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The influence of maleic hydrazide preharvest treatment on quality and storage ability of early onion cultivars at cold store conditions

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Abstract: *The influence of maleic hydrazide preharvest treatment on quality and storage ability of early onion cultivars at cold store conditions.* The aim of the experiment was to determine the influence of maleic hydrazide (Fazor) preharvest treatment on some quality parameters and storage ability of nine popular onion hybrid cultivars from the group of early or semi-early ones: 'Bonus', 'Fireball', 'Spirit', 'Sterling', 'Takmark', 'Takstar', 'Teton', 'Paraat', 'Utopia'. As the reference cultivar, late standard Polish cultivar 'Sochaczewska' was used. Onions were stored for 7 months in a cold store, at the temperature of 1–2°C and RH of 80–85%, an then for one week at simulated retail conditions. Weight losses, percentage of sprouted and rooted onions after storage, darkening level of inner buds, as well dry matter, vitamin C, and essential oils content in freshly harvested and stored onions were determined. Results of the experiment showed that the treatment of onions with MH positively influenced their storage ability. The best storage ability showed cvs. 'Sochaczewska' and 'Spirit', and the worst ability – 'Bonus' and 'Sterling'. MH treatment decreased tendency to sprouting and rooting of onions during storage, and decreased natural weight losses. Vitamin C content in stored onions was higher after MH treatment, compared with untreated onions. Treatment onions with MH significantly affected essential oils content in bulbs, which was lower in the case of the untreated onions. MH treated onions showed the signs of inner buds darkening, but the level of darkening related to the cultivar, and was generally low. The results obtained showed significant influence of MH treatment on decreasing storage losses of early-maturing onion cultivars.

Key words: onion, storage, sprouting, losses, cultivars, maleic hydrazide, Fazor.

INTRODUCTION

Common onion (*Allium cepa* L.) belongs to the group of vegetable species of long durability in storage, however noticeable quality degradation during long-term storage can occur. The reasons of onion postharvest losses are: sprouting, transpiration, cracking of dry scales and storage diseases. Bulb sprouting occurs when the leaf primordia that are produced in stored onion develop green leaves, which elongate and eventually protrude from the neck of the bulb (Chope et al., 2006). The growth rate of the sprout relates to the cultivar and storage conditions. For long-term storage of onions cold store conditions, i.e. temperature of 0°C and RH of about 80% are recommended. However, even at cold store conditions some storage losses can occur. The storage losses are influenced also by a term of harvest. It is believed that optimal term for onion harvest is when 50–80% of plants have bounded leaves but 2–3 leaves on each plant are still green (Gruszecki and Tendaj, 2000; Adamicki and Czerko, 2002). Besides visual changes, changes in chemical composition of onion bulbs

during storage can occur. Concentration of certain substances may coincide with sprouting process in onions (Crowther et al., 2005; Chope et al., 2006).

In respect of storage ability big differences between onion cultivars are observed. It is pointed out in literature that for long-term storage late-maturing cultivars, of long physiological dormancy state, are preferred. Those cultivars show significantly delayed sprouting and rooting process during their storage (Patil and Kale, 1989; Adamicki, 1996, 1998; Adamicki and Czerko, 2002). Other genotype traits positively influencing storage ability are: thick and strong dry scales, resistance to diseases and high dry matter content. For prolonging storage ability of onions, various methods are applied. The most known methods of sprouting inhibition are: treatment bulbs after harvest with ionizing radiation (Gajewski, 1994) and pre-harvest spraying of onion plants with maleic hydrazide (MH).

Maleic hydrazide (1,2-dihydro-3,6--pyrydazynedione) belongs to the group of exogenic plant growth regulators and is classified as a herbicide (Marcano et al., 2004). After entering the onion bulb it shows cell division inhibition action. Preparation Fazor, based on this substance, is produced on the market and applied by vegetable growers. It contains 80% of maleic hydrazide in the form of potassium salt. This chemical is legally approved and commercially applied in most European countries and other countries of the world, also in Poland (El-Otmani et al., 2003; Benkeblia, 2004). MH is applied on onion plants in the field about two weeks before harvest. For better effect of the treatment onions should be uniform in maturity (Adamicki, 1999). Despite of high efficiency of MH, negative effects of its application are sometimes observed. These are softening of onions and darkening of inner buds, what is evident after storage onions at the temperature above 5°C, especially (Kępkowa, 1959).

