned within a subcluster.

High level of similarity was recorded between P2024 and KWS 2024 (Pioneer 9911, year 2024; KWS Kashmir, year 2024), at SDI level = 230, table 5 (SDI – Similarity and Distance Indices).

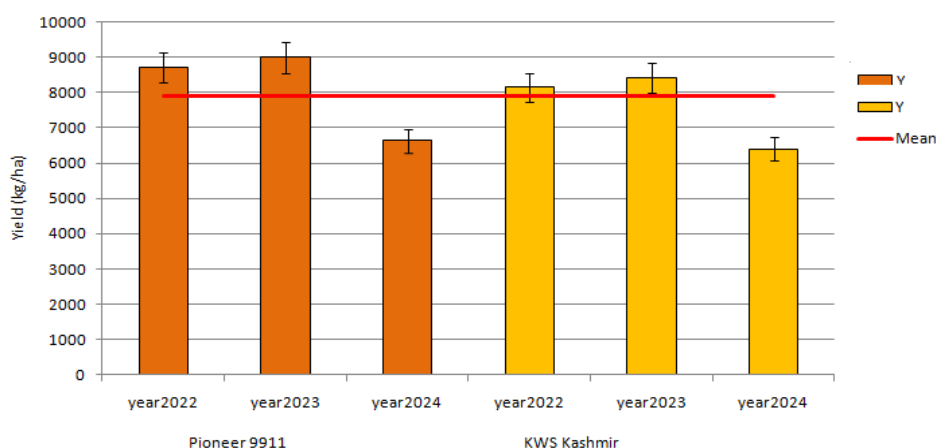


Figure 4. Graphical representation of yield values for corn hybrids in relation to the mean value at the experiment level during the study period

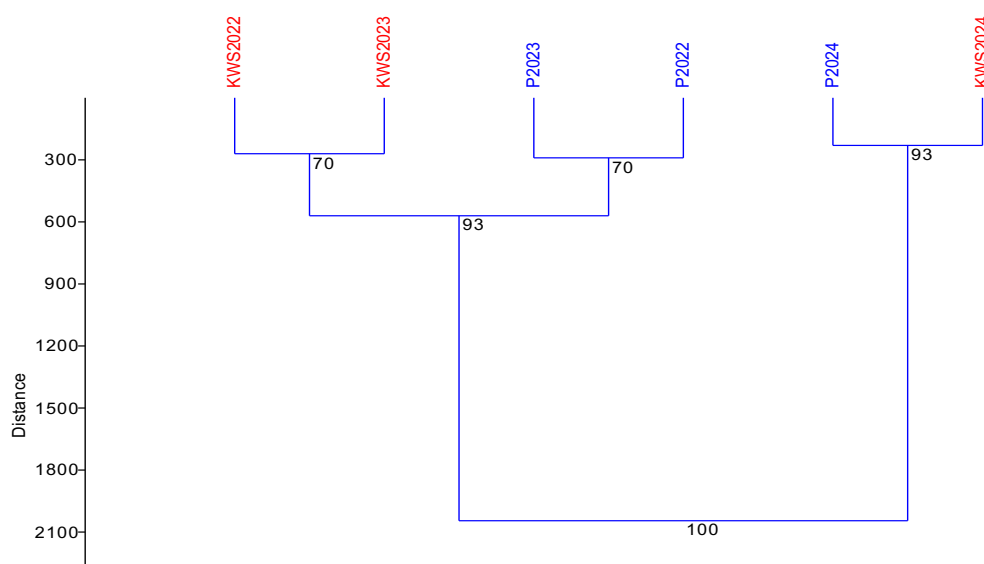


Figure 5. Cluster dendrogram of grouping corn hybrids by crop year

Table 5. SDI values for corn hybrids and crop year

	P2022	P2023	P2024	KWS2022	KWS2023	KWS2024
P2022		290	2070	560	290	2300
P2023	290		2360	850	580	2590
P2024	2070	2360		1510	1780	230
KWS2022	560	850	1510		270	1740
KWS2023	290	580	1780	270		2010
KWS2024	2300	2590	230	1740	2010	

Regarding the parameters foreign bodies (FB) and broken grains (BG), an interdependence relationship described by equation (1) was found, which described the variation of BG in relation to FB under conditions of $R^2 = 0.981$, $F = 77.25$, $p=0.0026$, with the graphical distribution in figure 6. The results obtained suggest that the two parameters can be improved simultaneously, so that the market quality of the production increases.

$$BG = -2.083x^2 + 6.175x - 2.567 \quad (1)$$

where: x – foreign bodies (FB, %)

