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ASSESSMENT OF SEED QUALITY OF DIFFERENT CABBAGE LOTS DURING AGING
OCENA KVALITETA SEMENA RAZLIČITIH PARTIJA KUPUSA TOKOM STARENJA

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ABSTRACT

The aim of the research was to evaluate the influence of the year and the seed lots on the most important indicators of cabbage seed quality. Quality testing of nine different seed lots of Potomac F1 cabbage was performed during three years (2019, 2020 and 2021). Analyses of variance showed a significant effect ($p<0.01$) of the year (Y), while seed lot (L) and their interaction (Y × L) showed a significant effect ($p<0.05$) on all observed parameters quality (germination energy, total germination, abnormal seedlings and dead seeds). The strongest correlation between the examined parameters was in the first year and weakened in the second and third years. In the first year as expected, significant positive correlation between germination energy and total germination was found ($r = 0.84779$, $p<0.01$). The highly and negative interdependence was achieved between total germination and dead seeds ($r = -0.94363$, $p<0.001$) and abnormal seedlings ($r = -0.78019$, $p<0.05$). Also negative interdependence was found between germination energy and dead seeds ($r = -0.80000$, $p<0.01$) and abnormal seedlings ($r = -0.66144$, $p<0.05$). The germination energy and the total germination of the cabbage seeds considered were found to decrease with the increasing seed age, in contrast to the numbers of their abnormal seedlings and dead seeds which continued to increase with seed aging. The obtained results indicate that the germination of highly hybrid conventional cabbage seeds decreases significantly during aging, as a direct consequence of a very significant increase in the number of abnormal seedlings.

Key words: *cabbage, germination, seed lots, abnormal seedlings.*

REZIME

Cilj istraživanja je bio da se izvrši ocena uticaja godine i partije semena na najznačajnije pokazatelje kvaliteta semena kupusa. Ispitivanje kvaliteta semena devet različitih partija kupusa Potomak F1, izvedena su tokom tri godine (2019, 2020 i 2021). Analiza energije klijanja, ukupne klijavosti, nenormalnih klijanaca i mrtvog semena kupusa pokazala je visoko značajne razlike ($p<0,01$) pod uticajem faktora godina (Y), dok je uticaj partija semena (L) i interakcija (Y × L) na ispitivane pokazatelje bio na nivou ($p<0,05$). Najjače korelacije između ispitivanih parametara kvaliteta semena zabeležene su u prvoj godini i slabile su drugoj i trećoj godini. U prvoj godini zabeležena je značajna korelacija ($r = 0,84779$, $p<0,01$) između energije klijanja i ukupne klijavosti, odnosno u drugoj godini ($r = 0,75057$, $p\leq0,05$), dok je u trećoj godini izostala. Visoka negativna međuzavisnost dobijena je između ukupne klijavosti i mrtvog semena ($r = -0,94363$, $p<0,001$) i nenormalnih klijanaca ($r = -0,78019$, $p<0,05$). Takođe, negativna korelacija utvrđena je između energije klijanja i mrtvog semena ($r = -0,80000$, $p<0,01$) i nenormalnih klijanaca ($r = -0,66144$, $p<0,05$). Zabeleženo je da se energija klijanja i ukupna klijavost ispitivanog semena kupusa smanjuju sa povećanjem starosti semena, za razliku od broja nenormalnih klijanaca i mrtvog semena, koji rastu sa starenjem semena. Na osnovu dobijenih rezultata možemo konstatovati da se ukupna klijavost visoko hibridnog konvencionalnog semena kupusa veoma značajno smanjuje tokom starenja, kao direktna posledica veoma značajnog povećanja broja nenormalnih klijanaca.

