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INFLUENCE OF MAIZE HYBRIDS AND SEED SIZE AFTER PROCESSING ON THE PHYSICAL CHARACTERISTICS OF THE SEEDS, GERMINATION AND RACES GROWTH

UTICAJ HIBRIDA KUKURUZA I VELIČINE SEMENA NAKON DORADE NA FIZIČKE OSOBINE SEMENA, KLIJAVOST I RAST KLIJANCA

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ABSTRACT

In these studies, the physical and physiological seed properties and seedling's vigour properties in five ZP maize hybrids (ZP1, ZP2, ZP3, ZP4 and ZP5)were investigated. Hybrid seed was divided into small (SF) and large fractions (LF) The hybrid combination and seed size did not significantly (p ≥ 0.05) affect seed germination. Width, thickness, length, seed weight, dead seeds, abnormal seedling, stem and root growth and fresh seedling weight were significantly influenced by hybrid and seed fraction LF produced higher stems by 1.18 cm, longer roots by 2.94 cm and higher seedling weight by 0.032 g (the hybrid average) as compared to SF. The influence of hybrids on stem growth differed by 1.9 cm on SF seed and 1.7 cm on LF seed. Significant and positive dependence (p ≥ 0.001) between seed germination was determined with the growth of stem, root and seedling weight, as well as with the 1000 seed weight (p ≥ 0.01) and with a thickness (TS) (p ≥ 0.05). Seed germination with abnormal seedlings achieved a negative (p ≥ 0.01) significant correlation.

Keywords: *seed fractions, hybrids, seed and seedling quality, seed processing.*

REZIME

U ovim istraživanjima su prikazane fizičke,fiziološke i osobine vigora semena pet ZP hibrida kukuruza (ZP1, ZP2, ZP3, ZP4 i ZP5). Seme hibrida podeljeno je na sitnu (SF)i krupnu frakciju (LF). Hibridna kombinacija i frakcija semena nije značajno uticala na klijavost semena. Hibrid i frakcija semena ispoljili su značajan uticaj na osobine: debljina, širina, dužina, masa semena, mrtvo seme, nenormalno seme, dužina stabaoceta i korenka i sveža masa semena. (p ≥ 0.05 , p ≥ 0.01). Krupna frakcija dala je duže stabaoce za 1,18 cm, duži korenak za 2,94 cm i veću masu klijanca za 0,032 g u poređenju sa sitnom frakcijom. Uticaj hibrida na dužinu stabaoceta se razlikovao za 1,9 cm u SF, odnosno 1,7 cm u LF

Između klijavosti semena i osobina vigora klijanca (dužine stabaoceta i korenka i sveže mase klijanca) kao i mase semena i osobina vigora klijanaca utvrđena je značajna i pozitivna korelacija (p ≥ 0.001) Između klijavosti semena i procenta nenormalnih klijanaca utvrđena je značajna negativna korelacija (p ≥ 0.01).

Ključne reči: *frakcija, hibrid, kvalitet semena i klijanca, dorada.*

INTRODUCTION

Intensive maize breeding has produced many hybrids that are highly variable depending on the growing season, grain yield, and intended use (*Buhiniček et al. 2021*).). In seed production, there is a variability of hybrids according to the physical characteristics of seeds (*Babić et al. 2011*). Seed processing and packaging have changed over time, following the requirements of mechanisation of sowing and cultivation techniques, i.e. market requirements. In the time when mechanical seeders were used for sowing, it was necessary to have seeds in different fractions and seed sizes. With the use of pneumatic seeders, fractions and sizes are of minimal importance, and it is sufficient to have two or three seed fractions: small (round + flat fractions), medium, and large, although it is not necessary to separate round from flat fractions (*Pavlov et al. 2008*). On the other hand, as reproductive material, seeds come in a range of shapes, dimensions, and masses. These morphological features have a significant impact on plant production (*Tabaković et al, 2018*). The most important quality attributes of seeds are shape, size, and mass. These parameters play a critical role in the design of classifiers and grading machines (*Çetin, 2022*). *Egli and Rucker* (2012) are giving preference to larger seeds with the explanation that larger seeds germinate uniformly and produce stronger seedlings. Therefore, our goal was to examine the impact of hybrid and the seed fraction on seed physical and physiological characteristics and seedling's vigour.

