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GERMINATION, VIGOUR AND HEALTH OF PRIMED *Allium cepa* L. SEEDS AFTER STORAGE

Hanna Dorna, Magdalena Jarosz, Dorota Szopińska, Izabela Szulc, Agnieszka Rosińska

Poznań University of Life Sciences

Abstract. Priming is one of the most common methods of improving seed quality, which many a time significantly affecting their storability. The influence of two storage temperatures on germination and vigour of hydro- and osmoprimed onion (*Allium cepa* L.) seeds and the incidence of seed-borne fungi was examined. Seeds cv Wolska were osmoprimed in polyethylene glycol (-1.5 MPa, 15°C, 7 days, darkness) or hydroprimed by addition of water to the seeds (500 µl of distilled water per 1 g of seeds, 20°C, 48 h, darkness). After priming seeds were dried back at 20°C and 45% RH for 48 h. The primed and non-primed onion seeds were stored in air-tight plastic containers for 6 and 12 months at 4 and 20°C. The seed germination, vigour and health tests were performed before and after storage for untreated and treated seeds at 10 and 20°C. The results showed that for maximal seed viability and germination rate after 6 and 12 months storage, both hydro- and osmoprimed seeds should to be stored at 4°C rather than 20°C. Osmopriming significantly increased seed infestation with *Penicillium* spp., which remained stable up to 12 months storage. The number of seeds infested with *Botrytis* spp. significantly decreased after priming and storage, especially at 20°C.

Key words: onion, seed quality, hydropriming, osmopriming, *Botrytis* spp., *Penicillum* spp.

INTRODUCTION

Onions are an important food crop worldwide. Quality of onion seeds depends on many factors, such as: environmental conditions during growth of mother plant and seed development, location of seeds on the plant, time and technology of seed harvesting, storage conditions and methods of pre-sowing seed treatment. Brocklehurst [1985] as the main reasons of low quality of onion seeds listed: long flowering period resulted in different stages of seed maturity in the umbel, very fast reduction of seed viability if stored in suboptimal conditions and seed infestation with fungi. Seeds infected with

Corresponding author: Hanna Dorna, Dorota Szopińska, Department of Seed Science and Technology, Poznań University of Life Sciences, Baranowo, ul. Szamotulska 28, 62-081 Przeźmierowo, Poland, e-mail: dorota.szopinska@up.poznan.pl

Botrytis allii Munn, *B. byssoidea* Walker and *B. cinerea* Pers. ex Pers. had been shown to be a major source of severe diseases of onion crop, such as seedling damping off, neck rot of stored onion bulbs, and grey mould [Chilvers and du Toit 2006, Maude and Presly 1977a, 1977b, Richardson 1990]. Tylkowska and Dorna [1996, 2001], apart from pathogens, detected on onion seeds numerous saprotrophic fungi from the genera: *Alternaria*, *Aspergillus*, *Cladosporium*, *Epicoccum*, *Penicillium* and *Rhizopus*. Among them *Aspergillus* spp. and *Penicillium* spp. could strongly influence viability of the seeds during storage [Maude 1996]. The germination of onion seeds, especially under stressful conditions such as low temperature, continues to be a matter of great importance to growers who seed directly in the field. Seed priming is a pre-sowing, controlled-hydration treatment in which seeds are exposed to an external water potential sufficiently low to prevent radicle protrusion but stimulate physiological and biochemical activities [Bradford 1986, Khan 1992]. The process can improve speed and uniformity of germination, especially under adverse conditions such as low and high temperature, salinity and matric stress [Dearman et al. 1987, Frett and Pill 1989, Pill and Finch-Savage 1988, Pill at al. 1991, Wurr and Fellows 1984]. Handling of primed seeds in a dry state have practical advantages for growers, however there are limited and ambiguous reports on the effects of extended storage period of dried primed seeds on their germination and vigour. Drew et al. [1997] observed that primed onion and leek seeds stored at 10°C, maintained viability after one year of storage. Argerich et al. [1989] found that non-primed tomato seeds maintained viability after one year of storage at 4 and 30°C, however, viability and germination rates of primed seeds were significantly reduced after six months storage at 30°C. The results of the studies of Owen and Pill [1994] showed that for maximal germination percentage and rate primed asparagus and tomato seeds after up to three months of storage should be held at 4°C rather than 20°C. Basra et al. [2003] noted that primed canola seeds maintained their increased vigour by six months of low temperature (8°C) storage. Moreover, the authors observed that osmoprimed seeds performed better than hydroprimed. Oluoch and Welbaum [1996] reported that osmotic priming had a deleterious effect on the seed storage life of muskmelon seeds. Drew et al. [1997] in turn found that storing of osmoprimed onion, carrot and leek seeds for 12 months at 10°C, had no effect on a total number of germinating seeds, however negatively affected germination capacity.

