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EVALUATION OF QUANTITATIVE AND QUALITATIVE INDICATORS IN MAIZE HYBRIDS (*Zea mays* L.) CULTIVATED IN NORTH-EASTERN OF BULGARIA

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Abstract

Maize (Zea mays L.) is one of the most produced cereal crops on a global scale. The field experiment was held in the experimental of the selected area in region Razgrad (North-Eastern Bulgaria) during the period 2021-2023. The randomized complete block design with 4 replications and 25 m^2 plot size was applied with five maize hybrids - P9415 (FAO 360); P9889 (FAO 420); P9903 (FAO 420); KAPITOLIS (FAO 380) and INTELIGENS (FAO 420). The purpose of the study was to establish the productivity and quality of some maize hybrids, grown in North-Eastern Bulgarian region. The following characteristics were reported: grain yield; cob length; number of rows per cob; number of grains per row; mass of grain per cob; 1000 grains weight; test weight and crude protein. The analysis of the results showed that the highest grain yield was obtained from P9889 hybrid due to the higher values of yield structural elements, while the highest values of the crude protein were reported by the hybrid INTELIGENS. The values of the indicators 1000 grains weight and test weight were highest by the hybrid KAPITOLIS (313 g and 74.2 kg, respectively).

Key words*: maize, hybrids, grain yield, quality, protein.*

INTRODUCTION

Maize (*Zea mays* L.) is one of the main food and technical crops in the world's grain production. It is used for a great number of purposes – gran, fodder, technical, etc. The biological potential of the crop is determined by hybrid, specific meteorological conditions during the respective economic year and the technology of growing the plants (Ali et al., 2020; Dimitrova et al., 2013; Kirchev, 2016; Komitov et al., 2022; Kuneva et al., 2015; Manilov and Manhart, 2024; Kirchev, 2016; Yankov et al., 2014; Yan et al., 2021). The hybrid with its specific genetic potential is the most dynamic factor in production (Horablaga et al., 2023; Hussain et al., 2011; Katsenios et al., 2021; Mosisa et al., 2023). Seed producers use breeding to develop hybrids that are more tolerant to climate changes and can withstand such high temperatures and droughts (Duvick, 2005; Nagy, 2004; Șuteu et al., 2013). The growing of high-quality hybrids not only improves the grain yield and its quality but also increases the income per hectare (Dimitrova et al., 2021; Gul et al., 2020; Yousif et al., 2001; Shahini et al., 2023).

Even though there was a tendency to select the high-yield hybrids, the need for overall stability and dependability favors the selection of hybrids with stress tolerance. The main focus of the new hybrids now is to aim for a high and stable yield in both favorable and unfavorable growing conditions (Duvick, 2005; Katsenios et al., 2021).

The agroecological and climatic conditions in the separate regions of the country influence the development and productivity of maize (Delibaltova et al., 2019; Ruswandi et al., 2021; Stoyanov and Kuneva, 2024).

The right choice of hybrids and the proper regional distribution, as well as their growing by strictly following the agrotechnical practices, are of vital importance for the yield amounts and the quality of the produce obtained (Dallev and Ivanov, 2015; Delibaltova, 2018; Dimitrova et al., 2019; Mandić et al., 2020; Mitkov et al., 2018; Yanev, 2023; Zivkov and Matev, 2005). That necessitates the constant introduction of new maize hybrids that are the most suitable and efficient for the separate microregions of the country.

The aim of the investigation was to establish the productivity and quality of five maize

hybrids for grain, grown in the North-Eastern Bulgarian region.

