

EVALUATION THE QUALITY INDICATORS OF PEPPER HYBRID SEEDS DURING GERMINATION

OCENA POKAZATELJA KVALITETA SEMENA HIBRIDA PAPRIKE TOKOM KLIJANJA

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ABSTRACT

The aim of the research was to evaluate the influence of the hybrid and the medium for germination testing on indicators of pepper seed quality. The obtained results should provide an answer as to whether the application of different growing media for testing seed germination can lead to discrepancies between test results in quality indicators for hybrid seeds. The seed quality of three pepper hybrids: KG 2025 F1, KG 2129 F1 and KG 2032 F1 was tested on two growing media (filter paper and substrate). Statistical analysis of germination energy, total germination, diseased seedlings and dead seeds showed highly significant differences ($r < 0.01$) under the influence of the hybrid factor. The growing media factor also had a highly significant effect on all examined quality indicators, except for total germination. A significantly lower number of abnormal and diseased seedlings was found on the filter paper compared to the substrate. A highly negative significant correlation ($r = -0.90951$, $p \leq 0.001$) was recorded only between total germination and diseased seedlings. The obtained results indicate that the application of different media for testing the germination of hybrid pepper seeds can lead to inconsistencies in the obtained values for all evaluated quality indicators.

Keywords: pepper, hybrid, germination.

REZIME

Cilj istraživanja je bio da se izvrši ocena uticaja hibrida i podloge za ispitivanje klijavosti na pokazatelje kvaliteta semena paprike. Dobijeni rezultati treba da daju odgovor da li primena različitih podloga za ispitivanje klijavosti može dovesti do neslaganja između rezultata ispitivanja u pokazateljima kvaliteta kod hibridnog semena paprike. Ispitivani su tri različita hibrida paprika: KG 2025 F1, KG 2129 F1 i KG 2032 F1 na dve različite podloge (filter papiru i supstratu). Statistička analiza energije klijanja, ukupne klijavosti, bolesnih klijanaca i mrtvog semena pokazala je visoko značajne razlike ($p < 0,01$) pod uticajem faktora hibrid, dok je uticaj hibrida na broj nenormalnih klijanaca izostao. Faktor supstrat značajno je uticao na nivou ($p < 0,01$) na sve ispitivane pokazatelje kvaliteta, osim na ukupnu klijavost. Veoma značajna interakcija ($p < 0,01$) ispitivanih faktora u pogledu svih ispitivanih pokazatelja kvaliteta semena paprike dobijena je kod međusobnog uticaja faktora hibrid \times supstrat. Kod hibrida KG 2025 F1 konstatovana je prosečno vrlo značajno veća energija klijanja i ukupna klijavost, u odnosu na ostala dva hibrida. Ispitivani hibridi su značajno brže klijali sedmog dana u proseku za 26% na podlozi filter papir, u odnosu na utvrđenu energiju klijanja na podlozi supstrat. Na podlozi filter papir konstatovan je značajno manji broj nenormalnih i bolesnih klijanaca u odnosu na podlogu supstrat. Visoko negativna značajna korelacija ($r = -0,90951$, $p \leq 0,001$) zabeležena je samo između ukupne klijavosti i bolesnih klijanaca. Ostvareni rezultati ukazuju da primena različitih podloga za ispitivanje klijavosti hibridnog semena paprike može dovesti do nepodudarnosti dobijenih vrednosti kod svih ocenjivanih pokazatelja kvaliteta.

Ključne reči: paprika, hibridi, klijavost.

INTRODUCTION

Pepper is one of the most important vegetable crops in Serbia. Pepper is grown in Serbia on about 10,186 ha with an average yield of 14.1 t ha⁻¹, and compared to 2010, there is a trend of decreasing areas under this plant species, but also an average increase in yield per unit area. Vegetable production in the Republic of Serbia takes place on about 130,000 ha, which represents approximately 3.5% of the total vegetable production. Based on the area, peppers come just behind potatoes and tomatoes with 10,186 ha in 2022, which represents about 7.8% of the total area under vegetables according to the data of the Statistical Office of the Republic of Serbia (www.stat.gov.rs). Seeds represent one of the most important factors of successful agricultural production, and that is why ensuring their high quality is a priority of modern seed production and a prerequisite for high yields of all plant species (Tabaković et al., 2013; Poštić i sar.