Ključne reči*: kupus, klijavost, partija semena, nenormalni klijanci.*

INTRODUCTION

Cabbage production in our area has a long tradition, as well as the possibility of multiple uses. Cabbage belongs to the group of vegetables that can be grown all year round. The value of cabbage comes from multiple uses: fresh in salads, pickled, as a stew, semi-fresh during the winter, after a certain period of storage. Vegetable production in the Republic of Serbia takes place on about 130.000 ha, which represents approximately 3.5% of total plant production. Cabbage together with kale on the basis of established areas comes right behind potatoes, tomatoes and peppers with 12.534 ha in 2019, which represents about 9.5% of the total area under vegetables according to the Statistical Office of the Republic of Serbia (www.stat.gov.rs). The main cabbage producers in Serbia are family farms. The cabbage is mostly grown in the region of Šumadija and Western Serbia, where 42% of total cabbage production is carried out, followed by the region of Southern and Eastern Serbia with 25%, Vojvodina autonomous province 24% and the region of the city of Belgrade, where 9% of total cabbage production is carried out (*Červenski and Medić-Pap, 2018*). Average yields of

cabbage are range from 20-30 t ha^{-1} in heads for early varieties, 35-45 t ha^{-1} in medium late varieties and 40-50 t ha^{-1} in late varieties. Consumption of cabbage per capita is high and amounts to about 20 kg (*Petrović et al., 2021*). In order to achieve the appropriate commercial high quality of cabbage heads, the quality of seeds plays a decisive role in the production of cabbage.

Good quality seeds (high vigor) play a decisive role in the production of every plant species (*Tabaković et al., 2013; Poštić et al., 2019*). In that direction, today most seed houses perform "seed priming" during seed processing due to faster and more uniform germination after sowing. Seed priming techniques are routinely employed to improve germination performances and stress tolerance of commercial seed lots (*Farooq et al., 2019*). Seed priming stimulates the activation of pre-germinative metabolism through an incomplete imbibitions that prepares the seeds for an accelerated and coordinated germination and a more efficient stress response. Primed seeds are subsequently dehydrated (dry-back) and stored in view of sowing or commercialization (*Macovei et al., 2017*).

The aim of this study was to assessment effect of the year and seed lots on most important indicators of cabbage seed quality. The obtained results should contribute to the understanding of the decline in the value of quality indicators of highly hybrid cabbage seeds during aging.

MATERIAL AND METHOD

Our research was done on the seed of nine different cabbage lots (L1, L2, L3, L4, L5, L6, L7, L8 and L9) of Potomac F1 hybrids, which were produced in 2018. year and were imported from France in 2019 to the Republic of Serbia. The seeds were stored in a warehouse packed in PVC bags at a temperature below 15ºC, RH 50%. Cabbage hybrid Potomac F1 is one of the represented hybrids in production in our country, intended for summer and early autumn production. The length of the vegetation period is 75-80 days with an average head weight of 2-3 kg. Due to its good adaptability to environmental conditions and high quality leaves, it has found its place in fresh consumption as well as for pickling.

The evaluation of cabbage seed lots quality indicators (germination energy, total germination, abnormal seedlings and dead seeds) was conducted in 2019, 2020 and 2021 at the Laboratory for Seed and Planting Material Testing of the Institute for Plant Protection and the Environment in Belgrade. The germination testing of nine cabbage seed lots considered was performed using a standard laboratory method 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).

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 was performed using the Tukey method and 95.0% confidence. The variability for each feature is expressed using the coefficient of variation (CV, %). Correlations between the parameters observed were determined using the Pearson correlation coefficient (r).

RESULTS AND DISCUSSION

According to the analysis of variance (ANOVA), our results showed a significant effect ($p<0.01$) of the year (Y) on the all examined parameters seeds (Table 1). The obtained results are consistent with results (*Stanisavljević et al., 2018; Poštić et al., 2020*). Furthermore, a significant effect ($p<0.05$) of the seed lot (L) and interaction (Y × L) on all investigated characteristics was established.

Table 1. F-values for observed factors

Factors	Germination energy	Total germination	Abnormal seedlings	Dead seeds
Year (Y)	**	**	**	**
Lot (L)	*	*	*	*
Y × L	*	*	*	*

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

As expected, the highest germination energy of the seed lots were recorded in 2019 and is very significantly higher, compared to the observed values of germination energy in 2020 and 2021 (Table 2). Decreases in germination energy as a consequence of seed aging were observed earlier on alfalfa seeds (*Stanisavljević et al., 2018*) and on tomato seeds (*Poštić et al., 2020*). The average germination energy of the examined lots in 2019 was (95%), in 2020 (74%), and in 2021 only (24%). The values of germination energy of cabbage seeds on average decrease during aging in 2020 by 21%, and in 2021 by 71%, compared to the average germination energy recorded in 2019.