MATERIALS AND METHODS

The field experiment was held in the experimental of the selected area in region Razgrad (North-Eastern Bulgaria) during the period 2021-2023. The randomized complete block design with 4 replications and 25 m^2 plot size was applied, after previous crop winter wheat. Five maize hybrids - P9415 (FAO 360); P9889 (FAO 420); P9903 (FAO 420); KAPITOLIS (FAO 380) and INTELIGENS (FAO 420) were included in the study. The experiment was carried out following the adopted cultivation technology under non-irrigated conditions. Soil cultivation included ploughing in of the stubble in August and plowing at a depth of 28-30 cm in October, pre-sowing cultivation with harrowing was performed twice in March and April. Fertilization was performed in autumn before deep ploughing, with 80 kg/ha active substance phosphorus and 10 kg/ha active substance potassium and before sowing with 180 kg/ha active substance nitrogen. The sowing was performed in the third decade of April at the spacing between the rows of 70 cm and a seed rate of 65000 germinating seeds per ha at a depth of 6-8 cm. Weed control was achieved by treatment with the herbicide Principal plus - 440 g/ha (920 g/ha nicosulfuron, 5500 g/ha dicamba, 230 g/ha rimsulfuron) applied during the maize vegetation (after formation of 3-5 leaves). During the vegetation the inter rows were cultivated twice. All the steps of the adopted maize cultivation technology were respected.

The following characteristics were reported: cob length; number of rows per cob; number of grains per row; mass of grain per cob; grain yield; test weight; 1000 grains weight and crude protein.

The experimental data were processed by the method of dispersion and correlation analyses and the differences between the variants were determined by means of the Dunkan's Multiple Range Test.

The climatic conditions determining maize growth, development and productivity were temperatures and precipitation, their combination and distribution during the vegetative period. The analysis of these factors showed that the values of the average monthly temperatures during the years of study did not differ significantly from those of the multi-year period and satisfied completely the requirements of the maize towards heat from the period of sowing to the period of ripening (Figure 1).

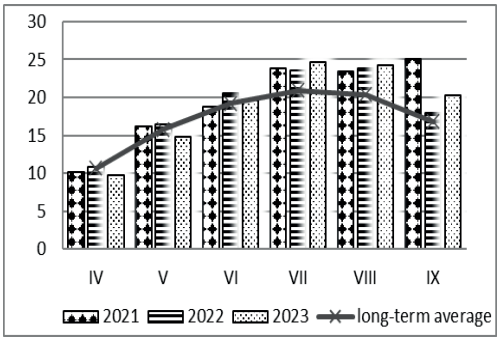

Figure 1. Average monthly air temperature, ^0C

Significant differences were observed in the quantity of precipitation during the individual agricultural years (Figure 2).

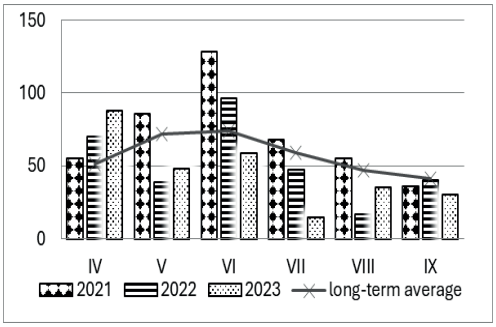

Figure 2. Precipitation, mm

In the first year of the experiment (2021), the amount of precipitation in the April-September period was 428 mm, which is with 84 mm more than the multiannual period (344.0 mm). The good moisture supply and the uniform distribution of rainfall from the beginning of the vegetation to the beginning of ripening had a beneficial effect on the growth and development of maize plants.

In 2023, the amount of rainfall during the vegetation was with 69 mm less than the multi-year period and with 153 mm less than in 2021.

The significant amount of precipitation in the period April - June (195 mm) was followed by a drought period. The lack of precipitation, combined with high temperatures, negatively affected the growth processes and productive capabilities of the maize plants.
The second year of the study the amount of precipitation during the of maize vegetation was 309 mm, which is 35 mm lower than the multiannual period. That determined the 2022 experimental year as less favorable for the productivity of maize compared to 2021.

