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INFLUENCE OF VARIOUS CHEMICAL COMPOUNDS ON POSTHARVEST LONGEVITY OF CUT LEAVES OF *Waldsteinia geoides* Willd.

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Abstract

The influence of conditioning and different methods of application of chemical compounds on cut leaves of *Waldsteinia geoides* was assessed. Gibberellic acid and benzyladenine at a concentration of 50 or 100 mg × dm^{-3}, and 8-hydroxyquinoline sulphate at a concentration of 200 mg × dm^{-3} were used in the process of conditioning. The leaves were conditioned in two different ways. In the first one, half of leaf stalks were soaked for 24 hours. In the latter, whole leaf blades were dipped for thirty seconds. Cut leaves were stored either in water or in the solution of 8-hydroxyquinoline sulphate at a concentration of 200 mg × dm^{-3}. It was both the chemical compounds applied and the application method that influenced the postharvest longevity of the leaves. The leaves conditioned in 8HQS and stored in water, those conditioned in BA at a concentration of 50 mg × dm^{-3} and stored in 8HQS, and those which were not conditioned and stored in 8HQS exhibited the highest level of postharvest longevity. The application of 8HQS for conditioning had a favorable effect on the increase in the weight of *Waldsteinia geoides* cut leaves. 8HQS applied in storing resulted in a smaller decrease in the values of the leaf greenness index.

Key words: *Waldsteinia geoides*, leaves, vase life, 8-hydroxyquinoline sulphate, gibberellic acid, benzyladenine

INTRODUCTION

The range of florist green is growing as the demand for new species is getting higher and higher. However, because of economical reasons, exotic florist green is being replaced more and more often by cheaper and more available plants that can be grown in open field. Leaves of the following perennial plants: *Hosta*, *Bergenia*, *Heuchera* L., *Limonium latifolium* (Sm.) Kuntze and many others [1–3], are gaining in importance.

Waldsteinia geoides is a perennial plant that occurs naturally in the eastern part of Europe. The leaves of this species are highly lobed. Moreover, the leaf edges are serrated, which may be treated as an additional ornamental value [4].

Different chemical agents are used to extend the vase life of cut leaves. However, their effectiveness varies from species to species or even cultivar [5]. To prolong the vase life of cut flowers, special practices and preparations are employed to ensure their maximum post-harvest longevity. Conditioning usually takes between 4 and 24 h or a few seconds in short soaking of leaf blades in conditioning solutions [6]. This often involves the use of hydroxyquinoline esters or gibberellic acid [7–9]. Due to the differences in aging time of leaves, conditioning media are not usually very effective and may even lower the decorativeness [10].

Waldsteinia geoides could be used in creating smaller flower compositions; however, in the available literature there is no information on the influence of various chemical compounds on postharvest longevity.

That is why it would be considered appropriate to determine the postharvest longevity of *Waldsteinia geoides* cut leaves and their response to the most commonly used chemical compounds.

MATERIALS AND METHODS

The experiment was conducted from 16 May to 2 June 2012 in the growth chamber of the Department of Ornamental Plants of the University of Life Sciences in Poznań. Fully-developed leaves of *Waldsteinia geoides* Willd. were obtained from open field culture which was part of the educational collection of the abovementioned Department. The length of the leaf stalk was 19–20 cm, while the diameter of the leaf blade was 7.5–8.5 cm.

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Conditioning was performed in two different ways. The leaf stalks of half of the leaves were soaked up to 4 cm for 24 hours. The other half of the leaves were totally immersed in conditioning solutions for 30 seconds. Gibberellic acid (GA_3) at a concentration of 50 or 100 mg × dm^{-3}, benzyladenine (BA) at a concentration of 50 or 100 mg × dm^{-3} and 8-hydroxyquinoline sulphate (8HQS) at a concentration of 200 mg × dm^{-3} were used in the conditioning process. The source of gibberellic acid was Gibrescol 10 mg with the active substance content of 10%. A few drops of the agent reducing the surface tension were added to the solutions used for dipping the leaf blades. After conditioning the leaves were placed either in water or in an aqueous solution of 8-hydroxyquinoline sulphate at a concentration of 200 mg × dm^{-3}. Both the water and the solution of 8HQS were changed every three days. The control group consisted of non-conditioned leaves stored in water.

