

Effect of saline water on the vase life of *Narcissus poeticus* L. flowers

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ABSTRACT

The vase life of *Narcissus poeticus* flowers collected at the white bud stage was investigated in 13 different concentrations of NaCl (0–5–10–15–20–30–40–...–100 mM). Every 12 hr, the opening stage of the flowers was recorded, divided into 4 main categories (bud, opening flower, full open (FO) flower and wilting flower) and 14 subcategories. The salinity did not affect the flower opening speed, diameter or weight. The duration of the full flowering stage decreased from 92 hr to 44 hr, the sum of the daily ornamental value score (OVS) decreased from 120 by 3 scores per each 10 mM concentration increase. The scape chlorophyll content increased at low salinity (10–15 mM) and then decreased significantly. The carotenoid content in the scapes of wilted flowers increased in 30–100 mM solutions compared to the values in the flowering stage and flowers grown at lower salt concentrations. The Na and Cl contents in the plant parts increased significantly with the increase in salinity (at the end of the experiment, 100 mM NaCl: scapes: 44.1 g · kg⁻¹ and 67.2 g · kg⁻¹ Na and Cl; flowers: 16.8 g · kg⁻¹ and 24.8 g · kg⁻¹ Na and Cl, respectively). There was an inverse correlation between the Na and K contents in the scapes. The EC value of the vase solutions decreased during the experiment.

Keywords: chlorophyll, cut flower, ornamental value, poet's narcissus

INTRODUCTION

Members of the genus *Narcissus* are widely used as ornamental plants. They are planted in perennial beds, annual flower beds and flowering lawns and are also grown both in the open field in greenhouses for cut flower use (Armitage and Laushman, 2003; Křesadlová and Vilím, 2009). The white-flowered *N. poeticus* is mainly used in cottage gardens and perennial beds but has also long been known to the perfume industry for its intense fragrances (Remy, 2002; Baranauskienė and Venskutonis, 2022). Its presence in the cut flower market

is negligible, and it is practically unheard of in today's professional cultivation. However, in recent years, there has been an increasing demand for its floristic use, mainly due to its snowwhite petals and fragrance.

One of the most important factors in the potential use of cut flowers is the length of vase life. From this point of view, compared to other species used as cut flowers, the useable life of narcissus flowers is relatively short (Dole and Wilkins, 2005; Whale, 2017). For the more commonly used single-flowered varieties, the useable

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life is estimated to be 3–6 days (Sun and Brosnan, 1999; Whale, 2017), and for multi-flowered *N. tazetta* cultivars, it is 6–12 days (Gun, 2020), up to 12–17 days with specific treatments (Gul and Tahir, 2013). Rabiza-Świder et al. (2020) distinguish between the vase lives of the perianth and corona in trumpet-type daffodil cultivars (4–5 days and 5–8 days, respectively). In the case of *N. poeticus*, depending on different picking stages and storage methods, the vase life is 5–7 days (Jezdinská Slezák et al., 2022).

Factors determining the vase life include the prestorage temperature and storage method of flowers (Cevallos and Reid, 2001; Armitage and Laushman, 2003), temperature and humidity during vase storage (Bittnerová and Martínek, 2007), and the composition of vase water and the use of additives (nutrients, preservatives) (Dole and Wilkins, 2005; Bittnerová and Martínek, 2007; Gul and Tahir 2013; Lou et al., 2021).

In cut flower experiments, the control vase solution is usually distilled water for reproducibility and comparability, but in floristic and everyday practice, tap water or some local water is used. The quality of the water source can vary widely and may have too high salinity or different pH values or can be contaminated with microorganisms. Overall, it can be said that there is relatively less literature on the basic water quality of vase water, although several authors have pointed out the importance of this in the case of cut flowers (Conrado et al., 1980; Van Doorn, 2012; Van Meeteren et al., 2019). The salt sensitivity of cut flowers is dependent on plant species (Ahmad et al., 2013; Carlson and Dole, 2013), and to evaluate total salt measuring results, it is also important to test the buffering capacity and alkalinity of the water (Armitage and Laushman, 2003).

According to the WHO (2022), no health-based guideline value is proposed for chloride or sodium in drinking water. For this reason, the official guidelines note only that chloride should be kept $<250 \text{ mg} \cdot \text{L}^{-1}$ and sodium $<200 \text{ mg} \cdot \text{L}^{-1}$ as any excess of these approximate levels can give rise to a detectable taste in water. These threshold values set by the WHO are only suggestions for human perception. However, in practice, they often do not mean upper limits, and they are ‘indicator’ of water quality for evaluations (Directive (EU) 2020/2184).

However, in addition to the WHO recommendations, local water sources can have a much higher Na and Cl contents, and this can vary significantly throughout the year (Sappa et al., 2015; Shammi et al., 2019). Based on climate change projections, in the context of decreasing freshwater supplies, there is a lot of research on testing water at higher salt concentrations in cultivation using seawater after different levels of dilution (Bian and Pan, 2018; Wang et al., 2019; Yasemin et al., 2022). The desalination and its high cost are current topics (Hilal et al., 2005; Karagiannis and Soldatos, 2008; Chandra Garg and Joshi, 2015), which suggests that the salinity of environmental water supplies (from which tap water is drawn for floriculture) is an important issue.

For cut flowers, the water uptake of plants from the vase solution, the xylem and the vase solution have a direct connection. So, in the absence of a complete (rooted) plant system, transfer through the root tissues, with its filtering–regulating effect, is lacking (Reid and Jiang, 2013). Accordingly, the uptake of solutes from the vase solution is unhindered or slightly hindered.

This suggests that high salinity water can have a significant effect on the length of the vase life and quality of flowers.

The experiment described in this article aims to find out whether the use of saline vase water reduces the ornamental value or/and longevity of flowers, how many Na and Cl ions are taken up by plants from the vase solution, which of the monitored parameters are subject to changes and whether these changes can be described by functions. The aim was also to test an ornamental value system linked to various flower stages that characterises the current decoration value of the plants.