RESULTS AND DISCUSSIONS

The impact of both factors - hybrid and year on the grain yield, as well as on the other qualitative components are presented in Table 1. Data showed that both by years and in average for the experimental period hybrid, P9889 surpassed in grain yield all the other hybrids included in the study. The higher grain yield of the hybrid was due to the higher values of its structural elements.
The highest grain yields were obtained in the favorable for maize 2021 year when the temperature values and the precipitation sum fully met the plant requirements for warmth and moisture throughout the whole vegetation period. The yields obtained reached up to 8760 kg/ha. The hybrid P9889 surpassed the hybrids P9903, INTELIGENS, KAPITOLIS and P9414 by 1.4%, 10.4%, 11.8% and 14.9%, respecttively, the differences being statistically significant.
In the 2022 experimental year the grain yields obtained varied from 6483 kg/ha to 7226 kg/ha, i.e. they were by 20.5% lower in average in comparison with the previous year. The differences between the studied hybrids were mathematically significant. The lowest yields were realized by hybrid P9415 - 6483 kg/ha.
In the third year of the study (2023) the meteorological conditions during the hybrid vegetation were extremely unfavourable and the plants were not able to attain their biological potential. The grain yields obtained were within the limits of 5225 to 5820 kg/ha. Statistically proven, the lowest ones were those of hybrid P9415 and the highest - of P9889. The results of the hybrids P9903 and INTELIGENS had quite close values and they were statistically insignificant.
Average for the period of examination of the tested hybrids the highest yield is obtained of P9889 - 7269 kg/ha he is superior to 2.3, 6.8 and 9.0% hybrids P9903, INTELIGENS and KAPITOLIS, and the lowest yield is realized to P9415 (6443 kg/ha). The dispersion analysis shows a strong statistically proven influence of both the tested hybrids and the years with their specific climatic conditions on indicator “grain yield”. An interaction between Hybrid and Year was proven.
Differences in the climatic conditions during the years of the experiment are one of the reasons for the formation of cobs with different length. In the first experimental year (2021), the cob length varied from 19.5 cm in hybrid P9415 to 21.4 cm in - P9889, while in 2023 the values of this indicator were significantly lower (on average by 38%) and ranged from 14.0 to 15.6 cm, and in 2022 - from 17.2 to 19.1 cm. On average for the study period, the cob length of hybrid P9889 was 18.7 cm and surpassed hybrids P9903 and INTELIGENS by 6.2%, KAPITOLIS by 8.7%, and P9415 by 10.6%.
The analysis of variance (Anova) shows the impact of the factors hybrid and year, together with their interaction, on cob length indicator and the results indicate a statistically significant influence of the examined factors and significant effect of their interaction.
Genetically controlling factor is the number of rows per cob but environmental conditions may also influence on this indicator. The more number of rows per cob results in more grain yield (Tahir et al., 2008). Maximum number of rows per cob was found in P9889
hybrid as well as by years and in average for the experimental period hybrid. The dispersion analysis about the effect of the factors Hybrid and Year, as well as their interaction, on the number of rows per cob, shows a significant influence of the factors on the changes of the characteristic and statistically insignificant effect of the interaction between them.
The studied hybrids differed significantly in the number of grains per row. The lowest values of that indicator were reported in 2023 when the climatic conditions were less favorable for the growth and development of maize compared to 2021 and 2022. Mathematical processing of data showed that the differences between all the studied hybrids were significant. Out of all

the investigated hybrids the smallest number of grains per the row, in average for the three years, was established in hybrid P9415 - 30.5 and it fell behind the hybrids INTELIGENS, KAPITOLIS and P9903 by 6.9, 8,8 and 11,1%, respectively, the biggest values being formed by hybrid P9889 (37.0).