The experiment comprised twenty-four combinations consisting of nine leaves each. The replication was a single leaf.

The experiment was conducted in a room at a temperature of 18 ± 1°C and under artificial light with a quantum irradiance of 25 μmol × m^{-2} × s^{-1} lasting for 10 hours a day.

The length of the ornamental value period expressed in days was assessed. The leaves were removed when the following symptoms appeared: yellow or brown spots, rolling or drying leaf blade edges. Measurements of the values of the leaf greenness index were taken by means of the YARA N – tester apparatus on the first and last day of the experiment.

After finishing the experiment, the percentage changes in the leaf greenness index and the changes in fresh matter in comparison with the initial values were calculated.

The obtained results were analyzed statistically by means of two-factor analysis of variance with the use of Statistica software and the means were grouped with the use of Duncan test at a significance level of α=0.05. Bliss transformation was used for the percentages.

RESULTS

The postharvest longevity of *Waldsteinia geoides* leaves was between 2 and 17 days (Table 1). All the experimental factors influenced the length of the ornamental value period. Depending on the preliminary treatment, non-conditioned leaves (15.11 days) and those conditioned in 8HQS (14.25 days) exhibited the highest longevity. The leaves conditioned in gibberellic acid at the concentration of 50 and 100 mg × dm^{-3} had the shortest ornamental value period.

Table 1
Postharvest longevity of cut leaves of *Waldsteinia geoides* (days)

Conditioning		Holding solution		Mean for conditioning	Mean for application method
Solution	Application method	Water	8HQS 200 mg × dm^{-3}		
Water		13.6 fg	16.7 h	15.1 c	Leaf stalk soaking
GA_3 50 mg × dm^{-3}	Leaf stalk soaking	5.7 bcd	3.1 ab	3.2 a	9.4 b
	Leaf blade dipping	2.1 a	2.0 a		Leaf blade dipping
GA_3 100 mg × dm^{-3}	Leaf stalk soaking	4.3 ab	4.2 ab	3.3 a	4.8 a
	Leaf blade dipping	2.6 a	2.0 a		
8HQS 200 mg × dm^{-3}	Leaf stalk soaking	17.6 h	14.8 fgh	14.3 c	
	Leaf blade dipping	9.2 e	15.4 gh		
BA 50 mg × dm^{-3}	Leaf stalk soaking	7.3 cde	16.6 h	7.9 b	
	Leaf blade dipping	4.9 abc	2.9 ab		
BA 100 mg × dm^{-3}	Leaf stalk soaking	7.7 de	12.3 f	6.8 b	
	Leaf blade dipping	4.0 ab	3.0 ab		
Mean for holding solution		7.2 a	8.5 b		

Mean values marked with the same letter do not differ at the significance level α=0.05 according to Duncan's test.

Storing the leaves in 8-hydroxyquinoline sulphate at the concentration of 200 mg × dm^{-3} significantly prolonged their longevity. It was also the method of conditioning and agent application that influenced

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the length of the ornamental value period. Soaking the leaf stalks for 24 hours turned out to have a more favorable effect than dipping the leaf blades for 30 seconds.

The interdependencies of the experimental factors showed that the leaves whose stalks were soaked in 8HQS, the leaves which were not conditioned at all and stored in 8HQS, and finally the leaves which were conditioned in BA at the concentration of 50 mg × dm^{-3} and later placed in 8HQS exhibited the highest longevity. Similarly, the leaves conditioned by means of dipping the leaf blades in 8HQS and then stored in the same chemical compound exhibited high longevity.

The leaf weight either increased or decreased depending on the experimental combination. Conditioning influenced the percentage change in the weight (Table 2). The weight of 8HQS-treated leaves increased by 8%. The leaves conditioned in gibberellic acid at the concentration of 50 and 100 mg × dm^{-3} and in benzyladenine at the concentration of 100 mg × dm^{-3} exhibited the most significant percentage weight loss.