Onion breeders work on combining good storage ability of onions with short vegetation period. This could increase possibility to store onions grown as an early crop, when there is necessity to prolong market supply. Early time of harvest of these cultivars has an important positive aspect as well, since makes easier natural curing of onions in ambient conditions. However, early and semi-early onion cultivars have generally shorter physiological dormancy period than late cultivars, which are destined especially for storage. This increases the risk of storage losses caused by sprouting and rooting of stored material. The possibilities for increasing the storage ability of these cultivars by maleic hydrazide application have not been studied yet.

The aim of this study was to evaluate the efficiency of maleic hydrazide in storage of onion cultivars from the group of early and semi-early ones. The efficiency was evaluated on the basis of storage losses and some quality traits of onions.

MATERIAL AND METHODS

The experiment was carried out in the season of 2004–2005 on following onion cultivars: ‘Bonus’, ‘Fireball’, ‘Spirit’, ‘Sterling’, ‘Takmark’, ‘Takstar’, ‘Teton’, ‘Paraat’ and ‘Utopia’. These cultivars are classified as early or semi-early ones. As the reference cultivar, ‘Sochaczewska’ was taken. This is standard late-yielding

cultivar of Polish origin, recommended for long-term storage. Onions were cultivated in the individual vegetable farm, near Ożarów Mazowiecki. The field was located on the III class black soil, having the loamy subsoil. Mineral fertilization was performed according to the results of soil analysis, and standard nutrient doses were applied. Seeds were sown on 20 April, and harvest was performed at the optimal maturity stage of each cultivar, from the middle of August. Two weeks before harvest, onions were sprayed with Fazor 80 SG preparation, according to the manufacturer's recommendations.

After harvest, onions were initially cured in the field, and then finally cured at the building. After curing, onions were transported to the cold store facility of the Department of Vegetable and Medicinal Plants. Storage conditions were: temperature of 1–2°C, relative humidity of 80–85%. Onions were stored for 7 months, and then kept at simulated retail conditions (15°C) for one week. The experiment was established as the two-factor one, with four replications in the combination. The factors of the experiment were: cultivar (10 cultivars) and MH treatment (treated or untreated onions). In each replication there were 15 kg of onions in one plastic crate.

Immediately after harvest and after storage period (i.e. 7 months of cold storage + 1 week of 'shelf life') there were determined: dry matter of onions (by drying at 104°C method), vitamin C content (by Tillmans' method), total essential oils content (by distillation of bulbs with water vapour in Deryng's device, according to Farmakopea Polska IV). After storage natural weight losses (in %), weight percentage of sprouted onions (in %) and weight percentage of rooted onions (in %) were determined. For inner buds darkening determination, randomly selected 20 onion bulbs from each replication were cut onto halves. The darkening level was evaluated visually, using 0–5 scale, where: 0 – not detectable darkening, 1 – slight browning of inner buds, without softening of the inner tissue, 2 – more intensive browning, but without softening, 3 – light-brown area surrounding inner buds, slight softening of the inner tissue, 4 – brown inner buds with some softening 5 – dark-brown inner buds area, soft inner tissue of the bulb.

Results were statistically elaborated with Anova, using Statgraphics Plus 4.1 software. Tukey's HSD test was used to determine significance of differences between values. LSD values for interaction between cultivar and the treatment were calculated at $P = 0.05$.