Table1. Quantitative indices in maize hybrids

Variable		Grain Yield, kg/ha	Cob length cm	Number of rows per cob	Number of grains per row	Mass of grain per cob, g
Years	2021	8159 ^{a}	20.2 ^{a}	15.0 ^{a}	36.8 ^{a}	164.2 ^{a}
(A)	2022	6771 ^{b}	18.0 ^{b}	14.2 ^{b}	34.6 ^{b}	140.5 ^{b}
	2023	5643 ^{c}	14.6 ^{c}	13.4 ^{c}	28.9 ^{c}	94.3 ^{c}
Hybrid	P9415	6443	16.9	13.3	30.5	120.7
(B)	P9889	7269	18.7	15.3	37.0	144.2
	P9903	7103	17.6	14.3	33.9	137.6
	KAPITOLIS	6666	17.2	14.0	33.2	129.7
	INTELIGENS	6808	17.6	14.1	32.6	132.7
2021	P9415	7622 ^{e}	19.5 ^{c}	14.0 ^{c}	34.0 ^{d}	157.2 ^{d}
	P9889	8760 ^{a}	21.4 ^{a}	16.4 ^{a}	42.0 ^{a}	174.8 ^{a}
	P9903	8643 ^{b}	20.2 ^{b}	15.2 ^{b}	37.2 ^{b}	167.3 ^{b}
	KAPITOLIS	7837 ^{d}	19.7 ^{c}	14.3 ^{c}	35.2 ^{c}	160.7 ^{c}
	INTELIGENS	7934 ^{c}	20.1 ^{b}	15.0 ^{b}	35.6 ^{c}	161.0 ^{c}
2022	P9415	6483 ^{e}	17.2 ^{c}	13.4 ^{c}	30.0 ^{c}	120.7 ^{e}
	P9889	7226 ^{a}	19.1 ^{a}	15.0 ^{a}	38.0 ^{a}	160.0 ^{a}
	P9903	6895 ^{b}	18.0 ^{b}	14.4 ^{b}	36.0 ^{b}	149.5 ^{b}
	KAPITOLIS	6520 ^{d}	17.4 ^{c}	14.0 ^{bc}	35.0 ^{c}	132.3 ^{d}
	INTELIGENS	6732 ^{c}	18.4 ^{b}	14.1 ^{b}	34.0 ^{d}	140.0 ^{c}
2023	P9415	5225 ^{d}	14.0 ^{c}	12.6 ^{c}	27.5 ^{d}	84.3 ^{d}
	P9889	5820 ^{a}	15.6 ^{a}	14.0 ^{a}	31.0 ^{a}	97.8 ^{a}
	P9903	5770 ^{b}	14.7 ^{b}	13.4 ^{b}	28.4 ^{c}	96.0 ^{c}
	KAPITOLIS	5642 ^{c}	14.6 ^{b}	13.6 ^{b}	29.5 ^{b}	96.2 ^{c}
	INTELIGENS	5760 ^{b}	14.3 ^{bc}	13.2 ^{b}	28.3 ^{c}	97.0 ^{b}
Anova	A	**	**	*	**	**
	B	**	*	*	*	**
	AB	*	*	n.s	*	*

Means within columns followed by different lowercase letters are significantly different (P<0.05) according to the LSD test F-test significant at P<0.05; ** F-test significant at P<0.01; ns non-significant.

The results of the dispersion analysis about the effect of the factors Hybrid and Year, as well as their interaction, on the indicator “number of grains per row”, show a statistically significant effect of the studied factors and significant of their interaction.

An important indicator on which the yield of maize depends is the mass of grains per cob and the factors influencing the values of this characteristic are the technology of cultivation, the weather conditions, as well as the genetics of the hybrid (Ali et al., 2020; Devasree et al., 2020).