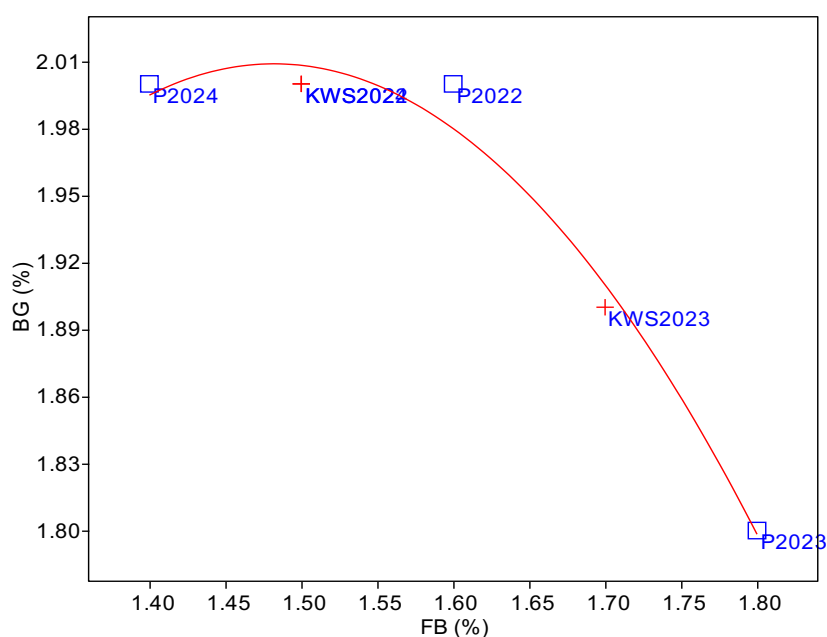


Figure 6. Graphical distribution of BG values in relation to FB values in corn grain samples, by hybrids and years of study

The efficiency of nitrogen (N) use provided by mineral fertilization by each corn hybrid in each crop year was evaluated. For this, the Partial Factor Productivity (PFP) index was calculated, relation (2) (Dobermann, 2005; Fixen et al., 2015). The results recorded, at the level of nitrogen applied by the two types of mineral fertilizers applied, in relation to each hybrid and crop year, are presented in Table 6. From the analysis of the results, the highest value was recorded for the Pioneer 9911 hybrid in 2023, $PFP = 80.991 \pm 6.694$.

$$PFP = Y/F \quad (2)$$

where: PFP – Partial Factor Productivity;
Y – yield (kg/ha);
F – nitrogen dose from fertilizers (N kg/ha a.s.)

Table 6. PFP index values in corn hybrids during the study period

Corn hybrid	Year	PFP
Pioneer 9911	2022	78.378
	2023	80.991
	2024	59.730
	SE (±)	±6.694
KWS Kashmir	2022	73.333
	2023	75.766
	2024	57.658
	SE (±)	±5.674

The ranking analysis generated a hierarchy of corn hybrids by crop year, based on the values of the elements considered in the study. The ranking diagram in Figure 7 resulted, and the distribution of hybrids in relation to the confidence interval is presented in Figure 8. The Pioneer 9911 hybrid in 2023 (P2023) was positioned in the top position, followed by the Pioneer 9911 hybrid in 2022 (P2022), and the KWS Kashmir hybrid in 2023 (KWS2023) was positioned in the third position.

The response of corn hybrids, in relation to genetic potential for yield, agronomic parameters and quality indices, was evaluated under different environmental and technological conditions, for the selection of hybrids with high adaptability for the crop area (Chen et al., 2022; Agapie et al., 2024; Ereimi et al., 2024; Vacariu et al., 2024; Zhang and Lu, 2024). Under the conditions of the present study, the Pioneer 9911 hybrid generated better yield values compared to the KWS Kashmir hybrid.