MATERIALS AND METHODS

Plant material

For the cut flower cultivation, plants were grown under field conditions. The own-grown bulbs (Faculty of Horticulture, Mendel University in Brno, Czech Republic) of a cultural form of *poeticus* L. were originally collected from a local population in Hungary (Pákozd, 4712.9380 N, 1832.7940 E) in 2011 and propagated over the years in the experimental area of the faculty. After lifting and drying in the middle of June 2021, the bulbs were stored at 17°C during summer and planted on 2 October 2021. The soil is brown, with a pH (H_2O) of 7.7, a pH (KCl) of 7.34 and an electrical conductivity (EC) of $330 \mu\text{S} \cdot \text{cm}^{-1}$, and the nutrient supply is N-poor, P-very good and K-medium. The soil Na content (measured in March) was $12 \text{ mg} \cdot \text{kg}^{-1}$. After spring sprouting, at 70–100 mm leaf length, a single application of $5 \text{ g} \cdot \text{m}^{-2} \text{ N}$ was applied, with an irrigation dose of 15 mm. Subsequently, two more applications of 15–18 mm of irrigation water were carried out the last 7 days before flowering.

Flower picking occurred in the early morning (6:30–7:30) of 29 April 2022. The flowers were picked at the pencil stage (scapes standing erect), and after picking, the scapes were cut to a uniform length (190–200 mm).

Experimental conditions

After cutting, the scapes were placed in distilled water at 4°C for 24 hr. Then, the scapes were rinsed once more with clean distilled water to remove any secreted sap (Armitage and Laushman, 2003; Bittnerová and Martínek, 2007). During the experimental period, transparent 250-mL plastic dishes (‘vases’) were used to store the flowers, with 200 mL of solution in each bottle, at an initial salt concentration corresponding to the treatment. The height of the water column in each vase was 55 mm, into which the 65–70 mm long scapes were

diagonally immersed. Laboratory pure NaCl was used to prepare saline solutions. The salt concentrations used in each treatment and the basic chemical properties of the salt solutions are presented in Table 1. Distilled water (0 mM NaCl) was used as the control. The solutions used for the treatments were prepared by diluting the stock solutions of 500 mM concentration prepared on an analytical balance (Kern 770, Kern and Sohn GmGH, Balingen, Germany).

At the start of the experiment, 10 scapes were placed in each vase, and three replicates of each treatment were set up. The vases were kept in a room with an air temperature of 20–24°C. Excluding the monitoring time, no artificial lighting was used, and the plants were protected from direct sunlight. The scapes were kept in the same solution (no change of vase water) throughout the experiment.

Measurement and analysis

Morphological examination

During the experiment, the state of openness of the flowers was recorded every 12 hr. The experiment was continued until the last flower senesced. Accordingly, records were done 16 times (start + 192 hr).

The condition of the flowers was classified according to Table 2. To characterise the current using value of the flowers, a different score for each condition was assigned, which is called ‘ornamental value’. For the evaluation, we used a previously developed classification (Jezdinská Slezák et al., 2022) and supplemented according to this study. Based on the number of pieces per category and the related score, the daily condition of the vase was expressed as a weighted average. The scores per 12 hr were summed to determine the total ornamental value.

The condition of the scapes was characterised by their colour and the length of degradation (mm) visible to the naked eye at the cut basis. The colour of the scapes was assessed above the brine and was classified as green, yellowish green, yellow and dry yellow (visually and palpably withered). The monitoring was carried out every 12 hr, at the same time as the condition of the flowers was measured, recording the number of scapes in each category.

The diameter of the flowers was measured at the full open (FO) stage of all flowers in the vases, 104 hr after the start of the experiment. The diameters of the tepals (perianth) and corona were measured in the widest part, in mm.

Plant weight

The weight of the scapes and flowers was measured two times. At the full opening stage of the flowers (108 hr after the start of experiment), three representative scapes were taken from each vase. The fresh weights (g) of the scapes and flowers were weighed separately, and after drying at 50°C to a constant weight, the dry weight (g) was measured. The dry and fresh weights were used to calculate the dry matter content ($\text{dry weight} \times 100 \times \text{fresh weight}^{-1}$). The second sampling was performed when all flowers in the vase had senesced (AF3 stage), at which time the weight of all seven flowers in the vase was individually weighed and dried as in the first sampling.

Laboratory analysis of the dry plant samples

The chlorophyll and carotenoid contents of the scapes, and the sodium, chlorine and potassium contents of the scapes and flowers (expressed in dry weight) were analysed. In addition, the basic chemical properties (pH, EC, total dissolved solids) of water extracts of scapes and flowers were measured. For the laboratory tests, in

Table 1. Treatments with basic chemical properties of the solutions.

Treatment (NaCl concentration, mM)	NaCl ($\text{g} \cdot \text{L}^{-1}$)	Na ($\text{g} \cdot \text{L}^{-1}$)	Cl ($\text{g} \cdot \text{L}^{-1}$)	pH	EC ($\text{mS} \cdot \text{cm}^{-1}$)	Brix°
0	0	0	0	*	0	0
5	0.277	0.109	0.168	5.93	0.67	0
10	0.554	0.218	0.336	5.68	1.05	0
15	0.832	0.327	0.505	5.58	1.50	0.1
20	1.109	0.436	0.673	5.51	2.10	0.1
30	1.663	0.654	1.009	5.51	2.90	0.2
40	2.218	0.873	1.345	5.47	3.70	0.2
50	2.772	1.091	1.682	5.45	4.30	0.3
60	3.327	1.309	2.018	5.43	5.00	0.4
70	3.881	1.527	2.354	5.44	5.60	0.5
80	4.435	1.744	2.691	5.45	6.10	0.5
90	4.990	1.963	3.027	5.46	6.60	0.6
100	5.544	2.181	3.363	5.44	7.30	0.7

*Cannot be measured with a stable value.
EC, electrical conductivity.

Table 2. Flower opening status categories and scores used to calculate the ornamental value (based on Jezdinská Slezák et al., 2022).

Phenological stage		Ornamental value (score)
Bud	WB: white bud, upright	4
Opening flower	OF1: 1 horizontal tepal	5
	OF2: 2 horizontal tepals	5
	OF3: 3 horizontal tepals	6
	OF4: 4 horizontal tepals	6
	OF5: 5 horizontal tepals	7
	OF6h: all tepals are half-opened (the centre of the corona is visible)	7
Open flower	FO: tepals are in a plane	10
	FOhb: tepals are standing half-backwards (45°>)	9
	FOb: tepals are standing backwards (45°<)	8
Senescent flower	AF0: the tips of the tepals become membranous, but keep their turgor	8
	AF1: all tepals become membranous, but keep their turgor	6
	AF2: the tepals start to gather, the corona still keeps its colour and turgor	1
	AF3: the tepals are shrivelled (complete wilting)	0

Completed and showing only the concerned phenological phases.

FO, full open.

case of both sampling times, one laboratory sample per treatment was prepared by mixing the three replicates to increase the homogeneity of the samples, and from this sample, the tests were performed in three technical replicates.