Differences in the climatic conditions during the years of the experiment are one of the reasons for the formation of grain with different mass. The largest mass of grains in a cob was observed in the firs year, because of the optimal weather conditions. With a value of 174.8 g hybrid P9889 distinguished significantly from the other hybrids. The differences among the studied hybrids were statistically significant. In the second year, mass of the grain per cob varied from 120.7 g by hybrid P9415 to 160.0 g by hybrid P9889 and the differences were proven. In line with the observations for the grain yield, the lowest values of mass of the grain per cob are reported in the third year, when the conditions were not so favourable and varied - from 83.4 for P9414 hybrid to 97.8 g - for P9889 hybrid. The values of P9903 were very closed to those of KAPITOLIS and the differences between both hybrids were unproven.

On average for the study period, P9889 hybrid was realized the mass of grains per cob of 144.2 g and surpassed hybrids P9903, INTELIGENS, KAPITOLIS and P9415 by 4.8,

8.7, 11.2 and 19.5%, respectively. The analysis of variance (ANOVA) shows a strong statistically proven influence on both the tested Hybrids (B) and the years with their specific climatic conditions (A) on the indicator mass of grain per cob. An interaction between Hybrid and Year was proven.

Table 2. Qualitative components in maize hybrids

Variable		1000 seed weight (g)	Test weight (kg)	Crude protein (%)
Years	2021	349.4 [a]	73.6 [a]	9.6 [c]
(A)	2022	304.0 [b]	71.5 [b]	10.6 [b]
	2023	238.4 [c]	68.8 [c]	11.4 [a]
Hybrid	P9415	292	70.3	10.6
(B)	P9889	300	70.8	9.9
	P9903	302	71.0	10.4
	KAPITOLIS	313	74.2	10.5
	INTELIGENS	280	70.1	11.3
2021	P9415	345 [d]	73.5 [bc]	9.6 [b]
	P9889	352 [c]	72.4 [c]	9.4 [bc]
	P9903	360 [b]	73.2 [bc]	9.5 [b]
	KAPITOLIS	368 [a]	76.0 [a]	9.5 [b]
	INTELIGENS	322 [c]	72.8 [c]	10.2 [a]
2022	P9415	300 [c]	70.4 [b]	10.7 [b]
	P9889	310 [b]	71.6 [b]	9.7 [c]
	P9903	307 [b]	71.0 [b]	10.6 [b]
	KAPITOLIS	315 [a]	75.4 [a]	10.7 [b]
	INTELIGENS	288 [d]	69.3 [c]	11.4 [a]
2023	P9415	231 [c]	67.1 [c]	11.4 [b]
	P9889	237 [b]	68.5 [b]	10.8 [c]
	P9903	240 [b]	68.9 [b]	11.2 [b]
	KAPITOLIS	255 [a]	71.2 [a]	11.3 [b]
	INTELIGENS	229 [c]	68.1 [b]	12.2 [a]
Anova	A	**	*	**
	B	*	*	*
	AB	*	n.s	*

*Means within columns followed by different lowercase letters are significantly different (P<0.05) according to the LSD test
*F-test significant at P<0.05; ** F-test significant at P<0.01; n.s non-significant

The impact of both variable hybrid and year on the qualitative components is presented in Table 2. The 1000 grains weight are influenced by environmental conditions, cultivation technology and genetics of the hybrids (Ali et al., 2020; Georgieva et al., 2023) The largest mass per 1000 grains was observed in the first year, because of the optimal weather conditions. With a value of 368 g hybrid KAPITOLIS distinguished significantly from the other hybrids. The lowest values of that characteristic were reported in hybrid INTELIGENS - 322 g. The differences between the hybrids were statistically significant. In the economic year 2022 the 1000 grain weights varied from 288 to 315 g, i.e. by 11.8 to 16.8% lower than 2021. The lowest values of that characteristic (within 229 to 255 g) was obtained in the third year.

During the period of study (2021-2023) KAPITOLIS hybrid realized the1000 grains weight of 313 g in average and it surpassed the hybrids P9903, P9889, P9415 and INTELIGENS by 11 g, 13 g, 21 g and 33 g, respectively.

The dispersion analysis about the effect of the factors Hybrid and Year, as well as their interaction, on the 1000 grains weight shows a significant influence of the factors on the changes of indices and statistically significant effect of the interaction between them.