Seed infestation with fungi, influencing their storability and condition of plants after sowing, can be additional problem during storage of primed seeds. The deterioration of the health status of seeds after priming has been observed by some researchers [Dorna et al. 2005, Janas et al. 2000, Jensen et al. 2004, Nascimento and West 1998, Tylkowska and Biniek 1996, Tylkowska and van den Bulk 2001, Wright et al. 2003].

The objective of this study was to investigate the effects of hydro- and osmopriming and storage on germination, vigour and health of onion seeds.

MATERIALS AND METHODS

Standard seeds of onion (*Allium cepa* L.), cultivar 'Wolska' (lot number 530/64/13135/404A), obtained from CNOS-PNOS Seed Company in Poznań, were used in the study.

For hydropriming seeds were placed in 100 ml flasks and 500 µl of distilled water per 1 g of seeds was added. Then flasks were sealed with parafilm and an aluminium foil and incubated in darkness at 20°C for 48 h. Afterwards, the seeds were surface dried with blotting paper, placed in semi-open Petri dishes and dried back at 20°C and 45% relative humidity for 48 h to an equilibrium moisture content.

For osmopriming 50 seeds were located in 9 cm diameter Petri dishes on four blotters moistened with 5 ml polyethylene glycol 8000 solution (PEG). The concentration of PEG used was 342 $g \cdot kg^{-1}$ water to give a nominal osmotic potential at 15°C of -1.5 MPa [Michel and Kaufmann 1973]. The Petri dishes were sealed with parafilm and incubated for seven days in darkness at 15°C. After priming the seeds from each replicate were washed separately under a tap water for 5 min and next rinsed three times in sterile water to remove PEG. Afterwards, the seeds were dried in the same way like after hydropriming.

The determination of seed moisture content before storage was carried out by means of the low constant temperature oven method [ISTA 2006]. Moisture content of non-primed seeds was 9.0%, whereas in case of hydro- and osmoprimed seeds respectively 8.5 and 8.6%.

The primed and non-primed onion seeds were stored in air-tight plastic containers for 6 and 12 months at 4 and 20°C.

The seed quality tests were performed before and after storage for untreated and treated seeds. Germination and vigour tests were conducted on six replicates of 50 seeds from each treatment. Seeds were placed in 9 cm diameter Petri dishes containing six layers of blotting paper wetted with distilled water and incubated at 10 and 20°C in darkness for 12 days. After 6 and 12 days of incubation, the percentages of normal seedlings (germination energy and germination capacity) and abnormal diseased and deformed seedlings were evaluated [ISTA 2006]. Additional the total number of germinating seeds (G_{max}) was calculated on the base of vigour test [Jalink and van der Schoor 1999].

Germinating seeds, i.e. showing a visible root protrusion through the seed coat, were counted daily until no new germs occurred and removed from Petri dishes to determined seed vigour. Speed and uniformity parameters: T_{10} (time to germination of 10% of the total number of germinating seeds), T_{50} (time to germination of 50% of the total number of germinating seeds), $U_{75–25}$ (time to germination from 25% to 75% of the total number of germinating seeds) and $U_{90–10}$ (time to germination from 10% to 90% of the total number of germinating seeds) were calculated using SeedCalculator 2.1 software [Jalink and van der Schoor 1999].