For performing the analysis of the chlorophyll and carotenoid contents, 0.2 g of the dried plant part was homogenised and transferred into 10 mL of acetone using microwave extraction (5-min irradiation at 60°C and 20-min extraction process). After cooling, the samples were quantitatively transferred to a 50-mL volumetric flask, supplemented using acetone and kept in the dark for 24 hr. The measurement preparation process was the same as the method used by Saleem et al. (2021), based on Holm's description (1954). After the preparation, the measurements were performed using a Specord 50 PLUS spectrophotometer (Analytik Jena, Germany), at 644 nm, 662 nm and 440 nm wavelengths, because of the absorbance maximum of evaluated pigments (Redzić et al., 2005).

The determination of the sodium and potassium contents was carried out using a 1:100 water extract of the plant samples. 0.5 g of the dry plant sample was shaken with 50 mL deionised water for 60 min, filtered to a 50-mL flask and filled to the mark with deionised water. The analysis was established by a method that works on the principle of capillary isotachophoresis (Blatný et al., 1997), using an IONOSEP 2003 (RECMAN – laboratory equipment, Ostrava-Hrabovka, Czech Republic).

The chlorine content was determined by using the titrimetric method, based upon silver nitrate (argentometric methods) (Jeffrey et al., 1989), *via* Mohr

titration. The test was performed in one replicate due to the small sample size available.

The pH and EC ($\text{mS} \cdot \text{cm}^{-1}$) values of the plant water extract prepared for the determination of sodium and potassium were measured using a PC 5 tester kit (XS Instruments, Carpi, Italy), with combined electrodes.

Basic chemical properties of the vase solutions

The pH and EC of the solutions in the vases were measured at the beginning of the experiment in the pure saline solutions and at 54 hr and 150 hr after the start of experiment, using the PC 5 tester kit mentioned. In addition, the Brix of the solutions was measured as 168 hr after the start of the experiment using an HI96801 Refractometer (Hanna Instruments, Woonsocket, Rhode Island, USA).

Data processing and statistical methods

Microsoft 365 Excel and Microsoft 365 Access were used for primary data processing and basic calculations. TIBCO STATISTICA 14.0.0 (2020) (TIBCO Software Inc./Statistica Software Inc., Palo Alto, California, USA) was used for performing all statistical analyses. First of all, normality was evaluated using the Shapiro–Wilk test, and homoscedasticity was evaluated using Bartlett's test. Simple and two-way analysis of variance (ANOVA) and a generalised linear model (GLM) were performed to evaluate the main and combined effects. The means between factor levels were compared using three-way ANOVA with Tukey's HSD *post hoc* comparisons. To evaluate the results, a level of $p < 0.05$ was used to conclude significant differences. The error bars on the graphs show the standard error of the means.

The means were compared with Tukey's HSD test, and the homogenous groups are shown in the results with the same letters.

RESULTS

The speed of opening and wilting of flowers

The flower opening status recorded every 12 hr for six representative treatments is shown in Figure 1. Graphs for all treatments are summarised in Figure S1 in the

Supplementary Material. The flowers remained in the bud stage for a relatively short period of time, with almost all flowers opening within 48 hr of being placed at room temperature (max. 1 bud stage flower per vase). The main differences between treatments were observed in the length of the opening stage and senescence process.

For the experiment as a whole, a time of 35 hr to 40 hr was needed for half of the plants in the vases to reach the open flower stage (FO+FOfb+FOh). It took



Figure 1. Flower stage distribution with 12-hr recordings in six representative treatments. Change of flower stage at 0 mM solution (A), 10 mM NaCl solution (B), 30 mM solution (C), at 50 mM NaCl solution (D), at 70 mM NaCl solution (E) and at 100 mM NaCl solution (F). FO, full open.

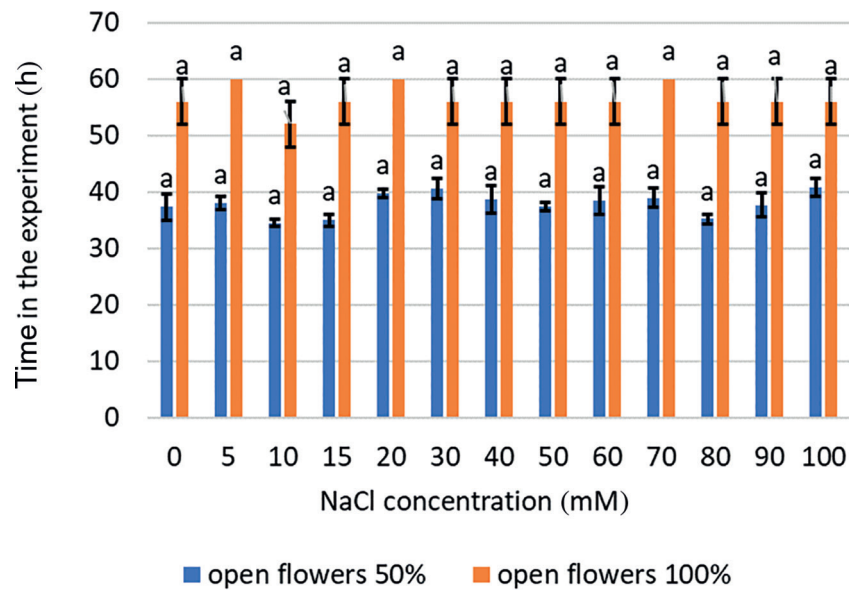


Figure 2. Time until the flowers opened (blue: the time until half of the buds opened, orange: the time until all of the buds opened). The error bars show the standard error of means, and the different letters above the groups show the significant differences between the treatments based on Tukey's HSD test.

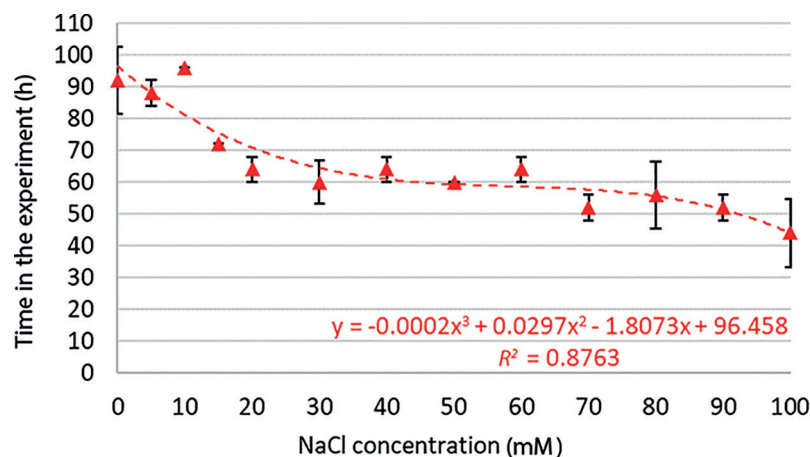


Figure 3. Duration of the full flowering stage. The error bars show the standard error of means, and the different letters above the groups show the significant differences between the treatments based on Tukey's HSD test.