MATERIAL AND METHOD

The seed material used in the experiment consisted of five maize hybrids from different maturity groups: ZP1 (FAO 300), ZP2 (FAO 400), ZP3 (FAO 500), ZP4 and ZP5 (FAO 600). The production of hybrid maize seeds (F1) was set at location Zemun Polje according to the *Official Gazette (RS, 2006; No. 2006/06*), in 2020. Harvesting was done with 30% seed moisture. After drying, maize ears were shelled by sheller Heid. Then, the seed was processed by a pre-cleaner Clipper and fine air-cleaner Heid, model Delta 106. Fine cleaning of the seeds was done by round perforated sieves Ø 6,5 mm (bottom) and Ø 11,0 mm (upper). Seed cleaning was followed by seed division by a cylindrical grader, with a round opening Ø 8,5 mm, into two sizes: small (6,5-8,5 mm) and large seed (8,5-11,0mm). Each size consisted of round and flat seeds. The seed goes through a fine selector and with additional air, over 99.5% to 99.6% purity of the seed is obtained and impurities are rejected.

The following traits were examined: i) physical properties of seeds; width (W), thickness (TS), length (LS), and 1000 seeds weight (WS), ii) seed physiological properties; germination (G), dead seeds (DS), and abnormal seedlings (AS), and iii) seedling's vigour properties: stem growth (GS), root growth(GR), and fresh seedling weight (FW). Seed testing was repeated in three different months during the year 2021. Each month represents one experimental cycle (C). The physical properties of seeds (width, thickness, length) were observed in three replicates by measuring with precise digital callipers (ISKRA, 150 mm). The 1000 seeds weight was measured by 4x100 seeds for each hybrid in three replicates, according to ISTA rules (*ISTA 2020*).

The physiological properties of seeds were assessed in a germination cabinet according to ISTA rules (*ISTA, 2020*), in sand-filled containers in three replicates. Germination, dead seeds and abnormal seedlings were observed on the 7th day, at an alternate temperature of 20-30^{o} C. The tetrazolium test was applied to distinguish dormant seeds from dead seeds

Seedling's vigour was determined by measuring stem growth and root growth with a ruler (0–1000 mm), and fresh seedling weight on the digital balance (Tehtnica ET 1111, max-1200.00/120.00 g, e-0.1 g, dd-0.1/0.01 g, Serbia) in three replications.

Descriptive statistics included means, standard mean errors and coefficients of variations for each trait. The analysis of variance (ANOVA) was applied to determine the influence of 3 factors. The significance of differences between different fractions within each hybrid was tested by Tukey's Multiple Range test. The relationship between the examined traits was examined using the Pearson correlation coefficients (r). Statistical analysis was done by Minitab Inc., version 16.1.0, statistical software.

RESULTS AND DISCUSSION

Using the F test, it was determined that factor C, as well as its interaction with hybrid and fraction, did not have a significant effect ($p \geq 0.05$) on the tested properties. In addition, factors A and B and their interactions did not significantly affect seed germination. On the other hand, factors A and B and their interactions had a significant effect ($p \leq 0.05$ to $p \leq 0.001$) on other examined properties (Table 1).

Table 1. - ANOVA for seed physical and physiological properties and seedling's vigour characteristics

Factor	df	Physical characteristics of seeds				Physiological properties			Seedling's vigour properties		
		WS	W	TS	LS	G	DS	AS	GS	GR	FW
Hybrid (A)	4	*	*	*	*	ns	**	*	*	*	*
Fraction (B)	1	***	**	**	***	ns	***	***	*	*	*
Cycle (C)	2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Interactions											
AxB	4	*	*	*	*	ns	**	*	*	*	*
AxC	8	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
BxC	2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
AxBxC	8	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

*F test, statistical significance levels: * p ≤ 0.05, ** p ≤ 0.01, *** p ≤ 0.001, ns – not significant (p ≥ 0.05). 1 df – degree of freedom WS - 1000 seeds weight, W - seed width, TS - thickness, LS – length, G - germination, DS - dead seed, AS - abnormal seedlings, GS - stem growth, GR – root growth, FW - fresh seedling weight.*

The physical properties of maize seeds are important for seedling's growth in the initial stages of development, crop uniformity, weed competitiveness, optimal harvesting time, and seed manipulation after the harvest (transport, processing, drying, and storage)(*Bande et al., 2012; Cerrudo, et al., 2017*). Physiological properties (germination rate and vigour) depend not only on physical properties but also on environmental and processing conditions. Seed processing technology equipment highly depends on the physical characteristics of the seed (*Karimmojeni, et al., 2021*). In our studies, a significant effect of hybrids on W in both tested fractions was observed (Table 2). A significant influence of hybrid ($P \leq 0.05$) on WS determined in our study, is confirmed by (Milander et all, 2016) stating the 1000 seed weight is a varietal characteristic. Regarding this trait, hybrids differed greatly within the small fraction as compared to differences between large fractions. Besides the effect of hybrid, a great influence on 1000 seed weight is reported for different environmental factors (drought stress, and insufficient lighting), especially after silking, (*Keszthelyi et al., 2022; Nikolić, et al., 2020*).