For mycological analysis 200 seeds from each treatment were placed on the surface of the potato dextrose agar (PDA) in 9 cm diameter Petri dishes, 10 seeds per dish, and then incubated at 10 and 20°C in darkness for 10 days. Streptomycine at concentration of 100 ppm was added to the PDA to prevent growth of bacteria. Determination of fungi

was based on the appearance of their colonies and sporulation [Machado et al. 2002, Mathur and Kongsdal 2003].

The results obtained, regarding seed germination vigour and health, were compared by means of variance analysis. Duncan's multiple range test was applied to estimate the differences between the means at a level $\alpha = 0.05$.

RESULTS

The tested seed lot was characterized by high total number of germinating seeds (G_{max}) generally exceeding 90% regardless of seed treatment and storage conditions. However, after hydropriming a decrease in G_{max} parameter was observed for seeds incubated at 10°C and after osmopriming for seeds germinated at 20°C. After 12 months storage at 4°C and 20°C non-primed seeds germinated at the lower percentages than before storage after incubation at 20°C. The significantly lower G_{max} parameter was also observed at 10°C for osmoprimed seeds stored for 12 months at higher temperature (tab. 1 and 2). Improvement of energy of germination was observed at 10°C for osmoprimed seeds stored for 6 months regardless of storage temperature. The osmotic treated seeds before storage showed better germination capacity at 10°C than non-primed seeds. After 6 months non-primed seeds germinated better than seeds before storage and seeds stored for one year. At 10°C, regardless of a period and temperature of storage, there were not significant differences in germination capacity between non-primed and primed seeds. Hydropriming decreased significantly a number of diseased seedlings at 10°C before storage, whereas after osmopriming lower percentages of diseased and deformed seedlings were detected. After storage these benefits were not observed (tab. 1). At higher temperature non-stored and 6 months stored seeds at 4 and 20°C, regardless of treatment, showed the same level of energy of germination and germination capacity. The parameters decreased significantly after one year storage at both temperatures. Osmoprimed seeds showed higher energy of germination than non-primed ones after storage at 4°C, but lower germination capacity after storage at 20°C. Moreover, for hydroprimed seeds stored at lower temperature, a decrease in seed germination capacity was observed in relation to non-primed seeds. The results showed that deterioration of germination after 12 months storage was connected with a significant increase in the percentages of diseased and deformed abnormal seedlings (tab. 2).

Before storage hydro- and osmopriming significantly reduced T_{10} and T_{50} parameters at 10°C, while at 20°C the increase in the speed of seed germination was observed only after osmopriming (tab. 3 and 4). At the same time none of priming methods affected the uniformity of germination at both temperatures. During storage successive deterioration of T_{10} and T_{50} parameters was observed for non-primed seeds after incubation at 10°C. The phenomenon was also noted at 20°C for seeds stored for 6 months at higher temperature. Deterioration of germination uniformity was observed at 10°C for non-primed seeds stored at 20°C regardless of a storage period and at 20°C for seeds stored for one year at both temperatures. In general, acceleration of germination, as an effect of both hydro- and osmopriming, was observed throughout a whole storage period, for seeds incubated at 10°C. Moreover, the effectiveness of osmopriming was in

Table 1. Effect of onion seed priming and storage on germination parameters at 10°C

