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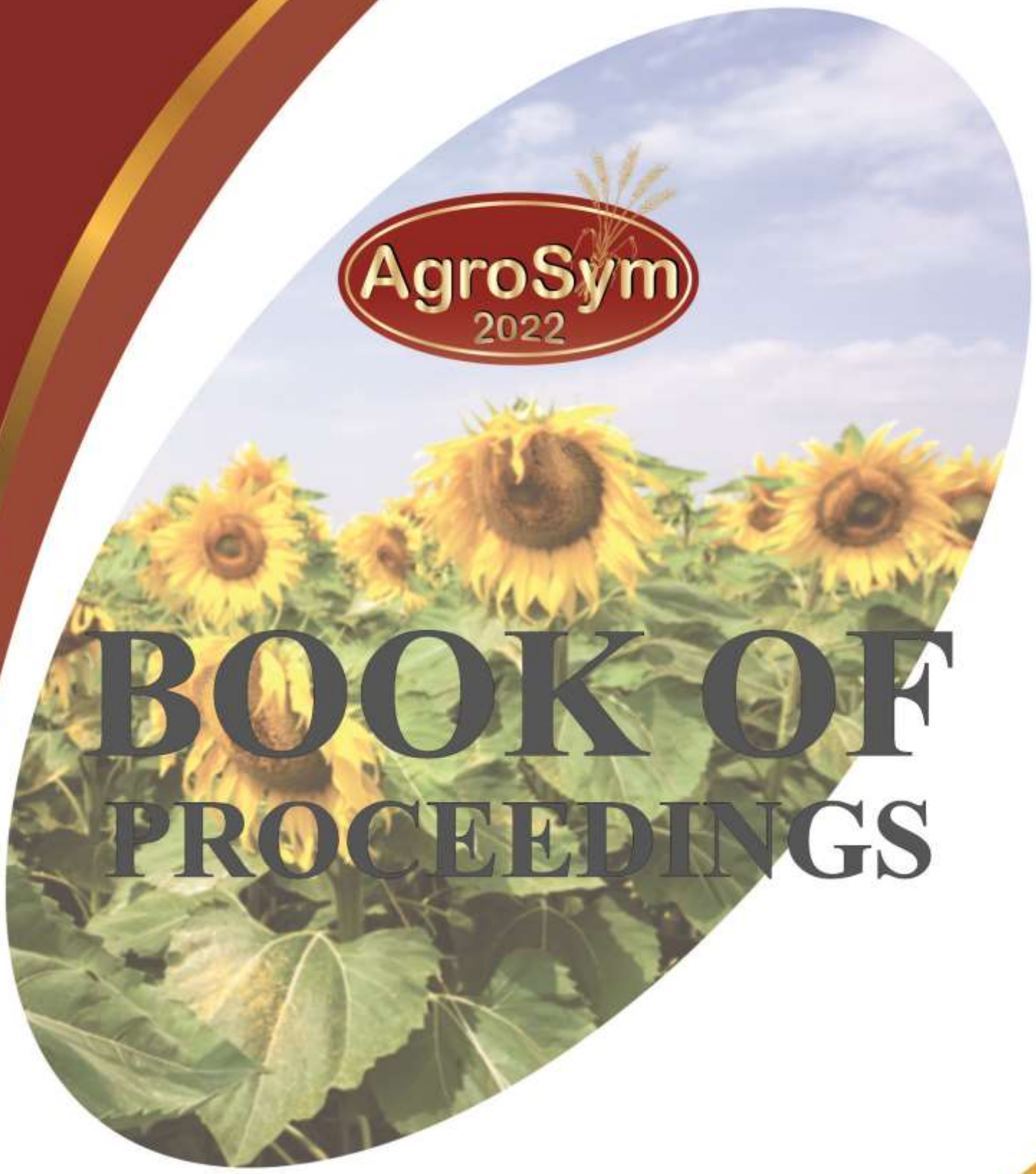

BOOK OF PROCEEDINGS

XIII International Scientific Agriculture Symposium "AGROSYM 2022" October 6-9, 2022

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Jahorina, October 06 - 09, 2022