Table 2. Physical properties of small (SF) and large (LF) seed fractions of tested maize hybrids after natural seed processing

Hybrid/ Fraction	W (cm)		TS (cm)		LS (cm)		WS (g)	
	SF	LF	SF	LF	SF	LF	SF	LF
ZP1	7.94 ± 0.52b	9.19 ± 0.19a	5.48 ± 0.22b	6.03 ± 0.52ab	9.69 ± 0.54ab	10.94 ± 0.62a	248.1 ± 0.91b	353.8 ± 0.69ab
ZP2	8.50 ± 0.33a	8.89 ± 0.33ab	5.42 ± 0.19b	6.09 ± 0.45ab	9.17 ± 0.41b	10.89 ± 0.49a	264.8 ± 0.72b	342.1 ± 0.75b
ZP3	7.84 ± 0.79b	8.64 ± 0.59b	6.11 ± 0.32a	6.60 ± 0.21a	10.09 ± 0.49ab	9.82 ± 0.61b	319.4 ± 0.69a	348.6 ± 0.92b
ZP4	7.72 ± 0.65bc	8.69 ± 0.41b	6.22 ± 0.43a	5.87 ± 0.33b	10.65 ± 0.72a	10.40 ± 0.73ab	333.5 ± 1.05a	375.1 ± 0.79a
ZP5	7.31 ± 0.36 c	8.60 ± 0.22b	6.08 ± 0.39a	5.96 ± 0.41 b	10.46 ± 0.69a	10.53 ± 0.89ab	286.3 ± 0.98ab	374.9 ± 0.98a
Average	7.86	8.80	5.86	6.11	10.01	10.52	290.4	358.9
CV %	5.47	2.77	6.49	4.68	5.96	4.30	12.4	4.25

Tukey's Multiple Range test a, b… x, significant effect P ≤ 0.05, Values are mean ± standard error of the mean (±SEM). SF - small seed fractions, LF - large seed fractions, W - seed width, TS - thickness, LS –seed length, WS - 1000 seeds weight.

As stated by Ambika et al. (2014), seed size also significantly affects germination and seedling vigour. According to our research, seed fractions did not significantly affect G, which means that higher germination of LF by 0.6% (average of all hybrids) compared to SF was not statistically significant. (Table 3). Depending on the hybrid, G differed by only 1% taking into account both fractions, while dead seed differed by 2% and 1% in SF and KF, respectively, (Table 3). The fraction showed a higher influence on variation in dead seeds (DS) in SF compared to LF. Abnormal seedlings (AS) were represented in a low percentage in both fractions, ranging from 1 to 3% in all examined hybrids. (Table 3).

According to Hampton (2002), seeds with high germination potential produce seedlings with strong vigour. It is expected that the high-vigor seeds would emerge more uniformly even under germination conditions that were less than ideal (Egli and Rucker, 2012). and provide rapid and steady growth, which affects high and stable yield (Tabakovic et al…). On the other hand, low-vigour seeds in field conditions can reduce the germination rate, emergence and initial growth, (*Schuch et al., 2000*). In our research, LF seeds gave higher stems by 1.18 cm, longer roots by 2.94 cm and higher seedling weight by 0.032 g (the hybrid average) as compared to SF (Table 4). The influence of hybrids on stem growth differed by 1.9 cm on SF seed and 1.7 cm on LF seed.

Table 3. Physiological properties of two seed fractions in five maize hybrids

Hybrid	G (%)		DS (%)		AS(%)	
	SF	LF	SF	LF	SF	LF
ZP1	97± 0.12a	97± 0.22a	1 ± 6.82ab	1 ± 0.70a	2 ± 0.21ab	2± 0.21a
ZP2	97 ± 0.22a	98± 0.09a	0 ± 0.00b	1 ± 0.00a	3 ± 0.70a	1 ± 0.00b
ZP3	97± 0.12a	98 ± 0.12a	2 ± 5.82a	0 ± 0.00b	1 ± 0.00b	2 ± 0.70a
ZP4	97± 0.09a	98± 0.23a	1 ± 0.70ab	0 ± 0.70b	2 ± 0.21ab	2 ± 0.21a
ZP5	98 ± 0.21a	98 ± 0.21a	1± 0.12ab	1± 0.21a	1± 0.70b	1 ± 0.00b
Average	97.2	97.8	1.00	0.60	1.80	1.60
CV %	0.460	0.457	70.7	91.3	46.5	34.2

Tukey's Multiple Range test a, b… x, significant effect P ≤ 0.05, Values are mean ± standard error of the mean, G - germination, DS - dead seed, AS - abnormal seedlings, SF-small seed fraction, LF- large seed fraction.