Storage duration (months)	Storage temperature (°C)	Treatment	Total number of germinating seeds (%)		Energy of germination (%)		Germination capacity (%)		Abnormal diseased seedlings (%)		Abnormal deformed seedlings (%)	
0	–	C[1]	99.0	a	0	b	72.7	d	9.0	a	14.7	a
		HP[2]	94.3	bc	0	b	81.7	cd	2.7	cd	16.0	a
		OP[3]	94.7	ab	0	b	93.3	a	1.7	c–e	0.7	d
6	4	C[1]	93.0	ab	0	b	92.0	a	1.0	de	3.3	cd
		HP[2]	97.7	ab	0	b	93.3	a	2.7	cd	1.7	d
		OP[3]	96.0	ab	19.0	a	90.3	ab	2.0	c–e	1.7	d
	20	C[1]	95.0	b	0	b	93.0	a	2.7	c–e	0.7	d
		HP[2]	95.0	ab	0.3	b	94.7	a	1.7	c–e	1.3	d
		OP[3]	92.7	bc	23.3	a	93.0	ab	1.7	c–e	1.3	d
12	4	C[1]	95.7	ab	0	b	79.0	cd	0.3	e	15.3	a
		HP[2]	95.3	b	0	b	83.3	bc	1.3	c–e	11.3	ab
		OP[3]	96.3	ab	0	b	80.7	cd	3.7	bc	9.7	ab
	20	C[1]	96.0	ab	0	b	80.0	cd	1.3	c–e	9.3	ab
		HP[2]	93.7	bc	0	b	87.0	a-c	1.3	c–e	7.0	bc
		OP[3]	87.0	c	0	b	73.0	d	6.3	ab	13.3	a

[1] Control – untreated seeds; [2] Hydroprimed seeds; [3] Osmoprimed seeds
Means in columns followed by the same letters are not significantly different according to the Duncan's test at the level $\alpha = 0.05$

Table 2. Effect of onion seed priming and storage on germination parameters at 20°C

Storage duration (months)	Storage temperature (°C)	Treatment	Total number of germinating seeds (%)		Energy of germination (%)		Germination capacity (%)		Abnormal diseased seedlings (%)		Abnormal deformed seedlings (%)	
0	–	C	98.7	ab	88.7	a	95.3	ab	1.7	c–e	0.3	e
		HP	96.0	b–e	82.0	a	87.7	b	2.7	b–e	0.7	e
		OP	93.7	c–e	90.3	a	94.0	ab	2.7	b–d	0	e
6	4	C	99.3	a	92.3	a	94.7	ab	0.3	e	0.3	e
		HP	94.7	b–e	92.0	a	94.3	a	1.3	de	0	e
		OP	96.7	a–c	93.3	a	94.3	ab	0.3	e	0	e
	20	C	96.0	b–d	89.3	a	92.7	ab	2.7	b–e	0.7	e
		HP	98.0	ab	92.3	a	95.3	ab	1.7	c–e	0.3	e
		OP	96.3	b–d	89.7	a	93.0	ab	1.0	de	0	e
12	4	C	91.3	de	16.7	d	75.3	c	7.0	b	11.7	d
		HP	96.7	b–d	24.3	cd	44.7	d	14.3	a	36.7	a
		OP	96.3	b–d	37.7	b	66.3	c	3.7	bc	24.7	b
	20	C	91.7	de	23.7	b–d	70.7	c	5.3	b	14.3	cd
		HP	94.7	c–e	32.0	bc	66.3	c	5.7	b	21.3	bc
		OP	90.7	e	10.0	d	30.3	d	16.3	a	43.7	a

For the explanation see table 1

Table 3. Effects of onion seed priming and storage on seed vigour at 10°C

Storage duration (months)	Storage temperature (°C)	Treatment	Speed of germination (days)				Uniformity of germination (days)			
			T_{10}[1]		T_{50}[2]		U_{75-25}[3]		U_{90-10}[4]	
0	–	C	4.19	de	5.22	de	1.15	de	2.23	e
		HP	3.41	g	4.62	g	1.26	de	2.39	de
		OP	2.94	h	3.65	i	0.99	e	2.20	e
6	4	C	4.07	ef	5.14	d–f	1.31	c–e	2.61	c–e
		HP	3.75	fg	4.95	f	1.37	cd	2.66	c–e
		OP	2.58	i	3.53	i	1.13	de	2.22	e
	20	C	4.51	c	6.08	b	1.62	a–c	3.07	a–c
		HP	4.09	ef	5.03	ef	1.17	de	2.34	de
		OP	2.88	h	4.06	h	1.47	b–d	2.93	b–d
12	4	C	4.96	b	6.19	b	1.43	b–d	2.79	c–e
		HP	4.03	ef	5.15	d–f	1.36	c–e	2.70	c–e
		OP	2.85	hi	4.16	h	1.60	a–c	3.16	a–c
	20	C	5.43	a	6.99	a	1.81	a	3.53	ab
		HP	4.52	cd	5.66	c	1.40	b–d	2.81	b–d
		OP	4.00	ef	5.31	d	1.72	ab	3.56	a