Table 2
The percentage change in the weight of cut leaves of *Waldsteinia geoides* (%)

Conditioning		Holding solution		Mean for conditioning	Mean for application method
Solution	Application method	Water	8HQS 200 $mg \cdot dm^{-3}$		
Water		-14.6 abc	11.4 h	-1.6 c	Leaf stalk soaking
GA_3 50 $mg \cdot dm^{-3}$	Leaf stalk soaking	-1.7 fg	-11.4 bcde	-8.6 a	-2.1 b
	Leaf blade dipping	-9.4 cde	-11.8 bcde		Leaf blade dipping
GA_3 100 $mg \cdot dm^{-3}$	Leaf stalk soaking	-13.2 abcd	-7.5 e	-10.5 a	-8.7 a
	Leaf blade dipping	-7.0 ef	-14.3 abc		
8HQS 200 $mg \cdot dm^{-3}$	Leaf stalk soaking	18.8 i	2.1 g	8.0 d	
	Leaf blade dipping	-6.9 ef	17.9 i		
BA 50 $mg \cdot dm^{-3}$	Leaf stalk soaking	-6.9 ef	17.3 i	-5.4 b	
	Leaf blade dipping	-18.5 a	-13.5 abcd		
BA 100 $mg \cdot dm^{-3}$	Leaf stalk soaking	-8.1 de	-10.9 cde	-10.6 a	
	Leaf blade dipping	-6.6 ef	-17.0 ab		
Mean for holding solution		-6.7 a	-5.5 b		

Mean values marked with the same letter do not differ at the significance level α=0.05 according to Duncan's test.

The percentage weight loss in the leaves conditioned by dipping the leaf blades was significantly higher than in the case of leaf stalk soaking. Storing the leaves in 8-hydroxyquinoline sulphate resulted in a significantly lower leaf weight loss than in the case of storing them in water.

The leaves whose stalks were soaked for 24 hours in 8HQS and then stored in water exhibited the highest percentage weight gain. It did not differ significantly from the values observed in the case of leaves conditioned by means of leaf blade dipping in 8HQS and by leaf stalk soaking in benzyladenine at the concentration of 50 mg × dm^{-3} and storing the leaves in 8-hydroxyquinoline sulphate.

Statistical analysis showed that it was only the solution used for storing that influenced the changes in the leaf greenness index (Table 3). Using 8HQS resulted in a decrease in the leaf greenness index. Analyzing Figure 1, one can notice that the SPAD values changed depending on the relationships between the experimental factors. In the case of soaking the leaf stalks for 24 hours in the solution of benzyladenine at the concentration of 50 mg × dm^{-3}, the values of the leaf greenness index increased by almost 10%. Using 8HQS for both conditioning by leaf stalk soaking and storing *Waldsteinia geoides* leaves had the most unfavorable effect on SPAD. The SPAD values decreased by 8.5%.

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Table 3
Effect of postharvest treatment of *Waldsteinia geoides* leaves on the leaf greenness index (SPAD)

Conditioning		Holding solution		Mean for conditioning	Mean for application method
Solution	Application method	Water	8HQS		
Water		0.43 abc	1.10 abc	0.76 a	Leaf stalk soaking
GA_3 50 mg·dm^{-3}	Leaf stalk soaking	0.47 abc	-0.19 abc	-0.15 a	0.42 a
	Leaf blade dipping	0.00 abc	-0.88 abc		Leaf blade dipping
GA_3 100 mg·dm^{-3}	Leaf stalk soaking	-0.03 abc	0.79 abc	0.30 a	0.01 a
	Leaf blade dipping	0.43 abc	0.00 abc		
8HQS 200 mg·dm^{-3}	Leaf stalk soaking	4.12 c	-3.08 a	0.49 a	
	Leaf blade dipping	1.73 abc	-0.81 abc		
BA 50 mg·dm^{-3}	Leaf stalk soaking	2.96 bc	-2.10 ab	0.15 a	
	Leaf blade dipping	-0.27 abc	0.00 abc		
BA 100 mg·dm^{-3}	Leaf stalk soaking	0.90 abc	0.36 abc	0.29 a	
	Leaf blade dipping	-0.09 abc	0.00 abc		
Mean for holding solution		0.97 b	-0.44 a		

Mean values marked with the same letter do not differ at the significance level α=0.05 according to Duncan's test.
"-" is the mean decrease in the value of the leaf greenness index.