52–60 hr for all flowers to open (Figure 2). The fastest flowers opened in the 10 mM solution, but overall, no correlation was found between salt concentration and opening speed.

In the 100 mM salt solution, the bouquets were in full flowering less than half as long as in distilled water (44 hr and 92 hr, respectively). From this point of view, at concentrations of 5–10 mM, the flowers appeared similar to the control, and then the time was shortened as the concentration increased. There was no significant difference between the results obtained at concentrations of 15–100 mM. A polynomial trend curve ($R^2 = 0.88$) was fitted to the series of results (Figure 3).

In the solutions with high salt concentrations, the senescence of the flowers started faster and reached the 50% threshold (half of the flowers started to wilt) faster,

as well as the stage when all flowers started to wilt (Figure 4). The complete wilting (AF3) stage followed a similar pattern.

In the control (without any salt), half of the flowers started to wilt after 162 hr from the start of the experiment, whereas in the 90 mM and 100 mM solutions, it took 124–125 hr. Low salt concentrations (<40 mM) were not distinguishable from the 0 mM treatment by statistical analysis. The results for higher salt concentrations (40–100 mM) were also not distinguishable from each other.

The start of senescence of all flowers was observed after 176 hr in the control, whereas it occurred 32–36 hr earlier in the 70–100 mM salt treatment. However, up to a concentration of 40 mM, water quality did not significantly impair the usability of the flowers in this aspect.

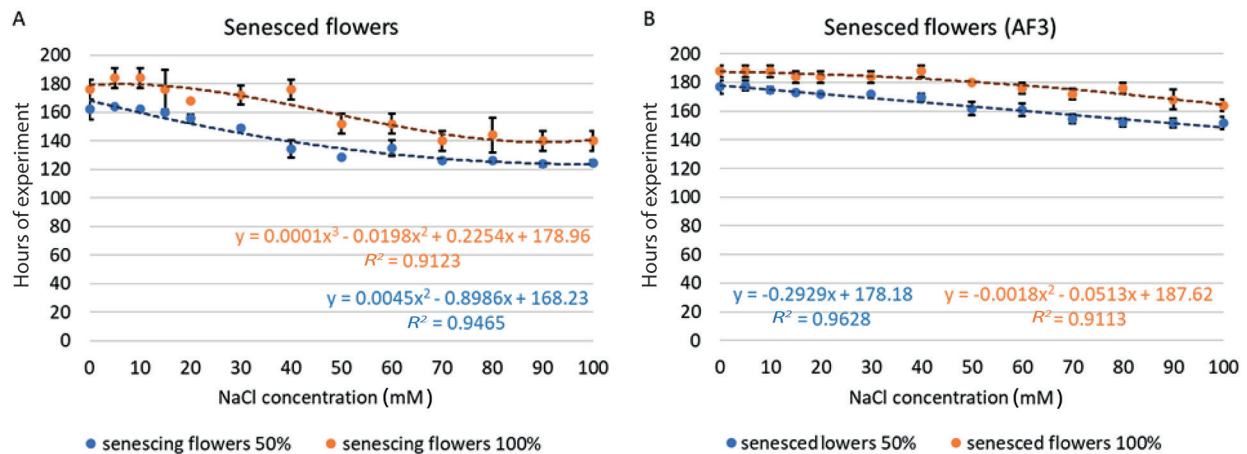


Figure 4. Senescence of the flowers (A) AF0+AF1+AF2+AF3; (B) AF3 (blue: the time until half of the flowers reach the marked stage and orange: the time until all of the flowers reach the marked stage). The error bars show the standard error of means.

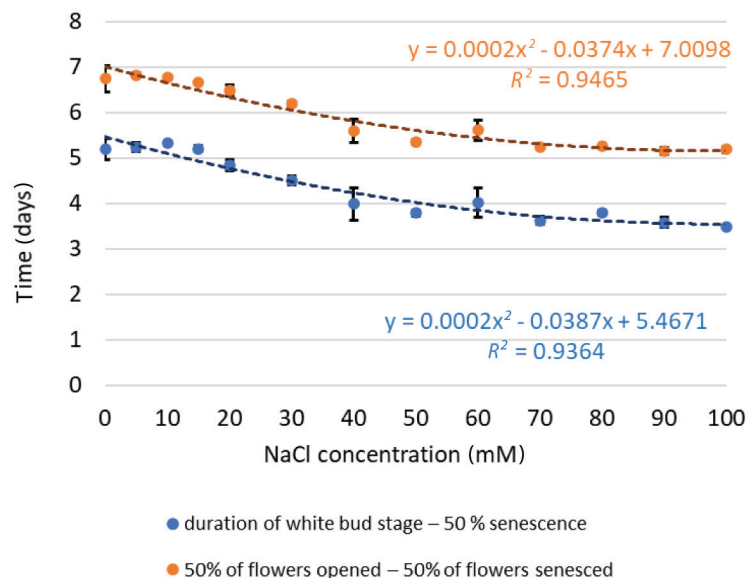


Figure 5. Vase life duration calculated in two ways (1. from the placement of the flowers in the vases (white bud stage) to the senescence of half of the flowers, 2. from opening of the half of the flowers to the senescence of the half of the flowers). The error bars show the standard error of means.

The complete senescence of half of the flowers (AF3 stage) occurred 170–177 hr after the start of the experiment in the no-salt and low-salt treatments (0–40 mM), while in the 80–100 mM salt treatments, it occurred 20 hr earlier. The effect of the concentration increase was well described by linear regression (the 10 mM salt concentration increase meant a 2.9-hr reduction in the total vase life).

In terms of total flower senescence, the 0 mM, 5 mM, 10 mM and 40 mM salt treatments were less harmful than the rapid wilting of flowers treated with 100 mM. Over the concentration range studied, the total vase life decreased at a slight slope, as described by a second-order curve.

In the control and low-salinity treatments, where the flowers were in the full flowering stage for a long time, it took only 28 hr from the onset of the first flower senescence to the total wilting of bouquet. In the 70–100 mM treatments (where the opening stage started earlier), this time was 48–52 hr.