RESULTS AND DISCUSSION

Sprouting of onion bulbs is the main reason of storage losses when the bulbs are stored in uncontrolled conditions, which typically occur in common storehouses (Adamicki, 1999; Gajewski, 2005). Early onion cultivars, chosen for the experiment, showed big differences in respect of the tendency to sprouting during storage period (Tab. 1). In the case of the untreated plants, there were found cultivars characterized by a very low level of sprouting (cvs. 'Spirit', 'Takmark', 'Utopia'), and the cultivars with all bulbs sprouted ('Bonus', 'Sterling', 'Takstar'). Since sprouted bulbs are non-marketable, it means that these totally sprouted cultivars shouldn't be destined for storage. However, the treatment with

MH caused significant decreasing of sprouting process for all cultivars. The highest level of sprouting in the case of treated onions was observed for cv. 'Takstar' (about 10% of onions sprouted). The same cultivar showed also the highest percentage of rooted onions after storage, even with MH treatment (45% rooted bulbs) (Tab. 1). It is evident that rooting of bulbs of all early cultivars was generally on a high level (except for cv. 'Spirit'). Generally, the treatment of onions with MH was very efficient in this respect, and decreased the percentage of rooted bulbs to the acceptable amount. In other storage experiment, cvs 'Paraat' and 'Bonus' showed also quite high level of bulbs rooting (Gajewski et al., 2005). The late-yielding cultivar 'Sochaczewska', taken as the reference, showed lower tendency to sprouting, both when treated and untreated. This opinion is in agreement with literature data concerning characteristics of this cultivar (Adamicki, 1999). Slightly differentiated effect of MH treatment for various cultivars can be explained by the differentiation in physiological stage of the bulbs at the time of the treatment. It is known, that the effect of MH treatment can be lowered as a result of too early or too late term of onion treatment in the field (Adamicki and Czerko, 2002).

The other reason of storage losses was natural weight loss, caused by respiration and transpiration processes. The level of natural weight loss was affected by the cultivar, but related also to the treatment with MH (Tab. 1). It can be noticed that cultivars of high tendency to sprouting or rooting showed also the highest level of natural weight loss. It is understandable, since sprouting or rooting opens the 'doors' to gas exchange, so water vapour can diffuse from the bulb tissues quite easily.

Onions treated with MH showed signs of darkening of inner buds, which were observed on various intensity levels, depending strongly on the cultivar

TABLE 1. Storage losses of onion bulbs in relation to the cultivar and treatment with maleic hydrazide (%)

Cultivar	Percentage of sprouted onions (%)		Percentage of rooted onions (%)		Weight losses (%)	
	treated	untreated	treated	untreated	treated	untreated
Bonus	0.0	100.0	16.1	100.0	6.5	9.2
Fireball	0.0	0.2	0.0	48.5	8.0	5.5
Spirit	0.0	0.0	0.0	14.5	3.5	4.0
Sterling	1.2	100.0	0.2	100.0	14.9	19.2
Takmark	0.0	0.5	0.0	15.0	5.0	13.8
Takstar	10.1	100.0	44.9	100.0	7.5	8.7
Teton	0.0	14.5	3.0	65.0	6.0	13.8
Paraat	0.0	10.0	8.9	82.9	7.0	7.2
Utopia	3.1	0.2	0.0	60.1	12.9	16.9
Sochaczewska	0.0	1.1	6.1	9.0	5.5	6.5
Means	1.4 a	32.7 b	7.9 a	59.5 b	7.7 a	10.5 b
LSD at P = 0.05 for interaction	2.8		5.7		0.9	

Note: means marked with the same letters do not differ according to Tukey's HSD test at P = 0.05.

(Tab. 2). The phenomenon of inner buds darkening was reported already in one of the earliest work, carried out by Kępkowa (1959) on onions cv. 'Wolska'. Darkening of the bulbs inner tissue is an effect of destroying of young cell structures by MH and is observed also in the case of onions treated with ionizing radiation for sprouting inhibition (Gajewski, 1994). The highest level of darkening was observed for cvs. 'Sterling' and 'Teton', however cvs. 'Fireball' and 'Takmark' showed lack of darkening or a very low level of this phenomenon.