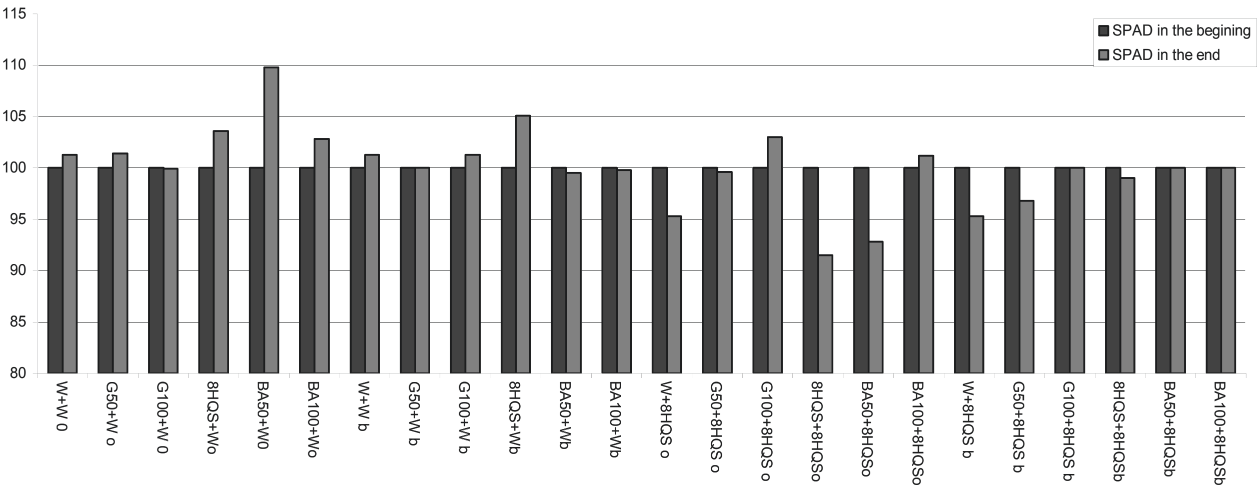

Fig. 1. Effect of postharvest treatment of *Waldsteinia geoides* leaves on the leaf greenness index (SDAP) (%).

DISCUSSION

The postharvest longevity of *Waldsteinia geoides* leaves was from 2 to 17 days, depending on postharvest treatment. The average longevity of non-conditioned leaves was 15 days. Therefore, this species can serve as an alternative to *Eucalyptus* L'Hér. or *Rumoha adiantiformis* (G. Forst.) Ching [5] in flower compositions.

Conditioning the leaves of *Waldsteinia geoides* in 8HQS, similarly as in the case of *Lathyrus odoratus* L. [8], *Allium* L. [11], *Hypericum* x *inodorum* Mill [12] and *Antirrhinum majus* L. [13], had a favorable effect on their postharvest longevity. Ferrante et al. [14], Hettiarachi and Balas [15] as well as Janowska and Schroeter-Zakrzewska [16] state that conditioning in 8-hydroxyquinoline sulphate does not influence the postharvest longevity of *Matthiola incana* (L.) R. Br., *Kniphofia uvaria* Oken, and *Arum italicum* Mill.

Gibberellic acid had a negative effect on the length of the ornamental value period of *Waldsteinia geoides* leaves regardless of its application. Skutnik et al. [17] presented interesting results:

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Asparagus densiflorus (Kunth) Jessop in the 'Meyerii' reacted in the way similar to *Waldsteinia geoides*. In the case of 'Myriocladus', gibberellic acid applied by immersing whole leaves had a negative effect on the length of the ornamental value period, whereas when the leaves were placed in the aqueous solution of GA_3 their postharvest longevity was higher. *Asparagus setaceus* (Kunth) Jessop reacted in the opposite way. Ferrante et al. [18] and Janowska and Jerzy [19] present different results. They claim that gibberellic acid has a favorable effect on the postharvest longevity of *Matthiola incana* and *Zantedeschia elliottiana* (W. Watson) Engl. The positive effect of gibberellic acid was also exhibited in the case of *Lilium candidum* L. [20], *Zantedeschia aethiopica* (L.) Spreng. [21], *Arum italicum* [16], *Hypericum* x *inodorum* [12], *Zantedeschia elliottiana* [22], *Weigela florida* (Bunge) A. DC. [23], and oriental lily [24]. Danaee et al. [25] drew interesting conclusions in assessing the longevity of *Gerbera jamesonii* Bolus ex Hook. f. 'Good Timing'. They claim that increasing the concentration of gibberellic acid can have an unfavorable effect on postharvest longevity. However, one must bear in mind that even in the case of higher dosages of GA_3 applied the length of the ornamental value period is higher than in the case of leaves which were not conditioned. This plant reacted similarly to conditioning with benzyladenine.