Summarising the results presented earlier, the vase life in days is shown in Figure 5. From the vase placement (white bud stage) to the opening of half of the flowers, vase longevity was >6.5 days in the concentration range of 0–15 mM. The longevity was significantly shortened only in the concentration of >30 mM NaCl compared to the control and low-salt treatments. The vase life calculated from the opening of half of the flowers was

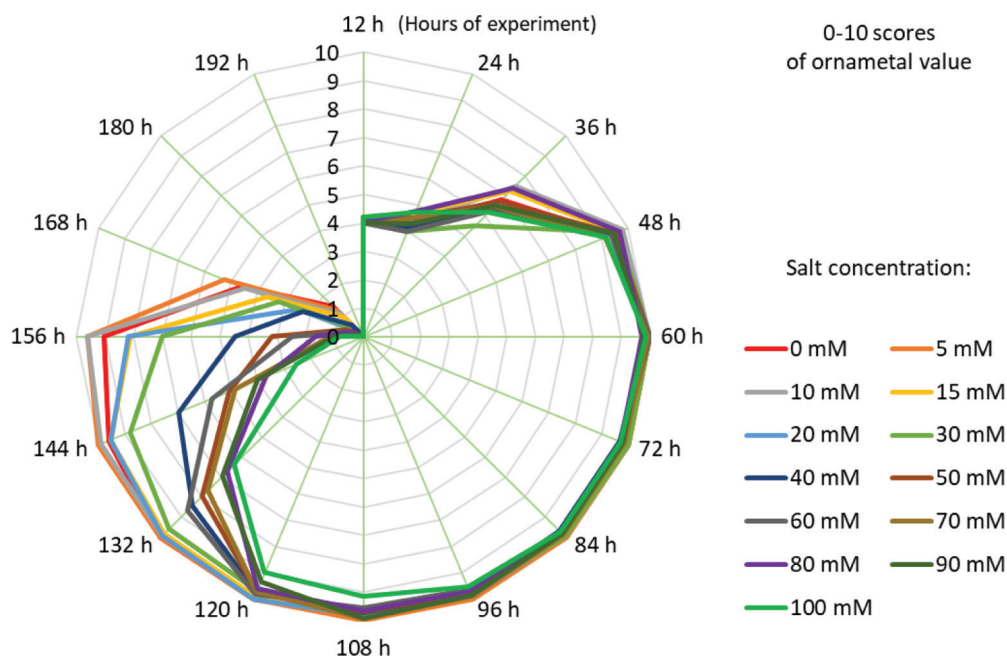


Figure 6. Time pattern of the ornamental value.

Table 3. Time of reaching the critical stages of flower opening and flower senescence based on OVSs (hours after the start of the experiment).

Treatment (NaCl concentration, mM)	Flower opening				Wilting of flowers			
	OVS = 5		OVS = 9		OVS = 9		OVS = 5	
0	27.9 ± 1.9	a	46.1 ± 1.7	a	156.3 ± 7.6	d	167.1 ± 4.7	d
5	28.6 ± 0.7	a	45.6 ± 0.4	a	157.7 ± 0.3	d	169.1 ± 1.7	d
10	26.4 ± 0.8	a	43.9 ± 0.8	a	157.4 ± 0.4	d	166.8 ± 0.4	d
15	24.7 ± 2.2	a	45.1 ± 0.6	a	151.8 ± 3.7	d	163.9 ± 0.8	cd
20	27.9 ± 1.6	a	46.6 ± 0.7	a	150.1 ± 2.7	d	162.6 ± 0.9	cd
30	33.0 ± 2.8	a	46.0 ± 1.0	a	143.3 ± 3.5	cd	161.4 ± 1.6	cd
40	29.5 ± 1.1	a	42.6 ± 2.4	a	129.3 ± 4.4	bc	152.8 ± 2.0	bc
50	26.7 ± 0.6	a	46.2 ± 1.0	a	126.1 ± 2.0	b	144.8 ± 3.5	ab
60	30.6 ± 1.9	a	46.8 ± 0.9	a	128.8 ± 1.4	bc	146.8 ± 3.7	ab
70	27.5 ± 1.8	a	47.5 ± 1.1	a	124.3 ± 0.9	b	143.6 ± 2.4	ab
80	25.1 ± 0.4	a	44.5 ± 1.0	a	122.3 ± 0.6	b	137.6 ± 2.2	a
90	28.6 ± 1.9	a	42.6 ± 2.5	a	122.4 ± 1.8	b	138.4 ± 2.7	a
100	24.9 ± 3.6	a	48.4 ± 2.2	a	102.4 ± 2.1	a	136.5 ± 1.5	a
Formula and R^2 of regression function					$y = -0.495x + 158.04$ $R^2 = 0.92$		$y = -0.358x + 168.88$ $R^2 = 0.95$	

Mean ± standard error, the different letters represent the difference between the treatments by parameter (column) based on Tukey's HSD test, at the $p < 0.05$ level.

OVSs, ornamental value scores.

5.2–5.3 days in the 0–15 mM concentration range. In the 40–100 mM range, there was no significant difference in the vase life. There is a well-described relationship ($R^2 = 0.94$ – 0.95) between the increase in salinity and the length of the vase lifetime (according to both calculation methods) with a second-order curve.

The changes in the ornamental value over time are shown in Figure 6. Considering that there were only a

few flowers with tepals that were not extended in plane at full flowering, the temporal presence of values close to the maximum '10' score was similar to the parameters associated with 100% full flower in Figures 2 and 3.

In the initial period, achieving ornamental value scores (OVSs) of 5 and 9 showed no difference in the effect of the salt treatments (Table 3). For the whole experiment, the flower bouquets achieved an average

score of 5 after 28 hr from the start and an average score of 9 after 46 hr.

There were significant differences in the decline of the numbers of opened flowers as a result of salt treatments, especially in the high-NaCl concentration treatments. However, there was no significant difference at the time of falling below the 9- and 5-point thresholds in the 0–30 mM concentration range. There were also no significant differences between the 40 and 90 mM salt treatments (especially when the value decreases below a score of 9). However, the regression line fitted to the mean values per treatment showed a strong correlation between the salinity of the solution and the onset of decline in the ornamental value of the flowers. The time of decline below the 5-point threshold (when wilted) occurred after 167–169 hr from the onset in

the 0–30 mM treatments and after 30 hr less in the 80–100 mM treatments.

The ornamental value retained 9 or higher scores for 110–113 hr in the 0–15 mM solutions, twice as long as in 100 mM solution. With 5 or higher scores, flowers persisted 30 hr more in the 0–15 mM treatments than in the 80–100 mM treatments (Figure 7). A polynomial trend curve was fitted to the decrease in these durations with good accuracy ($R^2 = 0.90–0.97$).