The test weight is an indicator of the commercial quality of grains, and it plays an important role in determining the sale price. The lowest values of indicator were established in the last experimental year (2023), in the tested hybrids varied from 68.1 kg (INTELIGENS) to 71.2 kg (KAPITOLIS). It showed that the low amount of rainfall during the vegetation has a negative influence on grain formation. The highest values of test weight were established in the first year of the study

(2021), from 72.4 to 76.0 kg. During the three-year period, values over 74.2 kg were documented for the hybrid KAPITOLIS. The lowest average value of test weight for INTELIGENS hybrid was observed at 70.1 kg. The analysis of variance (ANOVA) shows the impact of the factors hybrid and year, together with their interaction, on the test weight indicator and the results indicate a statistically significant influence of the examined factors and an insignificant effect of their interaction.

Unlike the other studied indicators, which were higher in the year with the highest and evenly distributed rainfall, the crude protein is favored by dry, hot weather, as well as by the lesser amount of precipitation during the grain-ripening stage. Due to dilution the increased amount of precipitation resulted in higher grain yields, but lower crude protein values (Georgieva et al., 2023; Mahmood et al., 2019). The highest protein content in grain was established in 2023 and varied from 10.8% in P9889 to 12.2% in INTELIGENS. In the other years of the experiment, the values of that characteristic were by 9.7 to 11.4 % and by 9.4 to 10,2% in 2022 and 2021, respectively. For the tested period hybrid INTELIGENS was distinguished with the highest values of protein content 11.4 % and surpassed the hybrids P9415, KAPITOLIS, P9903, P9415 and P9889 by 6.6%, 7.6%, 8.9% and 14.1%, respectively. The ANOVA variance analysis indicates a substantial impact of the two parameters, hybrid and year, on crude protein content. Their interaction has also been substantiated.

The analysis of correlation among the between the qualitative and quantitative parameters is shown in Table 3. The results of correlation evidenced that grain yield strong and positive associations (r>0.9) with cob length, mass of grains per cob and 1000 grains weight.

Table 3. Values of the coefficient of corelation

	Grain yield	Cob length	Number of rows per cob	Number of grains per row	Mass of grains per cob	1000 grains weight	Test weight	Crude protein
Grain yield	1							
Cob length	**0.958**	1						
Number of rows per cob	0.644	0.639	1					
Number of grains per row	0.848	0.877	0.673	1				
Mass of grains per cob	**0.950**	**0.970**	0.629	0.883	1			
1000 grains weight	**0.914**	**0.915**	0.540	0.793	**0.921**	1		
Test weight	0.581	0.609	0.341	0.523	0.631	0.722	1	
Crude protein	-0.845	-0.834	-0.501	-0.717	-0.825	-0.845	-0.567	1

*significance level alpha = 0.05

Strong positive values were reported for cob length and mass of grains per cob; 1000 grains weight and mass of grains per cob; cob length and 1000 grains weight. Negative correlation was observed between the crude protein and all other the qualitative and quantitative indicators. The same tendency was reported also from Georgieva et al. (2023) and Werle et al. (2014).

CONCLUSIONS

The qualitative and quantitative indices of tested maize hybrids in North-Eastern of Bulgaria largely determined by the meteorological conditions of the year and, above all, by the amount and the distribution of the precipitation as well as by genotype. The results of this study suggest the highest grain yield was obtained from P9889 hybrid due to the higher values of yield structural elements. Hybrid INTELIGENS distinguished with the highest values of the crude protein 11.3%. Grain yield and the crude protein content were negatively related. The values of the indicators 1000 grains weight and test weight were highest by the hybrid KAPITOLIS.

Out of the studied maize hybrids for the region of Razgrad, it is recommended to cultivate hybrid P9889 where the productivity and the quality are balanced under the contrast conditions of the studied years.

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