Onion bulbs contain typically 8–12% of dry matter. Cultivars containing high amount of dry matter are generally believed as more suitable for long-term storage (Chope et al., 2006). Investigated cultivars showed mean level of dry matter content (Tab. 3). Dry matter in stored onions was significantly affected by the MH treatment and was higher in treated onions. However, significant differences between cultivars in dry matter content were also evident. The highest dry matter content immediately after harvest was found in cv. 'Paraat'. Compared to freshly harvested onions, stored onions showed some changes in respect of dry matter content, but these changes did not show any clear tendency.

Onion is a significant source of vitamin C in human nutrition. According to the literature, vitamin C content is differentiated among onion cultivars and varied from 40 to 170 $mg \cdot kg^{-1}$ f.w. (Hallmann and Rembiałkowska, 2006). Vitamin C content in freshly harvested onions varied from 25 to 72 $mg \cdot kg^{-1}$ and the increasing tendency in vitamin C content for MH treated onions was found after storage period (Tab. 4). For the untreated onions, significantly lower level of this vitamin was noted after storage. The arise of ascorbic acid content for long-term stored onions was reported by Mahmoud et al. (1978).

Onions are eaten for their unique taste, which is related to essential oils content in bulbs. High content of essential oils results in a sharp, spicy flavour of onions. These compounds are very unstable and easy change enzymatically to other chemical compounds (Kopsell et al., 1999). Essential oils content in the bulbs was

TABLE 2. Level of darkening of inner buds in stored onions treated with maleic hydrazide, in relation to the cultivar, in scale 0–5

Cultivar	Percentage of onions of following darkening level (in %)					
	0	1	2	3	4	5
Bonus	61	39	0	0	0	0
Fireball	100	0	0	0	0	0
Spirit	21	19	22	20	18	0
Sterling	0	0	0	91	9	0
Takmark	92	8	0	0	0	0
Takstar	11	29	51	9	0	0
Teton	0	0	0	62	38	0
Paraat	0	0	0	79	21	0
Utopia	12	11	9	80	8	0
Sochaczewska	0	0	50	39	11	0
Means	30	11	13	38	11	0

TABLE 3. Dry matter in onion bulbs in relation to the cultivar and treatment with maleic hydrazide (%)

Cultivar	Freshly harvested	After storage	
		treated onions	untreated onions
Bonus	9.3	10.3	6.4
Fireball	10.4	10.3	10.9
Spirit	10.8	9.2	6.6
Sterling	8.1	9.4	7.7
Takmark	10.8	9.4	8.6
Takstar	9.4	10.1	9.7
Teton	9.8	11.1	7.5
Paraat	11.3	10.4	7.9
Utopia	8.3	7.2	6.9
Sochaczewska	10.2	10.4	8.8
Means	9.8	9.8 b	8.1 a
LSD at P = 0.05 for interaction	x	1.4	

Note: means marked with the same letters do not differ according to Tukey's HSD test at P = 0.05.

TABLE 4. Vitamin C content in onion bulbs in relation to the cultivar and treatment with maleic hydrazide (mg kg^{-1} fw)

Cultivar	Freshly harvested	After storage	
		treated onions	untreated onions
Bonus	25	82	43
Fireball	30	41	38
Spirit	72	92	38
Sterling	38	54	38
Takmark	43	83	36
Takstar	58	80	43
Teton	43	54	40
Paraat	58	94	46
Utopia	46	73	38
Sochaczewska	71	98	36
Means	48	75 b	40 a
LSD at P = 0.05 for interaction	x	15	

Note: means marked with the same letters do not differ according to Tukey's HSD test at P = 0.05.

strongly affected by the cultivar, but the influence of MH treatment was also evident (Tab. 5). The treated bulbs showed higher level of essential oils after storage than the untreated ones. Compared with the freshly harvested bulbs, the content of these compounds in the treated bulbs was generally on similar level.