In the 0–20 mM treatments, the ornamental value decreased from 9 to 5 after 9–13 hr and then from 5 to 0 after an additional 19–21 hr. In contrast, in the 50 mM treatment, the two durations were 19 hr and 35 hr (9 to 5 and 5 to 0 decreases, respectively), and in the 100 mM treatment, the durations were 34 hr and 28 hr (Table 4).

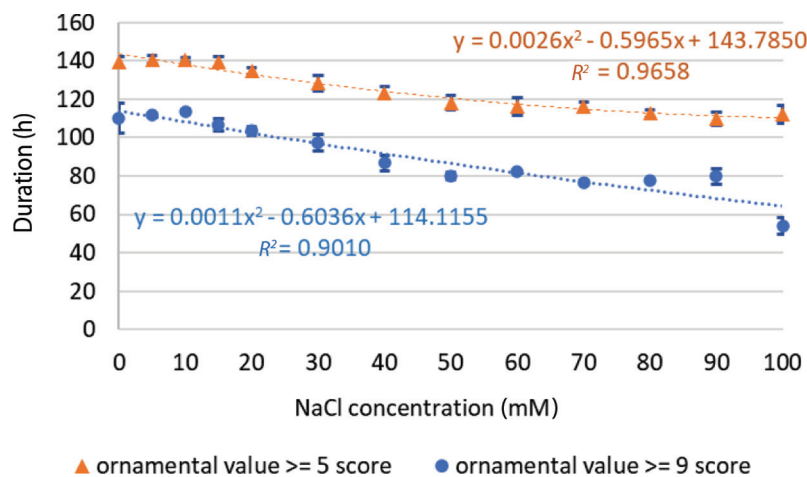


Figure 7. Duration of the vase life based on OVS limits. The error bars show the standard error of means. OVS, ornamental value score.

Table 4. Duration of decrease in the OVSs (hours).

Treatment (NaCl concentration, mM)	Duration of fall from 9 to 5 scores		Duration of fall from 5 to 0 scores		Duration of fall from 9 to 0 scores	
0	10.9 ± 4.2	ab	20.9 ± 4.8	a	31.7 ± 8.9	a
5	11.4 ± 1.8	ab	18.9 ± 3.1	a	30.4 ± 4.3	a
10	9.4 ± 0.6	a	21.2 ± 3.6	a	30.6 ± 3.8	a
15	12.1 ± 2.9	ab	20.1 ± 4.8	a	32.2 ± 7.7	a
20	12.5 ± 1.9	ab	21.4 ± 3.3	a	33.9 ± 2.8	ab
30	18.0 ± 3.7	ab	22.7 ± 5.6	a	40.7 ± 5.8	abc
40	23.5 ± 2.5	bc	35.2 ± 3.5	a	58.7 ± 3.7	bc
50	18.7 ± 1.6	ab	35.2 ± 3.5	a	53.9 ± 2.0	abc
60	18.0 ± 2.6	ab	29.2 ± 5.5	a	47.2 ± 5.0	abc
70	19.2 ± 2.0	ab	28.4 ± 2.5	a	47.7 ± 3.2	abc
80	15.3 ± 2.5	ab	38.4 ± 4.3	a	53.7 ± 4.5	abc
90	16.0 ± 1.1	ab	29.6 ± 4.3	a	45.6 ± 5.4	abc
100	34.1 ± 3.1	c	27.5 ± 2.5	a	61.6 ± 5.5	c

Mean ± standard error, the different letters represent the difference between the treatments by parameter (column) based on Tukey's HSD test, at the $p < 0.05$ level.

OVSs, ornamental value scores.

The change in the total ornamental score decreased linearly with the increase in saline concentrations. Starting from the 120 values with the 0–10 mM treatments, the 10 mM concentration increase resulted in a 3-score decrease (Figure 8).

Scape colour and healthy stage

Colour changes were first observed on the scapes 120 hr after the start of the experiment (Figure 9). At that time, yellowish green scapes were recorded in the 50 mM or

higher concentration treatments (at that time, the flowers were still in 'FO' condition, except for the 100 mM treatment, Figure 4). Subsequently, in the two treatments with the highest salt concentrations, the scape colour changed very rapidly; more than half of the scapes (the part above the water) discoloured within 12 hr. After an additional 12 hr, completely yellowed scapes were found in these treatments. In the two treatments with the highest salt concentrations, no scapes were green 144 hr after the start of the experiment. 24 hr later

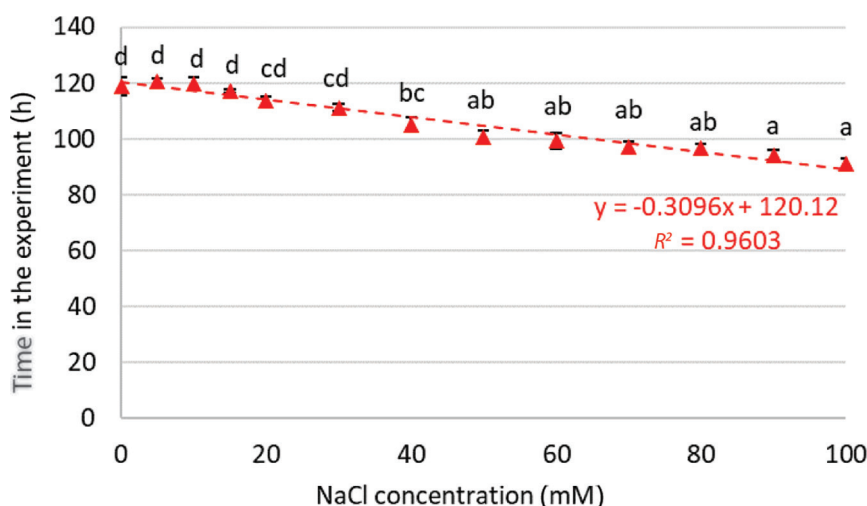


Figure 8. Sum of 12-hr ornamental values. The error bars show the standard error of means, and the different letters above the groups show the significant differences between the treatments based on Tukey's HSD test.