Benzyladenine has a favorable effect on postharvest longevity. This is proved by the research on *Lilium candidum* L. [20], *Anthurium andraeanum* Linden ex André, *Heliconia psittacorum* L. 'Andromeda', *Alpinia purpurata* (Vieill.) K. Schum. [26], *Zantedeschia aethiopica* [21], *Zantedeschia elliottiana* [22], and *Solidago canadensis* L. [27]. In the experiment in question, however, BA application shortened the ornamental value period of *Waldsteinia geoides* leaves by half. The negative effect of this chemical compound was also observed by Paull and Chantrachit [26] while conducting an experiment with *Lycopodium* (L.) and *Arundina graminifolia* (D.Don) Hochr. This is also confirmed by the research on *Hypericum* x *inodorum* [12] and *Weigela florida* [23]. The application method does not change the negative effect of benzyladenine, which is confirmed by the research on *Zantedeschia aethiopica* by Skutnik et al. [21] and the research on *Asparagus densiflorus* 'Meyerii' and 'Myriocladus' by Skutnik et al. [17].

Storing *Waldsteinia geoides* leaves in the solution of 8HQS prolonged the period of their ornamental value. Similar results were obtained by Hassan and Schmidt [28] in their research on *Dianthus caryophyllus* L. Janowska, while Jerzy [19] obtained interesting results when observing the response of *Zantedeschia elliottiana* leaves to storage in 8-hydroxyquinoline sulphate. In the case of the 'Black Magic' cultivar, no influence of storing in 8HQS was reported. The 'Florex Gold' cultivar, on the other hand, responded negatively to this chemical compound.

8HQS application in conditioning can have a favorable effect on the change in cut plant weight. This is confirmed by the research on *Arum italicum* [16], *Lathyrus odoratus* [8], and *Antirrhinum majus* [13]. Using this chemical compound in the present experiment also resulted in an increase in the weight of *Waldsteinia geoides* leaves in the case of their conditioning and a smaller weight loss in the case of storing the leaves in the solution rather than in pure water.

Both gibberellic acid and benzyladenine used in the conditioning process resulted in a significant weight loss. Different results were presented by Bunay-Atichart et al. [29]. They proved that the application of gibberellic acid retarded the weight loss of cut inflorescences of *Curcuma alismatifolia* Gagnep. Janowska and Schroeter-Zakrzewska [16] as well as Danaee et al. [25] also prove the positive effect of GA_3 on the change in the weight of *Arum italicum* and *Gerbera jamesonii* 'Good Timing'. Danaee et al. [25] also proved the favorable effect of benzyladenine on the retardation of the weight loss in the case of *Gerbera jamesonii* 'Good Timing'.

The method of application of the chemical compounds and the type of the compound used did not influence the SPAD values of *Waldsteinia geoides* leaves. Skutnik et al. [21] proved that soaking the leaf blades of *Zantedeschia aethiopica* in both gibberellic acid and in benzyladenine had an unfavorable effect on leaf chlorophyll content.

The leaf greenness index of *Waldsteinia geoides* cut leaves increased only in some of the experiment combinations. In the case of conditioning in the gibberellic acid solution and in the solution of benzyladenine at the concentration of 100 mg × dm^{-3}, a slight increase in the SPAD values was observed. In the case of the leaves stored in water and previously conditioned in 8-hydroxyquinoline sulphate, an increase in the SPAD values was found. While examining the longevity of *Arum italicum*, Janowska and Schroeter-Zakrzewska [16] proved no influence of 8HQS on the values of the leaf greenness index. Ferrante et al. [14] showed that this chemical compound can retard the decrease in the chlorophyll content in the case of *Matthiola incana.* Janowska and Śmigielska [12] claim that the concentration of 8-hydroxyquinoline sulphate affects SPAD values. When investigating *Hypericum* x *inodorum*, they noted that the dosage of 200 mg × dm^{-3} resulted in an increase in the values of the leaf greenness index. Higher dosages, on the other hand, did not influence the SPAD values.