EFFECTS OF PHYTOPATHOGENS ON THE QUALITY PARAMETERS OF CARROTS SEEDS (*DAUCUS CAROTA* L.) IN A THREE-YEAR PERIOD

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Abstract

Carrot (*Daucus carota* L.) is one of the most important root vegetables in the Apiaceae family grown around the world. Production of carrots in Serbia is generated in Vojvodina with the highest yields 27.4 t/ha, while other regions generate lower yields. Current studies on carrots mainly focus on nutrient content and carotenoid synthesis. Seeds can be infected with phytopathogens, which can contaminate other seeds or spread the infection to other crops. Out of the 16% of annual crop losses due to plant diseases, at least 10% are caused by seed-borne diseases. Changes in the quality of Nantes carrot seeds were monitored for three years (2019-2021). Total germination was highest in the first year with 92% (2019). In 2020, there was a significant decrise in total germination of 8%. Accordingly, germination energy was reduced ($p<0.05$). A statistically significant difference in total germination was not obtained between 2020 and 2021 ($p>0.05$). The decrease in total germination from 2019 to 2021 was significant ($p<0.05\%$). It has been noticed that the infection of *Alternaria* spp. and *Fusarium* spp. was the lowest in 2019 and increased in 2020 and 2021 (4% and 5%, $p<0.05$), respectively. The results may indicate an association between the percentage of phytopathogens present and germination. In conclusion, pathogen-free seeds are necessary to create a healthy plant population, better germination and higher yields.

Keywords: *seed, carrot, germination, quality, phytopathogens.*

Introduction

Carrot (*Daucus carota* L.) is one of the most important root vegetables in the Apiaceae family grown around the world (Que et al., 2019). The largest producer of carrots in the world is China, which generates 43% (Que et al., 2019; Xiong, 2010) of the total yield of carrots in the world. According to the data published by the Statistical Office of the Republic of Serbia from 2020, carrots were grown on 2,662 ha, with a total production of 52,740 tons. Production of carrots in Serbia is generated in Vojvodina with the highest yields 27.4 t/ha, while other regions generate lower yields (The Statistical Office of the Republic of Serbia, 2021). Current studies on carrots mainly focus on nutrient content and carotenoid synthesis (Sumekar Y., 2019). Seeds can be infected with phytopathogens, which can contaminate other seeds or spread the infection to other crops. Out of the 16% of annual crop losses due to plant diseases, at least 10% are caused by seed-borne diseases. The leaf blight is widely recognized as one of the most common and destructive carrot diseases caused by the pathogen *Alternaria dauci*(le Clerc et al., 2009). The diseases associated with *Alternaria* leaf blight cause root decay, which reduces carrot stands as

well as the quality of root. Diseases associated with alternariosis cause decay aboveground foliage and root which reduces the nutrients of carrots, as well as the quality and market usability of the root (Smoleń et al., 2016; Boedo et al., 2008, Farrar et al., 2004). Fungal infection of seed may occur during seed production, storage and transport. Infection ultimately resulting by decreasing germination and vigor, shortening the storage period, and inducing physiological change (Boedo et al., 2008). According to ISTA Rules, 2020 for selecting high-quality seeds the most common methods are based on physical properties, such as weight and germination as well as biochemical and other physical tests.
The aim of our research was to determine the changes in the seed quality of autochthonous carrot varieties: Nantes and Šantenej over a period of three years.

Material and method

Seed testing of two carrot varieties (*Daucus carota* L.): Nantes and Šantenej was performed by standard methods for assessing the quality and health of the seeds in the laboratory for seed quality testing at Institute for Vegetable Crops, Smederevska Palanka (Serbia). All tested seeds of two varieties of carrots are from the same locality in Smederevska Palanka in the periods from 2019 to 2021. The quality parameters (energy and total germination), seed health and moisture were used to assess the quality of two carrot seed varieties. The seed quality of selected carrot varieties was tested following the Regulations on the quality of agricultural plants (47/87), which is harmonized with the ISTA rules (2020). The seed germination parameters (energy and total germination) are performed using filter paper standard method. Samples of selected carrot varieties consisted of 100 seeds in four replicates were placed in petri dishes with filter paper moistened with 0.2% KNO3. Analysis of germination parameters indicates abnormal germs (damaged, defined, rot) have not developed by the end of the tested time and cannot develop into a normal plant and. The set samples were incubated for 7 and 14 days at 23ºC. The seed health of Nantes and Šantenej was tested on *Alternaria* spp. and *Fusarium* spp. Health testing of two varieties of carrot was performed with the standard method on filter paper. The allowed percentage of infected seeds was 5%. After incubation, the results were scored according to the following formula:

$$\text{Seed health} = \frac{\text{number of infected seeds}}{\text{total number of seeds}} \times 100\ \%$$