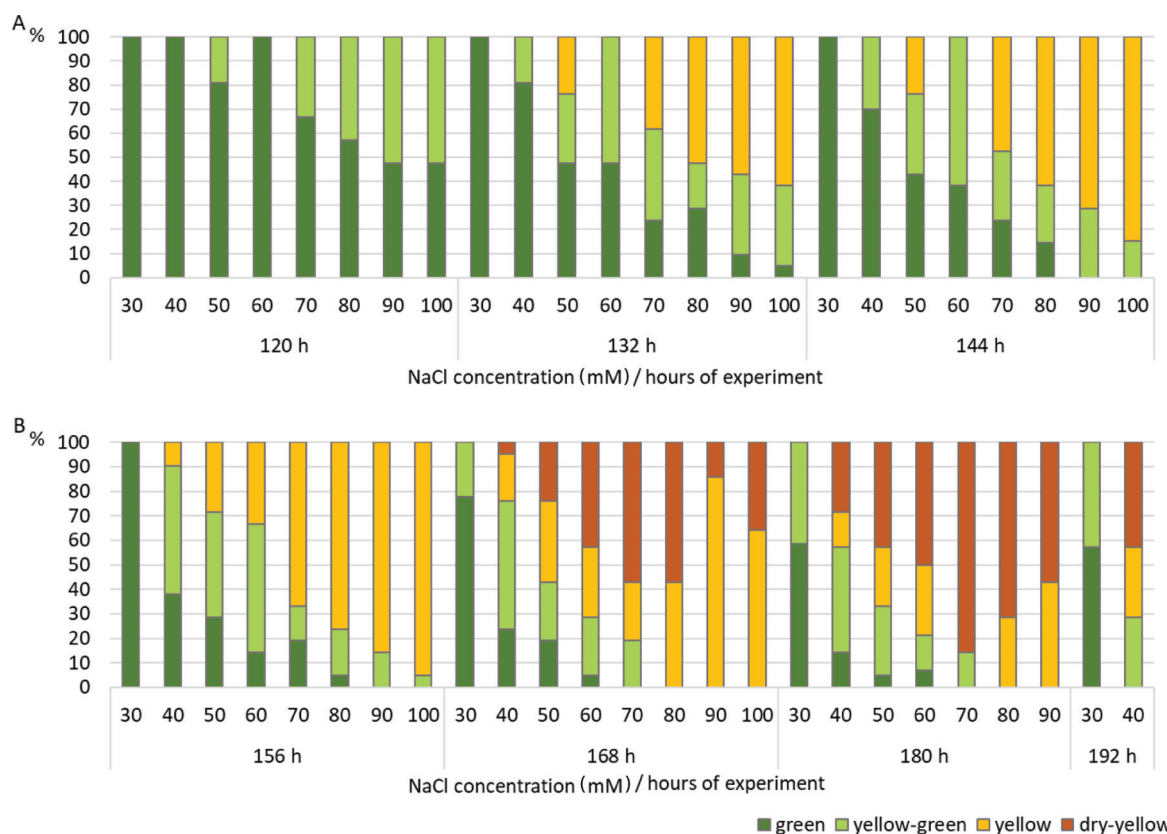


Figure 9. Development of scape colour change (A: at 120–140 hours of the experiment; B: after the 140th hour of the experiment).

(168 hr from the start of experiment), yellowish-green scapes were also found in the 30 mM solution, and in the more-concentrated treatments, the scapes were already drying. However, the colour changes were always only observed above the portion of the scape standing in the solution. In solutions with concentrations >70 mM, all scapes were yellow when the flowers were fully open, and many (57%–87%) had dried. In saline solutions with concentrations >30 mM, the scapes remained green until the flowers were fully open. In higher concentrations (>30 mM) of saline, we also observed broken scapes.

The cut surface of the scape in saline solutions with a concentration of <30 mM remained intact until the end of the experiment. In the 30 mM and more-concentrated solutions, the length of the damaged part of the scape increased proportionally with increasing concentrations (Figure 10). The coefficient of X of the well-fitting

linear regression curve ($R^2 = 0.97$) shows that in the concentration >20 mM, a concentration increase of 10 mM increased the scape length decomposition by 3.5 mm at the 108th hr of the experiment and by 6.6 mm at the final senesce.

Size and fresh weight of the flowers.

No difference was found in the diameter of the flowers at full flowering between the treatments. At full opening, the average petal diameter was 60–62 mm and the crown diameter was 15–16 mm. Likewise, there was no significant difference in the fresh weight of flowers and scapes at the same time (Table 5).

Dry weight and dry matter content

At full flowering, no correlation was found between the salinity of the solution and the dry weight of the plant

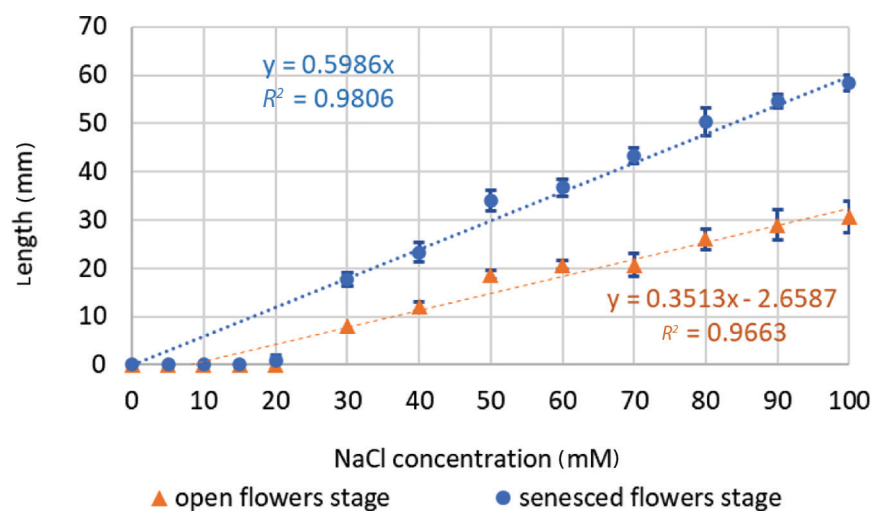


Figure 10. Length of scape-basis degradation. The error bars show the standard error of means.

Table 5. Diameter of the flowers and the fresh weight of the plant parts.