[1] time to germination of 10% of the total number of germinating seeds
[2] time to germination of 50% of the total number of germinating seeds
[3] time to germination from 25% to 75% of the total number of germinating seeds
[4] time to germination from 10% to 90% of the total number of germinating seeds
For the other explanations see table 1

Table 4. Effects of onion seed priming and storage on seed vigour at 20°C

Storage duration (months)	Storage temperature (°C)	Treatment	Speed of germination (days)				Uniformity of germination (days)			
			T_{10}		T_{50}		U_{75-25}		U_{90-10}	
0	–	C	2.08	bc	2.58	cd	0.60	e	1.20	de
		HP	1.95	b–e	2.48	de	0.67	c–e	1.36	de
		OP	1.28	h	1.94	f	0.74	c–e	1.40	de
6	4	C	2.15	ab	2.74	a–c	0.66	c–e	1.28	de
		HP	1.95	b–e	2.33	e	0.49	e	1.04	e
		OP	1.42	gh	2.03	f	0.77	c–e	1.55	de
	20	C	2.24	a	2.76	ab	0.66	e	1.37	de
		HP	2.01	b–d	2.50	cd	0.58	e	1.13	e
		OP	1.85	de	2.35	e	0.64	de	1.31	de
12	4	C	2.01	b–e	2.64	b–d	0.94	bc	2.19	bc
		HP	1.66	fg	2.32	e	0.89	c–d	1.84	b–d
		OP	1.22	h	1.87	f	0.85	b–e	1.74	b–e
	20	C	2.08	b–d	2.87	a	1.08	b	2.30	b
		HP	1.83	ef	2.33	e	0.72	c–e	1.63	c–e
		OP	1.92	c–e	2.83	a	1.47	a	3.49	a

For the explanations see table 1 and 3

Table 5. Effects of onion seed priming and storage on seed health at 10°C

Storage duration (months)	Storage temperature (°C)	Treatment	Seed infestation with fungi (%)						Seeds free from fungi (%)	
			Botrytis allii		*Botrytis cinerea*		*Penicillium* spp.			
0	–	C	18.0	a	0.5	c	14.5	de	2.0	de
		HP	16.0	a	1.0	c	6.0	ef	0	e
		OP	1.0	cd	0.5	c	93.0	b	0	e
6	4	C	6.5	b	17.0	a	10.5	de	1.0	de
		HP	2.0	c	6.0	b	16.0	de	0	e
		OP	0	d	0	c	71.5	c	2.0	de
	20	C	0.5	cd	5.0	b	8.0	de	19.0	c
		HP	2.5	c	4.5	b	2.0	fg	3.0	de
		OP	0	d	0	c	97.5	a	0	e
12	4	C	0	d	0	c	15.0	de	50.0	b
		HP	0.5	cd	1.0	c	16.0	d	0	e
		OP	0	d	0	c	99.0	a	0	e
	20	C	0	d	0	c	11.5	de	72.5	a
		HP	0	d	0	c	1.0	g	23.0	c
		OP	0	d	0	c	67.0	c	4.0	d