Moisture content is defined as the water in the seed and is expressed as a percent. The moisture testing procedure is performed with 5 g of a sample of three pepper varieties on an analytical balance. Moisture determination is performed at a temperature of 105ºC ± 2ºC for 17 h ± 1 h. Dry mass (SM) calculation is performed according to the following formula and is expressed at one decimal place:

$$SM=\frac{m3-m1}{m2-m1} \times 100\ \%$$

m1 (g) – the mass of a container and lid;
m2 (g) – the mass of a container, lid, and contents before drying;
m3 (g) – the mass of a container, lid, and contents after drying.

Statistical analysis was done with SPSS software (version 23, IBM, USA). Samples (done in triplicates) were compared with one-way ANOVA and Tukey post-hoc test. Statistical significance cutoff was $p< 0.05$.

Results and Discussion

Carrots (*Daucus carota* L.) are an important vegetable that is grown all over the world and represented a source of nutrients in the human diet. The analyses of quality parameter values (total germination, energy, seed health and moisture) were monitored from 2019 to 2021.nSeeds quality is one of the key factors for high yield production. In many crops, fungal infections are responsible for low-quality seeds. Carrot varieties (Nantes and Šantenej) were compared to each other, with a statistically significant difference between varieties and within one group in three years (Table 1).

Table 1. Quality parameters of carrot seeds (total germination energy, and moisture) in the three years period (2019 –2021).

Samples	**Total germination[a] (%)**			**Germination energy[a] (%)**			**Moisture content[a] (%)**		
	2019	**2020**	**2021**	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**
Nantes	92[b*]	85	84	69[*]	64[b]	65	8.6[b*]	8.4[*]	8.0[*]
Šantenej	87[*b]	82[*]	79[*b]	68[*]	60[*b]	63	8.1[b*]	7.8[b*]	7.5[b*]

a Qualty parameters were compared on statistical significance ($p<0.05$) with years and between varieties of carrots but not between parameters.

* Statistical significance between years ($p<0.05$)

b Statistical significance between varietes

The total germination for Nantes (2019) was 92%, germination energy 69% while *Alternaria* spp was detected 1 % and *Fusarium* spp was not detected (Table 1 and 2). When observing and comparing the total germination and energy of variety Nantes in 2019 and 2020, a statistical difference was observed ($p<0.05$). The total germination between 2020 and 2021 was not statistically significant and amounted to 85% and 84%, respectively. The total germination for Šantenej was 87 % (2019), decreased by 5% and 8%, in 2020 and 2021, respectively ($p< 0.05$). Comparing 2020 and 2021, it was noticed that there was no statistically significant difference between two experimental years ($p>0.05$). The decline in total germination was accompanied by a decrease in germination energy from 2019 to 2021. However, Nantes carrot seeds had better energy and overall germination as compared to Šantenej variety. (Table 1 and Figure 1).