2014; Poštić et al., 2019). Right choice of seed testing method is crucial in order to obtain adequate estimation of seed lot quality. Use of different growing media may lead to discrepancy between testing results (Milivojević et al., 2018). Diseases caused by phytopathogenic fungi that are transmitted through seeds have the negative impact on indicators of seed quality (Živković et al., 2023). Also, seed-borne pathogens can cause heavy losses in the field (Amani Machiani et al., 2019; Rajput et al., 2020). Germination testing in sand of maize landraces accessions from gene bank gave better results with higher correlation with field emergence than filter paper method (Babić et al., 2015). Filter paper, sand and soil were allowed substrates for germination testing until 2002, when compost was added in the ISTA Rules. In 2006 term "substrate" was replaced by "growing media" and "compost" by "organic growing media" (Milivojević et al., 2018). The importance of comparative testing of seeds on different growing media is reflected in obtaining more precise infor-

mation on each individual indicator of seed quality, as well as on the influence of different growing media on the assessed indicators of seed quality.

The aim of the research was to evaluate the influence of the hybrid and the medium for germination testing on the most important indicators of pepper seed quality. The obtained results indicate that the application of different media for testing the germination of hybrid pepper seeds can lead to inconsistencies in the obtained values for all evaluated quality indicators.

MATERIAL AND METHOD

The object of research are three new pepper hybrids KG 2025 F1, KG 2129 F1 and KG 2032 F1, which were produced in 2023. The assessment of seed quality indicators was carried out in 2023, in the Laboratory for Testing the Quality of Seeds and Planting Material of the Institute for Plant Protection and the Environment.

The following indicators of seed quality were evaluated: germination energy, total germination, abnormal seedlings, diseased seedlings and dead seeds. The percentage of seedlings infected with pathogens was determined according to ISTA Rules (ISTA, 2020). As growing media for testing seed germination, the following were used: a) qualitative corrugated filter paper with dimensions of 580 × 580 mm from the company Macherey-Nagel (Germany) and b) substrate for seed germination Klasmann TS1 Fine 210L (particle size 0 to 5 mm; pH value 6) from the company Klasmann-Deilmann (Germany).

Seed quality assessment

The germination testing of three hybrids considered was performed using a standard laboratory method involving filter paper moistened with a 0.2 % aqueous KNO₃ solution at 4 × 100 seeds. The seeds were incubated for 14 days at a temperature of 20-30°C and a relative air humidity of 95 %. The germination energy after 7 days of incubation, the total germination and the numbers of abnormal seedlings and dead seeds after 14 days of incubation of the pepper seeds considered were determined according to the Rules on the Quality of Seeds of Agricultural Plants ("Official Gazette of SFRY ", no. 47/87), which are in accordance with the ISTA Rules (ISTA, 2018).

Statistical analysis

The experimental data obtained were processed using the statistical package STATISTICA 8.0 for Windows. Differences between the treatments were determined using the analysis of variance (ANOVA), whereas the least significant difference (LSD) test was used for individual comparisons. Grouping information using Tukey method and 95.0% confidence. Correlations between the parameters observed were determined using the Pearson correlation coefficient (r).

RESULTS AND DISCUSSION

The analysis of germination energy, total germination, diseased seedlings and dead pepper seeds showed highly significant differences (r<0.01) under the influence of the hybrid factor (G), while the influence of the hybrid on the number of abnormal seedlings was absent (Table 1). Similar results of a significant influence of variety/hybrid on quality indicators of alfalfa, tomato, cabbage and cucumber seeds were noted earlier (Stanisavljević et al., 2018; Poštić et al., 2020; Poštić et al., 2022; Poštić et al., 2023).

The growing media factor (M) had a significant effect at the level (r<0.01) on all examined quality indicators, except for total germination. The interaction of the examined factors G × M had a significant effect (r<0.01) on all evaluated indicators of pepper seed quality.

Table 1. F-values for observed factors

Factors	Germination energy	Total germination	Abnormal seedlings	Diseased seedlings	Dead seeds
Hybrid (G)	89.51**	182.50**	1.50 ns	140.29**	47.29**
Growing media (M)	1563.8**	0.023 ns	7.89**	66.67**	141.87**
G × M	9.09**	27.50**	11.92**	44.04**	47.20**

** - significant at 0.01; * - significant at 0.05; ns - not significant

Average, the highest energy germination was recorded at the KG 2025 F1 hybrid (70.00%), while in the other two pepper hybrids, an approximate value of around 60.00% was determined (Table 2).