Table 2. Effect year and seed lots on energy germination (%)

Lot (L)	Year (Y)			Average (L)	CV (%)
	2019	2020	2021		
L1	93aA	70bB	25aC	63	55.2
L2	94aA	73abB	24abC	64	56.4
L3	95aA	74aB	28aC	66	52.2
L4	95aA	76aB	22bC	64	58.9
L5	94aA	72abB	20bC	62	61.3
L6	94aA	71bB	24abC	63	56.6
L7	95aA	76aB	28aC	66	52.1
L8	96aA	77aB	26aC	66	54.6
L9	96aA	76aB	22bC	65	57.2
Average (Y)	95	74	24	64	56.7
CV (%)	1.06	3.41	11.26		

* 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;

In the case of total germination (Table 3), the same tendency was observed as in the case of germination energy (Table 2). The highest total germination of seed lots was recorded in 2019 and is significantly higher, compared to the stated values of total germination in 2020 and 2021. The average total germination of examined lots in 2019 was (97%), in 2020 (85%), and (55%) in 2021. The values of the total germination of cabbage seeds on average decrease during aging in 2020 by 12%, and in 2021 by 42%, compared to the average total germination recorded in 2019. Total germination of cabbage seeds in the examined lots in 2019 and 2020 years was above the prescribed minimum value, which is 75% ("Official Gazette of SFRY", no. 47/87).

Seed ageing is a consequence of the production and accumulation of reactive oxygen species (ROS), which are toxic

oxidants that bring about physical and biochemical lesions (*Adetunji, et al., 2020*). The ROS attack major biomolecules such as proteins, nucleic acids, and lipids during oxidative stress, resulting in physiological injuries like the loss of membrane integrity, degradation and inactivation of enzymes and reduced respiration, thereby affecting seed quality, vigor and early seedling growth (*Adetunji, et al., 2021*).

We can conclude that no significant differences were found between the recorded values of germination energy (Table 2) and the total germination (Table 3) of the examined seed lots in 2019, while in 2020 and 2021 significant differences between seed lots were recorded.

Table 3. Effect year and seed lots on total germination (%)

Lot (L)	Year (Y)			Average (L)	CV (%)
	2019	2020	2021		
L1	95aA	82bB	56abC	78	25.6
L2	96aA	82bB	50cC	79	31.0
L3	96aA	84abB	61aC	80	22.1
L4	97aA	85aB	62aC	81	21.9
L5	95aA	84abB	60aC	80	22.5
L6	97aA	84abB	58aC	80	24.9
L7	97aA	85aB	54bC	79	28.2
L8	98aA	86aB	52bcC	82	30.3
L9	98aA	88aB	46cC	77	36.6
Average (Y)	97	85	55	79	25.0
CV (%)	1.17	2.22	9.76		

* 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 number of abnormal seedlings (Table 4) increases very significantly with increasing age of cabbage seeds and ranges in a very wide range from 1% in 2019 to 51% in 2021. The largest number of abnormal seedlings was recorded in 2021 and is significantly higher, compared to the stated values of abnormal seedlings in 2020 and 2019. The average number of abnormal seedlings in 2019 was (1%), in 2020 (10%), and (38%) in 2021. The average values of the number of abnormal seedlings increase during aging in 2020 by 9%, and in 2021 by 37%, compared to the number of abnormal seedlings recorded in 2019.

Table 4. Effect year and seed lots on abnormal seedlings (%)

Lot (L)	Year (Y)			Average (L)	CV (%)
	2019	2020	2021		
L1	2aC	15aB	41bA	19	102.7
L2	1aC	15aB	36cA	14	136.8
L3	1aC	13aB	34cA	16	104.4
L4	1aC	12abB	34cA	16	107.3
L5	2aC	12abB	36cA	17	104.8
L6	1aC	11bB	36cA	16	112.7
L7	1aC	12abB	42bA	18	115.8
L8	1aC	11bB	34cA	15	110.4
L9	1aC	10bB	51aA	20	129.0
Average (Y)	1	12	38	17	133.2
CV (%)	36.08	15.31	14.73		

* 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;

Based on the obtained results, we can conclude that the total germination of highly hybrid conventional cabbage seeds decreases significantly during aging, as a direct consequence of a very significant increase in the number of abnormal seedlings. The same conclusions were reached by *Poštić et al. (2020)*, assessing the germination of tomato seeds. The most common form of seedling deformity is the primary root is missing or stunted, among others (trapped primary root in the seedling, short hypocotyl and necrotic cotyledons.