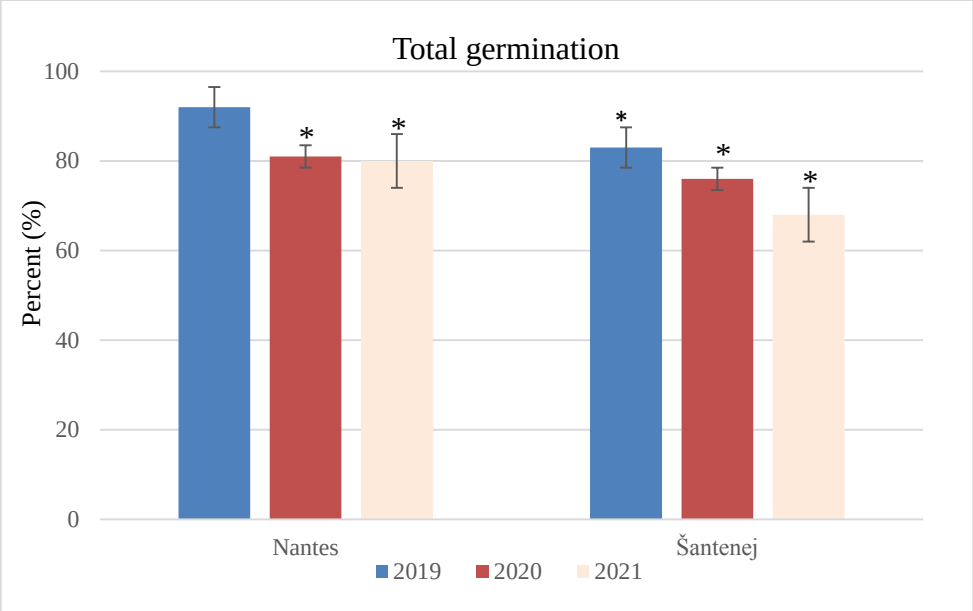

Figure 1. Total germination for two carrot varieties ((Nantes and Šantenej) as observed during three years with statistical significance p <0.05 using ANOVA one-way analysis.

For both varieties phytopathogens were detected in 2020 and 2021 in the higher percent than in 2019 (p<0.05) **(Table 2)**. Fungi can infect seeds by sticking to the surface of the seeds or by penetrating the seeds and causing infection later, resulting in deterioration. One of the factors that determines the effectiveness of chemical seed treatments is how much they can reach and be effective because deep-rooted infections can remain unchanged. For both pathogens during the three years of testing, except for 2021 (detected 5 % *Alternaria* spp), Nantes proved to be a more resistant variety compared to Šantenej (p<0.05) ((**Table 2**).

Table 2. Presence of phytopathogenic fungi in the seeds of selected pepper varieties

Samples	***Fusarium* spp (%)**			***Alternaria* spp (%)**		
	2019	**2020**	**2021**	**2019**	**2020**	**2021**
Nantes	0^{*b}	1^{b}	1	1^{*b}	4	5
Šantenej	1	3^{*b}	2	2^{*b}	5	4

* Statistical significance between years (p<0.05)

b Statistical significance between varietes. (p<0.05)

During seed production, storage, and transport, the seeds are exposed to many factors, ultimately resulting in fungal infections that may adversely affect seeds by decreasing germination, vigor and physiological change. Similar to the study by Zhang et al., 2020, in our study, seed infection rates differ among the tested carrot varieties. Indicating that resistance to seed pathogens could be varietal characteristic. Seed testing is crucial to ensure seed efficiency to determine whether infection levels are at or below economic thresholds. Prevention of carrot diseases caused by *Alternaria* spp is a challenge that aims to achieve or maintain the health of plants and seeds. (Farrar et al., 2004, Li et al., 2017). Since the of these diseases are transmitted by seeds in most

areas where carrots are grown, *Alternaria* spp can appear on the leaves and roots as black rot, which causes a large loss of yield (Biswas et al., 2015, Farrar et al., 2004). Selection of carrot varieties uninfected with fungi is a good agronomic practice to minimize the chances of fungal infections (Salim et al., 2022). Currently, there are no varieties of *Daucus carota* L with total resistance for *Alternaria spp*. Several studies with plant extract indicated their antifungal effect of medical plant extracts as treatments can inhibit fungal infection such*Alternaria alternate, Alternaria solani, Fusarium oxysporum, Rhizoctonia solani* on seeds. The ability of the extracts to increase seed germination and seedling germination can be attributed to controlling the infection of fungi found in the seed (Hasan et al., 2005; Tagoe et al., 2011). Baka et al., 2014 and Eltamany et al., 2012 showed that used plant extracts can reduce infection and prolong the quality of natural seeds. This indicates the possibility of reduced infection in Šantenej and Nantes.

Conclusion

Although, seed quality and health depend on agronomic measures such as fertilizer, irrigation, crop rotation, handling, and proper seed storage. These techniques contribute to yield improvement. Future research could be focused on plant extracts as natural disinfections for seeds and alternative to fungicide treatments. Quality parameters for two varieties of carrots were observed for three years and were below the legal maximum. Based on a three-year's period, it can be classified as a quality seed. The results indicated there was a relationship between germination and the percentage of phytopathogens on the seed. In the future, untreated seeds can be treated with some medicinal plants that could increase and prolong the quality of our seeds, but that remains for future research.

Acknowledgment

The research was financed by the Ministry of Education, Science and Technological Development, the Republic of Serbia, the project TR 31018, the Fund Innovation Activity, the Republic of Serbia, project IP 285, and 451-03-9 / 2021-14 / 200216

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