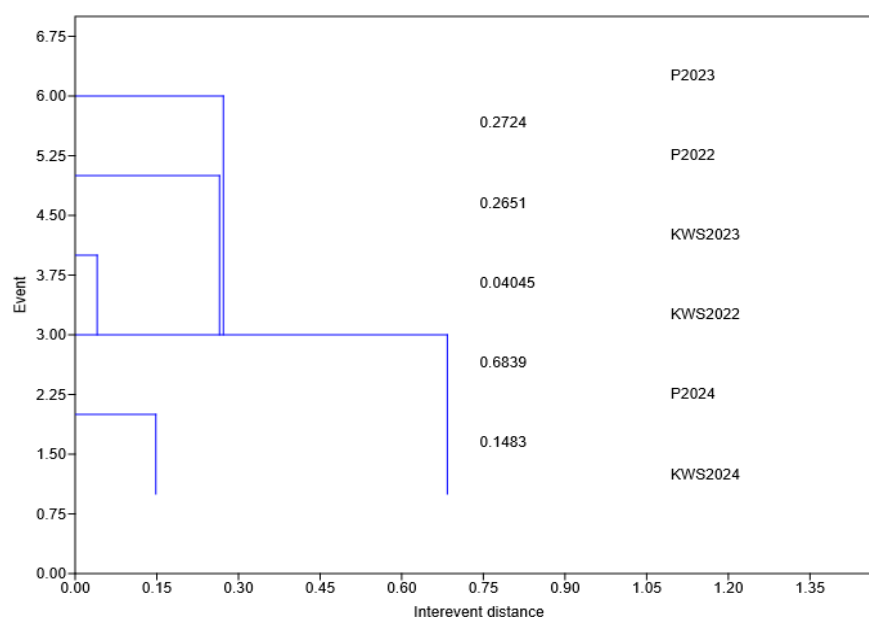


Figure 7. Ranking of corn hybrids by experimental years

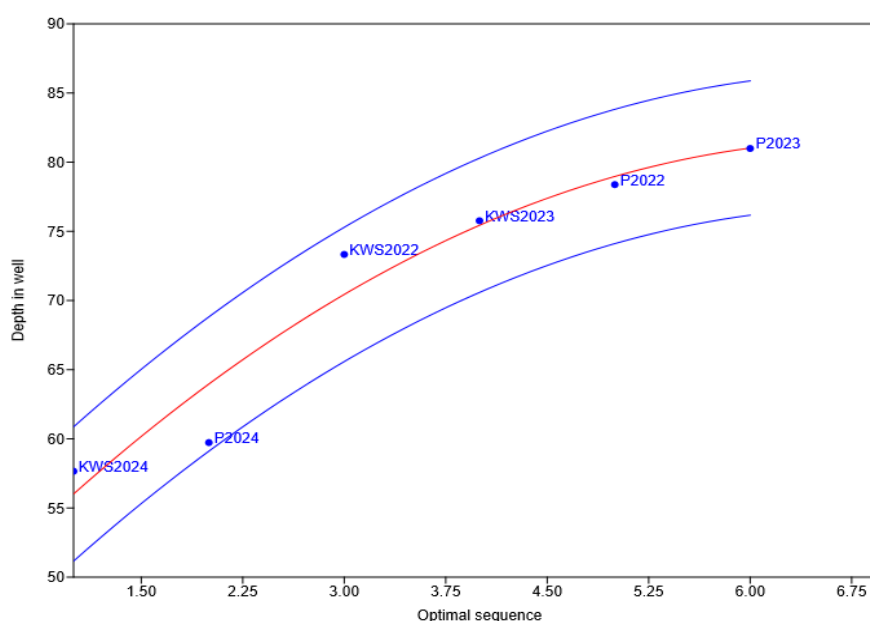


Figure 8. Distribution of hybrids by crop year, in the confidence interval

Variation and estimation models of agronomic parameters, physiological indices, yield and quality indices have been studied in different agricultural crops in order to provide information for agricultural practices and management decisions (Constantinescu et al., 2018; Bassu et al., 2021; Chang et al., 2023; Ge et al., 2025).

In the case of some seed quality parameters of the tested corn hybrids, the variation of broken grains (BG, %) in relation to foreign bodies (FB, %) was evaluated by regression analysis, and a polynomial equation of degree 2 resulted, under conditions of $R^2 = 0.981$, $p = 0.0026$.

The results obtained as a whole are useful for agricultural practice in the study area, by providing practical information regarding the results generated by each corn hybrid for yield and seed quality parameters, in relation to the fertilization level provided.

CONCLUSIONS

The Pioneer 9911 and KWS Khasmir corn hybrids behaved differently under the study conditions, by

generating specific yield values and seed quality parameters over the three agricultural years, 2022 - 2024. The Pioneer 9911 hybrid stood out compared to the KWS Kashmir hybrid, with higher yield values in each agricultural year. Within each hybrid, the year 2023 was more favorable, and each hybrid generated higher yield values compared to the other two years, 2022 and 2024 respectively. Compared to the mean at the experiment level ($\bar{Y}_{(Exp)} = 7878.30 \text{ kg/ha}$), the Pioneer 9911 hybrid in 2023 generated the best yield ($p < 0.001$, ***).

The variation of broken grains (BG, %) in relation to foreign bodies (FB, %) was described by a mathematical model under conditions of $R^2 = 0.981$, $F = 77.25$, $p = 0.0026$. The result suggested that the two parameters can be improved simultaneously, so that the market quality of the production increases.

Overall, the Pioneer 9911 hybrid made better use of the applied fertilizers compared to KWS Kashmir, and with regard to nitrogen utilization, the Partial Factor Productivity index recorded the highest level for the Pioneer hybrid in 2023, PFP = 80.991 ± 6.694 .

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