For the explanations see table 1

Table 6. Effects of onion seed priming and storage on seed health at 20°C

Storage duration (months)	Storage temperature (°C)	Treatment	Seed infestation with fungi (%)						Seeds free from fungi (%)	
			Botrytis allii		*Botrytis cinerea*		*Penicillium* spp.			
0	–	C	29.0	a	1.0	bc	28.0	cd	0	d
		HP	7.0	c	0	c	11.5	f	0	d
		OP	2.5	de	0.5	c	93.0	b	0	d
6	4	C	5.5	cd	17.0	a	21.0	de	0	d
		HP	2.5	de	3.0	b	26.5	cd	0	d
		OP	0	g	0	c	99.0	a	0	d
	20	C	0	g	2.0	bc	27.5	cd	4.5	c
		HP	2.0	ef	1.5	bc	13.0	ef	1.0	cd
		OP	0	g	0	c	100.0	a	0	d
12	4	C	13.5	b	0	c	22.0	de	24.5	b
		HP	5.5	cd	0	c	35.0	c	0	d
		OP	0	g	0	c	99.5	a	0	d
	20	C	0	g	0	c	25.0	cd	51.0	a
		HP	0	g	0	c	11.5	f	1.0	cd
		OP	0.5	fg	0	c	88.5	b	1.5	cd

For the explanations see table 1

each case higher than hydropriming. It was also noted that T_{10} and T_{50} values for both hydro- and osmoprimed seeds increased faster after storage at 20°C than at 4°C. The results were not so clear for seeds incubated at 20°C. Throughout a whole storage period the hydroprimed seeds germinated slower than the osmoprimed ones, if they were stored at lower temperature. However, after one year storage at 20°C, osmoprimed seeds germinated on the level of non-primed seeds, but beneficial effects of hydropriming were still significant. Hydropriming improved also uniformity of germination of seeds at 10°C after 6 and 12 months storage at 20°C. The effect was also observed at 20°C for seed stored for one year at higher temperature. On the contrary, at 20°C osmoprimed seeds after 12 months storage at 20°C germinated less uniformly than non-primed seeds.

A significant and successive increase in the number of seeds free from fungi was observed for non-primed seeds during storage, regardless of incubation temperature (tab. 5 and 6). Moreover, the number of these seeds was increasing faster at 20°C then at 10°C. The level of seed infestation with fungi was quite stable for both hydro- and osmoprimed seeds during a whole storage period. A small increase in the number of primed seeds free from fungi was observed only after 12 months storage at 20°C. After hydropriming a decrease in seed infestation with *Botrytis allii* and *Penicillium* spp. was observed at 20°C before storage. Meanwhile, osmopriming caused a significant decrease in seed infection with *B. allii* and a considerable increase in seed contamination with *Penicillium* spp., regardless of seed incubation temperature. The percentages of non-primed and primed seeds infected with *B. allii* decreased successively with prolongation of a storage period. The phenomenon was observed for seeds incubated at 10°C as well as at 20°C and it was faster if the seeds were stored at higher temperature. The level of seed infection with *Botrytis cinerea* was very low regardless of seed treatment. However, after 6 months storage a significant increase in seed infestation with the pathogen was observed at 10°C for non-primed and hydroprimed seeds regardless of storage temperature and at 20°C, if the seeds were stored at 4°C. High level of seed infestation with *Penicillium* spp., as a result of seed osmopriming, remained quite stable during a whole storage period.

DISCUSSION

Beneficial effects of seed priming on seed vigour had been frequently documented in the literature. However, it is still impossible to ensure that these benefits will be maintained after seed drying and storage.

The results obtained by Dearman et al. [1986] showed that osmoprimed onion seeds, dried to 9% moisture content, and stored 18 months at 10°C, maintained high seed vigour and germination capacity. At the experiment of Han [2003] osmoprimed onion seeds germinated better than non-primed seeds, both before and after storage for 2 months at 5 and 15°C. The author observed also that the effects of hydropriming on vigour of stored seeds were not as unequivocal. He found after storage that the priming method improved germination rate of one seed sample, but the other one showed a decrease in vigour parameters. Drew et al. [1997] found that storing of osmoprimed onion,