Tabaković et al. (2013a), report similar results on the influence of hybrids on germination energy in maize. No statistically significant difference was recorded between the hybrids KG 2129 F1 and KG 2032 F1 in terms of seed germination energy. In all tested hybrids, a significantly higher germination energy was found on media top filter paper, compared to media substrate. Tested pepper hybrids germinated significantly faster on the seventh day by an average of 26.00% on the filter paper, compared to the determined germination energy on substrate Table 2.

Table 2. Effect of hybrid and growing media on germination energy (%)

Hybrid (G)	Growing media (M)		Average (G)
	Filter paper (FP)	Substrate (S)	
KG 2025 F1	85.00aA	55.00aB	70.00
KG 2129 F1	73.00bA	47.00bB	60.00
KG 2032 F1	72.00bA	49.00bB	60.50
Average (M)	76.67	50.33	63.50

* Small letters show the difference a, b, for the column, capital letters show the difference A, B, for the line; Grouping Information Using Tukey Method and 95.0% confidence;

The highest average total germination of 95.00% was recorded in the hybrid KG 2025 F1, followed by 88.50% in the hybrid KG 2129 F1, while the lowest of 82.50% was found in the hybrid KG 2032 F1 (Table 3).

Hybrid KG 2025 F1 recorded a very significantly higher total germination, compared to the recorded total germination of the other two hybrids. These results are in agreement with the results reported by Tabaković et al. (2013a) and Omar et al. (2023). A significantly lower value of total germination was found in the hybrid KG 2129 F1, compared to the total germination found in the hybrid KG 2032 F1. The achieved value of total germination of pepper hybrids on both tested substrates is the same on average and amounts to 88.67%.

Table 3. Effect of hybrid and growing media on total germination (%)

Hybrid (G)	Growing media (M)		Average (G)
	Filter paper (FP)	Substrate (S)	
KG 2025 F1	95.00aA	95.00aA	95.00
KG 2129 F1	91.00bA	86.00bB	88.50
KG 2032 F1	80.00cB	85.00bA	82.50
Average (M)	88.67	88.67	88.67

* Small letters show the difference a, b, for the column, capital letters show the difference A, B, for the line; Grouping Information Using Tukey Method and 95.0% confidence;

Hybrid KG 2025 F1 formed on average the lowest percentage of abnormal seedlings, 2.00%, while the other two investigated pepper hybrids recorded 2.50% each (Table 4). No statistically significant difference in the number of abnormal seedlings was found between the tested hybrids.

A significantly lower number of abnormal seedlings was found on filter paper, compared to the substrate. These results are in contrast to the results of *Babić et al. (2015)*, who examined corn seeds on filter paper and in field conditions, and state that a greater number of abnormal seedlings are formed on filter paper, compared to field conditions. At hybrid KG 2025 F1, there was no difference between the tested media in the number of abnormal seedlings, while in the other two hybrids, a significantly lower number of abnormal seedlings formed on filter paper compared to the determined number of abnormal seedlings on substrate.

Table 4. Effect of hybrid and growing media on abnormal seedlings (%)

Hybrid (G)	Growing media (M)		Average (G)
	Filter paper (FP)	Substrate (S)	
KG 2025 F1	2.00aA	2.00cA	2.00
KG 2129 F1	2.00aB	3.00bA	2.50
KG 2032 F1	1.00bB	4.00aA	2.50
Average (M)	1.67	3.00	2.33

* Small letters show the difference a, b, for the column, capital letters show the difference A, B, for the line; Grouping Information Using Tukey Method and 95.0% confidence;

Examining the seed health of hybrids it was recorded presence of only *Alternaria* sp. In average, the lowest percentage of 3.00% of infected seedlings was recorded in the KG 2025 F1 hybrid, followed by 7.00% in the KG 2129 F1, while the highest number of 11.00% diseased seedlings was found in the KG 2032 F1 hybrid (Table 5).