CONCLUDING REMARKS

1. Investigated onion cultivars showed big differences in respect of storage ability. The best storage ability had 'Sochaczewska' and 'Spirit', and the worst 'Bonus' and 'Sterling' cvs.
2. Application of maleic hydrazide on onions decreased storage losses caused

TABLE 5. Essential oils content in onion bulbs in relation to the cultivar and treatment with maleic hydrazide (%)

Cultivar	Freshly harvested	After storage	
		treated onions	untreated onions
Bonus	0.11	0.08	0.06
Fireball	0.08	0.16	0.09
Spirit	0.16	0.08	0.06
Sterling	0.17	0.10	0.08
Takmark	0.08	0.12	0.05
Takstar	0.09	0.14	0.08
Teton	0.10	0.11	0.11
Paraat	0.13	0.14	0.06
Utopia	0.08	0.09	0.07
Sochaczewska	0.08	0.14	0.11
Means	0.11	0.12 b	0.08 a
LSD at P = 0.05 for interaction	x	0.02	

Note: means marked with the same letters do not differ according to Tukey's HSD test at P = 0.05.

by sprouting and rooting of bulbs. This resulted also on decreasing of natural weight losses of the onions.

3. The level of darkening of inner buds after treatment with maleic hydrazide differed for the cultivars, but was generally on a low level.
4. Treatment onions with maleic hydrazide affected significantly essential oils content in bulbs, which was lower in the case of the untreated onions.
5. Vitamin C content in stored onions was higher in the case of onions treated with maleic hydrazide, compared with the untreated onions.
6. Taking into account the quality traits of stored onions, the positive influence of MH treatment was evident, and this chemical can be useful for prolonging storage period of early onion cultivars.

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Streszczenie: *Wpływ przedzbiorczego traktowania wczesnych odmian cebuli hydrazydem kwasu maleinowego na ich jakość i trwałość przechowalniczą w warunkach chłodniczych.* Celem doświadczenia było zbadanie wpływu hydrazydu kwasu maleinowego (preparat Fazor) na cechy jakościowe i straty przechowalnicze cebuli zwyczajnej (*Allium cepa* L.) dziewięciu odmian, z grupy wczesnych i średnio-wczesnych: 'Bonus', 'Fireball', 'Spirit', 'Sterling', 'Takmark', 'Takstar', 'Teton', 'Paraat', 'Utopia'. Jako odmianę odniesienia wykorzystano standardową polską późną odmianę 'Sochaczewska', polecaną do długotrwałego przechowywania. Cebule przechowywano w warunkach chłodni zwykłej przez 7 miesięcy, w temperaturze 1–2°C i wilgotności względnej 80–85%, a następnie przez tydzień w symulowanych warunkach obrotu towarowego. Po przechowaniu określano ubytki masy cebuli, udział cebuli z wyrośniętym szczypiorem, udział cebuli z wyrośniętymi korzeniami, stopień ściemnienia okolic wierzchołków wzrostu w skali umownej. Bezpośrednio po zbiorze i po przechowaniu określano również suchą masę cebuli, zawartość witaminy C i olejków eterycznych. Badane odmiany wykazywały duże różnice pod względem zdolności przechowalniczej. Najlepiej przechowywały się odmiany 'Sochaczewska' i 'Spirit', a najgorzej 'Bonus' i 'Sterling'. Zastosowanie hydrazydu kwasu maleinowego wpłynęło na zmniejszenie stopnia wyrastania cebuli w szczypior i korzenie podczas przechowywania oraz na zmniejszenie ubytku naturalnego cebuli. Traktowanie hydrazydem kwasu maleinowego wpłynęło istotnie na większą zawartość olejków eterycznych w przechowywanej cebuli oraz spowodowało wzrost zawartości witaminy C w cebuli po przechowywaniu. U cebuli traktowanej preparatem Fazor obserwowano ciemnienie okolic wierzchołków wzrostu, jednak stopień tego ciemnienia zależał od odmiany i był na ogół niewielki. Wyniki wskazują na istotny wpływ hydrazydu kwasu maleinowego na zmniejszenie strat przechowalniczych badanych odmian cebuli, dzięki czemu można je przechowywać w chłodni zwykłej przez kilka miesięcy.

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