carrot and leek seeds for 12 months at 10°C and 50% relative humidity, had no effect on a total number of germinating seeds, however negatively affected germination capacity. Moreover, higher percentage of abnormal seedlings was observed after storage than before. In the present experiment it was also observed that osmoprimed seeds after storage at higher temperature were characterised by lower germination capacity at 20°C in comparison with non-primed seeds. The same phenomenon was observed for hydroprimed seeds stored at 4°C. That process, in both cases, was connected with growing numbers of abnormal deformed and diseased seedlings. On the other hand, values of germination rates (T_{10} and T_{50}) remained lower for primed than for non-primed seeds, during whole storage, especially at 4°C. One of the reported benefits of priming is to repair damages incurred during storage, which would in consequence improved the vigour of aged seeds [Dearman et al. 1986, Rao et al. 1987]. Pereira Kikuti and Marcos-Filho [2008] studied drying and storage procedures that maintain the physiological performance achieved after cauliflower seed hydropriming, without negative effects on storability. The authors observed that the advantages of priming, followed by fast drying, can be maintained up to four months of storage under controlled conditions (20°C, 50% relative humidity). In the present experiment it was observed that storage up to 6 months, regardless of temperature, is quite safe for the primed onion seeds. Although risk of losing the benefits obtained during priming time have been growing with prolongation of storage period. It was observed in the experiment that hydroprimed seeds seem to be less susceptible to higher storage temperature than osmoprimed seeds. The physiological differences between primed and non-primed seeds and the processes occurring during different priming methods had not been completely discovered and understood. Gallardo et al. [2001] observed that priming of *Arabidopsis* seeds led to synthesis and degradation of different proteins that occur during germination. The authors compared osmotic priming in PEG with imbibition in water, and detected significant differences between these two processes. They observed that a level of certain heat shock proteins (HSPs) increased during osmopriming, whereas during hydropriming their level decreased rapidly. It may be assumed that the HSPs might ensure proper folding of other proteins because of their hypothetical chaperone activity, and thus act in protecting the seeds. On the other hand, catalase activity increased, especially during hydropriming, presumably to alleviate oxidative stress occurring during germination. Priming can also reduce lipid peroxidation during seed storage. Choudhuri and Basu [1988] found that hydropriming of onion seeds effectively slowed down physiological deterioration under natural (15 months) and accelerated aging conditions, with the effect being dependent on seed vigour. This improvement was associated with greater dehydrogenase activity and lower peroxide formation in cells. Those phenomena can influence survivability of hydro- and osmoprimed seeds during storage. Nevertheless, it was concluded from our research that for maximal seed viability and germination rate after 6 and 12 months storage, both hydro- and osmoprimed seeds should to be stored at 4°C rather than 20°C. The beneficial effects of low-temperature storage may be attributed to slow down seed deterioration. A high temperature during storage, according to some reports, can be a factor significantly affecting quality of primed seeds. Argerich et al. [1989] detected that osmoprimed tomato seeds, dried to 13% moisture content, maintained high germination capacity after 6 months storage at 4°C, however storage at

30°C resulted in significant decrease of the parameter. Alvarado and Bradford [1998] examined the effect of storage temperature on quality of osmoprimed tomato seeds, dried to 6% moisture content. The seeds were stored at 10, 20 and 30°C. Storage at 10 and 20°C had no influence on germination capacity for 18 months, while a decrease of the parameter was observed after 5 months storage at 30°C.