Conditioning *Waldsteinia geoides* leaves in gibberellic acid did not affect the chlorophyll content,

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similarly as in the research by Philsoph-Hadas et al. [27], Janowska and Jerzy [19], and Ferrante et al. [16] on *Solidago canadensis*, *Zantedeschia elliottiana* and *Mathiola incana*, respectively. However, gibberellic acid can have a favorable effect on SPAD values, which is proved by the results of the research on *Lilium candidum* [20], *Asparagus densiflorus*, *A. setaceus* [17], and oriental lily [24].

Benzyladenine had the most favorable effect on the SPAD values in the case of the examined species. The leaves conditioned by means of leaf stalk soaking in its solution at the concentration of 50 mg × dm^{-3} exhibited an increase in the leaf greenness index values, but it was not significant. This result is confirmed by the research on *Lilium candidum* [20], *Solidago canadensis* [27], *Zantedeschia elliottiana* [22], *Hypericum* x *inodorum* [12], and *Weigela florida* [23]. It turns out that benzyladenine can have a favorable effect on the values of the leaf greenness index even if the effect of the solution in which the leaves were previously stored is unfavorable. In the present experiment, it was proved that the lower concentration of BA used in the conditioning process, the higher are the values of SPAD when leaves are stored in 8HQS.

CONCLUSIONS

1. The postharvest longevity of *Waldsteinia geoides* leaves placed in 8-hydroxyquinoline sulphate at the concentration of 200 mg × dm^{-3} used in the conditioning process and non-conditioned leaves stored in water was the highest (about 14–15 days).
2. The method of application of the chemical compounds influenced the postharvest longevity of *Waldsteinia geoides* leaves. Soaking the leaf stalks for 24 hours proved to be more favorable than dipping the whole leaf blades for 30 seconds.
3. It was only conditioning in 8HQS that resulted in an increase in the weight of *Waldsteinia geoides* cut leaves and their quality was the best. The application of the other chemical compounds resulted in a weight loss.
4. Neither the conditioning nor the method of application of the chemical compounds influenced the values of the leaf greenness index of *Waldsteinia geoides* leaves.

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Authors' contribution

The following declarations about authors' contributions have been made: conducting experiments and processing of results: MPUW; methodology development and editorial corrections: AK.

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Wpływ różnych związków chemicznych na trwałość pozbiorczą ciętych liści *Waldsteinia geoides* Willd.

Streszczenie

Oceniono wpływ kondycjonowania i sposobu aplikacji środków chemicznych na cięte liście *Waldsteinia geoides*. Do kondycjonowania zostały wykorzystane: kwas giberelinowy i benzyloadenina w stężeniu 50 lub 100 $mg \cdot dm^{-3}$, oraz siarczan 8 – hydroksychinoliny o stężeniu 200 $mg \cdot dm^{-3}$. Liście kondycjonowano dwoma sposobami. Ogonki liściowe połowy liści moczono przez 24 godziny. Drugim sposobem było moczenie całych blaszek liściowych przez 30 sekund. Cięte liście przechowywano w wodzie lub roztworze siarczanu 8 – hydroksychinoliny o stężeniu 200 $mg \cdot dm^{-3}$. Zarówno zastosowany środek do kondycjonowania jak również sposób aplikacji oraz roztwór zastosowany do przechowywania miał wpływ na trwałość pozbiorczą badanych liści. Największą trwałością wykazały się pędy kondycjonowane w 8HQS przechowywane w wodzie, kondycjonowane w BA o stężeniu 50 $mg \cdot dm^{-3}$ przechowywane w 8HQS oraz niekondycjonowane przechowywane w 8HQS. Zastosowanie 8HQS do kondycjonowania pozytywnie wpłynęło na wzrost masy ciętych liści *Waldsteinia geoides*. 8HQS zastosowany do przechowywania spowodował mniejszy spadek indeksu zazielenienia. Pozostałe czynniki doświadczenia nie miały wpływu na wartość SPAD.

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