The percentage of dead seeds (Table 5) increases with increasing age of cabbage seeds, as well as the number of abnormal seedlings (Table 4), but unlike the number of abnormal seedlings, it ranges in a very narrow range from 1% in 2019 to 6% in 2021. Observed by years, the highest number of dead seeds of 4% on average was recorded in 2021 and was slightly higher compared to the stated values of the number of dead seeds of 3% and 2% in 2020 and 2019, respectively. The percentage of dead cabbage seeds of different batches of cabbage increased with increasing age, but only by 1% per year.

The coefficient of variation can be stated that for germination energy (Table 2) and total germination (Table 3) it increases with seed age, while in abnormal seedlings (Table 4) and dead seed (Table 5) it has the opposite tendency.

Table 5. Effect year and seed lots on dead seeds (%)

Lot (L)	Year (Y)			Average (L)	CV (%)
	2019	2020	2021		
L1	3aA	3bA	3bA	3	0
L2	3aA	3bA	4abA	3	17.3
L3	3aA	3bA	5aA	4	31.5
L4	2aA	3bA	4abA	3	33.3
L5	3aA	4abA	4abA	4	15.7
L6	2aA	5aA	6aA	4	48.0
L7	2aA	3bA	4abA	3	33.3
L8	1bA	3bA	4abA	3	57.3
L9	1bA	2bA	3bA	2	65.5
Average (Y)	2	3	4	3	33.3
CV (%)	37.50	25.86	22.57		

* 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;

Coefficients of correlation (r) point out different the interdependence between the seed quality parameters by years (Table 6). The strongest correlation between the examined parameters was in the first year and weakened in the second and third years. In the first year as expected, significant positive correlation between germination energy and total germination was found ($r = 0.84779$, $p<0.01$) these results agreement with the results (*Stanisavljević et al., 2017; Poštić et al., 2020*). The highly and negative interdependence was achieved between total germination and dead seeds ($r = -0.94363$, $p<0.001$) and abnormal seedlings ($r = -0.78019$, $p<0.05$). Also negative interdependence was found between germination energy and dead seeds ($r = -0.80000$, $p<0.01$) and abnormal seedlings ($r = -0.66144$, $p<0.05$).

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

Traits		Germination energy	Total germination	Abnormal seedlings	Dead seeds
2019	Germination energy	-	0.84779**	- 0.66144*	- 0.80000**
	Total germination		-	- 0.78019*	- 0.94363***
	Abnormal seedlings			-	0.52915
	Dead seeds				-
2020	Germination energy	-	0.75057*	- 0.17761	- 0.58152
	Total germination		-	0.02710	- 0.39044
	Abnormal seedlings			-	0.08552
	Dead seeds				-
2021	Germination energy	-	- 0.01968	- 0.12702	0.22954
	Total germination		-	- 0.67661*	0.28030
	Abnormal seedlings			-	- 0.57957
	Dead seeds				-

Pearson correlation coefficient: *** P≤ 0.001, ** P≤ 0.01, * P ≤ 0.05, respectively

In the second year significant positive correlation only was found between germination energy and total germination ($r = 0.75057$, $p<0.05$), while in the third year a significant negative interdependence ($r = -0.67661$, $p<0.05$) was only noted between total germination and abnormal seedlings.

CONCLUSION

Year (L) had a strong impact ($p<0.01$), while seed lot (L) and their interaction (Y × L) showed a significant effect ($p<0.05$) on all observed parameters quality (germination energy, total germination, abnormal seedlings and dead seeds) conventional seeds cabbage.

The cabbage examined seed lots, a very significant decrease in the percentage of germination energy and total germination was observed with increasing seed age, while the number of abnormal seedlings in particular and the number of dead seeds had the opposite tendency. Germination of cabbage seeds in the third year decreases by an average of 45%, which is a due to consequence of the increase in the number of abnormal seedlings by 37% in the third year. The strongest correlation between the examined parameters was in the first year and weakened in the second and third years. The obtained results indicate that the germination of highly hybrid conventional cabbage seeds decreases significantly during aging, as a direct consequence of a very significant increase in the number of abnormal seedlings.

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