One of the potential disadvantages of hydro- and osmopriming is an increase of seeds infestation with some pathogenic and saprotrophic microorganisms [Nascimento and West 1998, Tylkowska and Biniek 1996]. Osmopriming increased the number of onion seeds infested with *Penicillium* spp. and reduced significantly seed infection with *B. allii* at the experiment of Zhang [2000]. The author observed additionally, that after the treatment the number of diseased seedlings and dead seeds increased. Dorna et al. [2005] also observed an increase in seed infestation with *Penicillium* spp. after osmopriming. However, the effect of hydropriming on seed health was diverse. In a better germinating sample, a decrease in the percentage of seeds infested with *B. alli* and an increase in the number of seeds colonised by some saprotrophic fungi was observed. On the contrary, in a worse germinating sample, seed infestation with *Penicillium* spp. declined. In the present experiment a significant increase in seed infestation with *Penicillium* spp. was also observed after osmopriming and remained stable during a whole storage regardless of temperature. On the other hand, after hydropriming a decrease in seed infestation with these fungi was detected. This phenomena clearly showed that the way of priming strongly influence the spread of fungi on and in the seeds. The presence of so-called storage fungi can strongly influence a quality of the seeds, especially if they are stored at relatively high temperature and for longer time. Nevertheless, after storage, regardless of treatment, the decrease in the percentage of seeds infested with *Botrytis alli* was observed, especially at 20°C. However, infection of non-primed and hydroprimed seeds with *B. cinerea* increased significantly after 6 months storage at 4°C. The authors suspect that the reduction of the expansion of one of the microorganisms made possible the growth of the second one. Various factors, such as: pathogen and host species, kind and location of inoculum, and method and duration of seed storage, can modified viability of the seed-transmitted pathogens. Fungi with pale hyphae, which have been producing spores with thin cell walls, such as *Botrytis* spp., usually are characterised by short survivability in storage [Maude 1996]. According to discussed results lower temperature of storage can help to maintain beneficial effects of priming, however it can also enable some pathogens to survive. Therefore, it's so important to control health of the seeds destined to priming – first, to avoid losses of seed viability during storage and second, to prevent transmission of seedborne pathogens.

CONCLUSIONS

1. For maximal seed viability and germination rate after 6 and 12 months storage, both hydro- and osmoprimed seeds should to be stored at 4°C rather than 20°C. Hydroprimed seeds seem to be less susceptible to higher storage temperature than osmoprimed seeds.

2. Osmopriming significantly increased seed infestation with *Penicillium* spp., which remained stable up to 12 months storage. However, after storage, especially at 20°C, regardless of a treatment the decrease in the number of seeds infested with *Botrytis* spp. was observed.

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KIEŁKOWANIE, WIGOR I ZDROWOTNOŚĆ KONDYCJONOWANYCH NASION *Allium cepa* L. PO PRZECHOWYWANIU

Streszczenie. Kondycjonowanie jest jedną z popularnych metod poprawy jakości nasion, która niejednokrotnie znacząco modyfikuje ich zdolność przechowalniczą. Badano wpływ sześcio- i dwunastomiesięcznego przechowywania hydro- i osmokondycjonowanych nasion cebuli (*Allium cepa* L.) w temperaturze 4 i 20°C na ich kiełkowanie, wigor i zasiedlenie nasion przez grzyby. Nasiona odmiany Wolska osmokondycjonowano w glikolu polietylenowym (-1.5 MPa, 15°C, 7 dni, ciemność) lub hydrokondycjonowano poprzez dodanie do nasion określonej ilości wody (500 µl wody destylowanej na1 g nasion, 20°C, 48 h, ciemność). Po kondycjonowaniu nasiona suszono w temperaturze 20°C i wilgotności względnej powietrza 45% przez 48 h. Kondycjonowane i niekondycjonowane nasiona przechowywano w szczelnie zamkniętych plastikowych pojemnikach przez 6 i 12 miesięcy, w temperaturze 4 i 20°C. Ocenę kiełkowania, wigoru i zdrowotności nasion wykonano w temperaturze 10 i 20°C, zarówno dla nasion traktowanych jak i nietraktowanych, przed i po przechowywaniu. Na podstawie uzyskanych wyników stwierdzono, że korzystniej na kiełkowanie i wigor nasion kondycjonowanych wpływało przechowywanie w temperaturze 4°C. Osmokondycjonowanie powodowało istotne zwiększenie zasiedlenia nasion przez grzyby rodzaju *Penicillium*, które utrzymywało się na wysokim poziomie przez cały okres przechowywania. Natomiast liczba nasion zasiedlonych przez *Botrytis* spp. zmniejszyła się znacząco po kondycjonowaniu i w trakcie przechowywania, zwłaszcza w temperaturze 20°C.

Słowa kluczowe: cebula, jakość nasion, hydrokondycjonowanie, osmokondycjonowanie, *Botrytis* spp., *Penicillium* spp.

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