Table 4. Seedling's vigour properties of two seed fractions in five maize hybrids

Hybrid	Seedling vigour					
	GS (cm)		GR (cm)		FW (g)	
	SF	LF	SF	LF	SF	LF
ZP1	11.2±4.21b	12.6±5.68b	13.4±2.68b	15.8±5.53b	0.856±1.29b	0.899±1.48b
ZP2	11.9±4.48ab	12.7±3.34 b	13.5±4.03b	15.9±4.21b	0.862±0.89b	0.902±1.14b
ZP3	12.4±4.52ab	13.7±4.49ab	16.5±5.66a	19.8±3.48a	0.925±1.18a	0.952±0.92a
ZP4	12.9±3.43a	14.3±5.02a	16.8±4.41 a	20.0±2.99 a	0.931±0.99a	0.959±1.05a
ZP5	13.1±4.72 a	14.1±4.39a	16.6±3.33a	19.9±4.48a	0.933±1.12a	0.953±2.11a
Average	12.30	13.48	15.36	18.3	0.901	0.933
CV %	6.27	5.85	11.4	12.1	4.31	3.19

Tukey's Multiple Range test a, b… x, significant effect P ≤ 0.05, Values are mean ± standard error of the mean, GS - stem growth, GR – root growth, FW - fresh seedling weight.

The highest FW had a hybrid ZP5 from SF seeds and a hybrid ZP4 from LF seeds. ZP1 had the lowest seedling weight (0.856 g from SF and 0.899 g from LF), but there was no significant difference between ZP1 and ZP2 hybrids, while these two hybrids differed significantly from ZP4, ZP5 and ZP3 hybrids (Table 4).

Table 5 Pearson's correlation coefficients between seed physical and physiological properties and seedling's vigour characteristics in five maize hybrids

Properties	DS (%)	AS (%)	Physical properties				Seedling's vigour properties		
			WS (g)	W (cm)	TS (cm)	LS (cm)	GS (cm)	GR (cm)	FW (g)
G	-0.339 ns	-0.463 **	0.490 **	0.157 ns	0.402 *	0.042 ns	0.786 ***	0.701 ***	0.659 ***
DS	-	-0.697 ***	-0.071 ns	-0.380 *	0.055 ns	0.473 **	0.350 ns	-0.238 ns	-0.061 ns
AS		-	-0.319 ns	0.229 ns	-0.416 **	-0.468 **	-0.276 ns	-0.221 ns	-0.449 *
WS			-	0.549 ***	0.593 ***	0.221 ns	0.841 ***	0.831 ***	0.782 ***
W				-	0.029 ns	0.032 ns	0.234 ns	0.219 ns	-0.019 ns
TS					-	0.091 ns	0.561 ***	0.637 ***	0.719 ***
LS						-	-0.013 ns	-0.009 ns	0.020 ns
GS							-	0.972 ***	0.954 ***
GR								-	0.967 ***

*Statistical significance levels: * p ≤ 0.05, ** p ≤ 0.01, *** p ≤ 0.001, ns – not significant (p ≥ 0.05)., W - seed width, TS - thickness, LS – length, WS - 1000 seeds weight, G - germination, DS - dead seed, AS - abnormal seedlings, GS - stem growth, GR – root growth, FW - fresh seedling weight.*

Significant and positive dependence (p ≥ 0.001) between seed germination was achieved with the growth of the stem, root and seedling weight, as well as with the 1000 seed weight (p ≥ 0.01) and thickness (p ≥ 0.05). Seed germination with abnormal seedlings achieved a negative (p ≥ 0.01) significant dependence (Table 5).

CONCLUSION

None of the factors examined in this study (hybrid, fraction, cycle), as well as their interactions showed an influence on seed germination rate. For other properties (physical, physiological and seedling's vigour properties), a high influence of hybrid and fraction was observed. The effects of hybrid had the greatest influence on physical seed properties, while the division of seeds into LF and SF decreased the difference in seed physical properties. Seedling's vigour properties expressed significant differences concerning hybrid and fraction. LF showed stronger stem and root growth and seedling weight in comparison with SF, as well as hybrids ZP3, ZP4 and ZP5 compared to ZP1 and ZP2.

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