Only on filter paper a significantly higher percentage of infected seedlings of *Alternaria* sp. was found in the hybrid KG 2032 F1, compared to the number of diseased seedlings found in the other two hybrids. At hybrid KG 2025 F1 recorded a significantly lower number of diseased seedlings, compared to KG 2129 F1. In most countries, the seed is not good for further planting if more than 5.00% of the seed is infected with one or more of the following fungi: *Alternaria*, *Aspergillus*, *Fusarium*, *Penicillium*, *Cladosporium*, *Curvularia*, *Macrophomina*, *Phoma* and *Rhizopus*. A significantly lower number of diseased seedlings were found on filter paper average, compared to substrate. In the hybrids KG 2025 F1 and KG 2032 F1, there was no difference between the tested media in the number of diseased seedlings, while in the hybrid KG 2129 F1, a significantly higher number of diseased seedlings was found on substrate, compared to filter paper.

Table 5. Effect of hybrid and growing media on diseased seedlings (%)

Hybrid (G)	Growing media (M)		Average (G)
	Filter paper (FP)	Substrate (S)	
KG 2025 F1	3.00bA	3.00bA	3.00
KG 2129 F1	3b.00B	11.00aA	7.00
KG 2032 F1	11.00aA	11.00aA	11.00
Average (M)	5.67	8.33	7.00

* Small letters show the difference a, b, for the column, capital letters show the difference A, B, for the line; Grouping Information Using Tukey Method and 95.0% confidence;

The highest percentage of dead seeds 4.00% on average, was recorded in the hybrid KG 2032 F1, followed by 2.00% in KG 2129 F1, while the lowest of 0.00% was found in KG 2025 F1 (Table 6). A significantly higher number of dead seeds were found in the hybrid KG 2032 F1, compared to the number of dead seeds found in the other two hybrids. Hybrid KG 2025 F1 showed a significantly lower number of dead seeds compared to KG 2129 F1.

On average, a significantly higher number of dead seeds were found on filter paper than on substrate. In the hybrid KG 2025 F1, there was no difference between the tested media in the number of dead seeds, while in the hybrids KG 2129 F1 and KG 2032 F1, a significantly higher number of dead seeds was determined on filter paper, compared to substrate as a growing media.

Table 6. Effect of hybrid and growing media on dead seeds (%)

Hybrid (G)	Growing media (M)		Average (G)
	Filter paper (FP)	Substrate (S)	
KG 2025 F1	0.00cA	0.00aA	0.00
KG 2129 F1	4.00bA	0.00aB	2.00
KG 2032 F1	8.00aA	0.00aB	4.00
Average (M)	4.00	0.00	2.00

* Small letters show the difference a, b, for the column, capital letters show the difference A, B, for the line; Grouping Information Using Tukey Method and 95.0% confidence;

A highly negative significant correlation ($r = -0.90951$, $p \leq 0.001$) was recorded only between total germination and diseased seedlings (Table 7). No statistically significant correlation was found between the other examined parameters. These results not agreement with the results of *Stanisavljević et al. (2017)*, *Soares et al. (2019)*, *Poštić et al. (2020)* and *Poštić et al. (2022)*.

Table 7. The correlation coefficients between the observed traits (n=6)

Traits	Total germination	Abnormal seedlings	Diseased seedlings	Dead seeds
Germination energy	0.27677	- 0.68084	- 0.53492	0.41244
Total germination	-	- 0.04287	- 0.90951***	- 0.59541
Abnormal seedlings		-	0.35355	- 0.69437
Diseased seedlings			-	0.21822
Dead Seeds				-

Pearson correlation coefficient: *** $P \leq 0.001$, ** $P \leq 0.01$, * $P \leq 0.05$, respectively

CONCLUSION

Obtained results indicate that the application of different growing media for testing the germination of hybrid pepper seeds can lead to inconsistencies in the obtained values for all evaluated quality indicators.

The greatest inconsistency between the obtained values of the quality indicators between the tested media was found in the germination energies. On filter paper, in all tested pepper hybrids, the highest significant discrepancy was obtained in the germination energy, which was 23 to 30% higher, compared to substrate.

At hybrid KG 2032 F1 was recorded the lowest percentage of germination energy and total germination, which is a consequence of the highest percentage of *Alternaria* sp. infected seeds. At the hybrid KG 2025 F1, which achieved the highest total germination, as expected, the lowest values of inconsistency of quality indicators were obtained on the tested growing media.

Occurrence of dead seeds of the tested pepper hybrids was not recorded on substrate, based on which it can be concluded that the substrate caused the germination of each pepper seed. A significantly higher percentage of abnormal and diseased seedlings were found on substrate, compared to filter paper, which was formed as a direct consequence of the absence of dead seeds.

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