NaCl concentration (mM)	Petal diameter (mm)		Corona diameter (mm)		Flower fresh weight (g)		Scape fresh weight (g)	
0	62.0 ± 0.5	a	15.4 ± 0.1	a	1.19 ± 0.06	ab	1.50 ± 0.08	a
5	62.2 ± 0.7	a	15.7 ± 0.1	a	1.24 ± 0.10	ab	1.64 ± 0.13	a
10	59.8 ± 0.9	a	15.4 ± 0.1	a	1.12 ± 0.02	ab	1.58 ± 0.08	a
15	61.5 ± 0.1	a	15.5 ± 0.2	a	1.20 ± 0.03	ab	1.69 ± 0.04	a
20	60.4 ± 1.7	a	15.3 ± 0.2	a	1.07 ± 0.07	ab	1.52 ± 0.16	a
30	61.4 ± 1.1	a	15.6 ± 0.2	a	1.22 ± 0.02	ab	1.52 ± 0.24	a
40	61.5 ± 1.3	a	15.4 ± 0.3	a	1.11 ± 0.00	ab	1.55 ± 0.00	a
50	62.1 ± 0.5	a	15.7 ± 0.3	a	1.20 ± 0.16	ab	1.45 ± 0.02	a
60	60.6 ± 1.2	a	15.6 ± 0.2	a	1.32 ± 0.02	b	1.96 ± 0.07	a
70	60.2 ± 0.8	a	15.5 ± 0.2	a	1.00 ± 0.03	a	1.39 ± 0.05	a
80	60.5 ± 1.0	a	15.5 ± 0.1	a	1.21 ± 0.03	ab	1.77 ± 0.12	a
90	60.6 ± 1.5	a	15.5 ± 0.6	a	1.16 ± 0.02	ab	1.59 ± 0.18	a
100	61.4 ± 1.2	a	15.4 ± 0.1	a	1.20 ± 0.06	ab	1.51 ± 0.05	a

Mean ± standard error, the different letters represent the difference between the treatments by parameter (column) based on Tukey's HSD test, at the $p < 0.05$ level.

parts. At the senesced stage, the dry weight changed with the increase in salt concentrations. A polynomial regression curve could be fitted to the mean values with a high degree of accuracy (scapes: $R^2 = 0.90$; flowers: $R^2 = 0.81$). For the scapes, the lowest values were in the middle salt range, where for the flowers, the highest values were recorded (Figure 11). For salt concentrations >15 mM, the dry weight of the flowers exceeded that of the scapes, with the highest flower-to-scape weight ratio being 1.4–1.5 (40–60 mM NaCl concentration).

The dry matter content was not clearly affected by the salinity of the soaking solution. At the senesced flower stage, the average dry matter content of the scapes was identical to the previous samples. However, the dry matter content of the flowers changed significantly during the wilting, 1.2–1.6 value increase over the 3

days (Figure 12). In case of the dry matter content of the flowers, the interaction between the salt concentration and sampling time was significant.

Chlorophyll and carotenoid contents of the scapes

The chlorophyll content of the scapes initially increased with the increase in salt concentrations and then decreased significantly (Figure 13). At the first sampling (full flowering), the chlorophyll a and b contents were the highest in the scapes of the flowers in both the 10 mM NaCl and 15 mM NaCl solutions, and they were the lowest at concentrations of 50 mM and above. At senescence, the chlorophyll a content was the highest in the 5–20 mM solutions, followed by the lowest values for samples from 40 mM and higher concentrations. In the same sampling, the chlorophyll b content was the highest

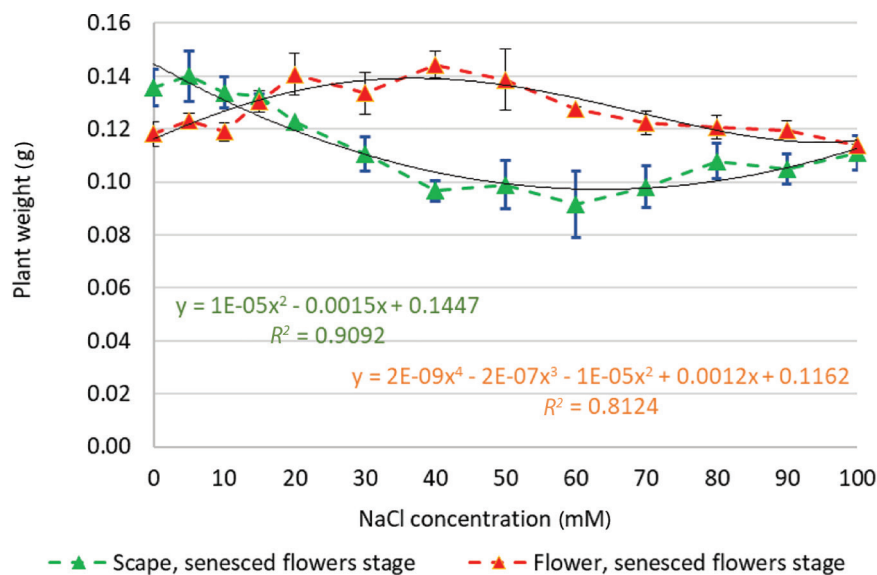


Figure 11. Dry weight at the senesced flower stage. The error bars show the standard error of means.

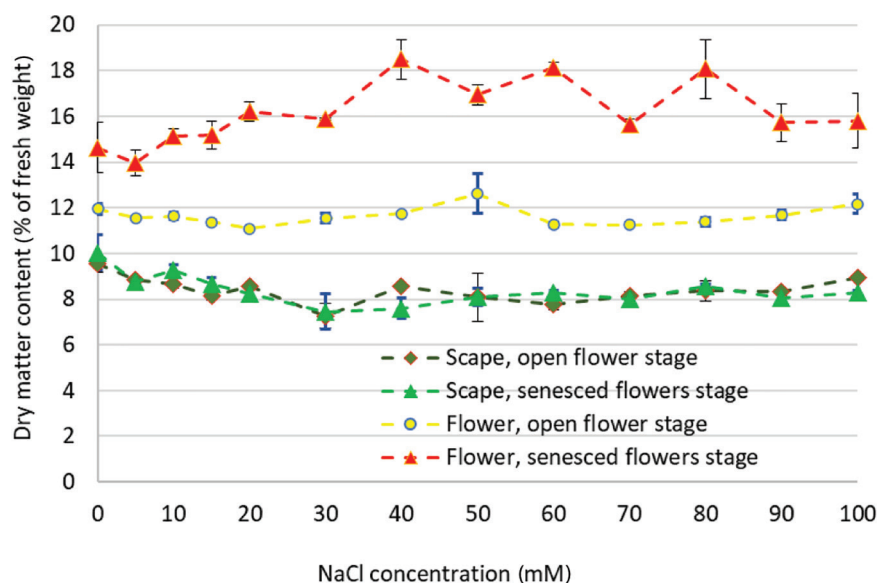


Figure 12. Dry matter content of the flowers and scapes in the full flowering period and the senesced flower stage (108 hr and 168–192 hr after the start of the experiment). The error bars show the standard error of means.

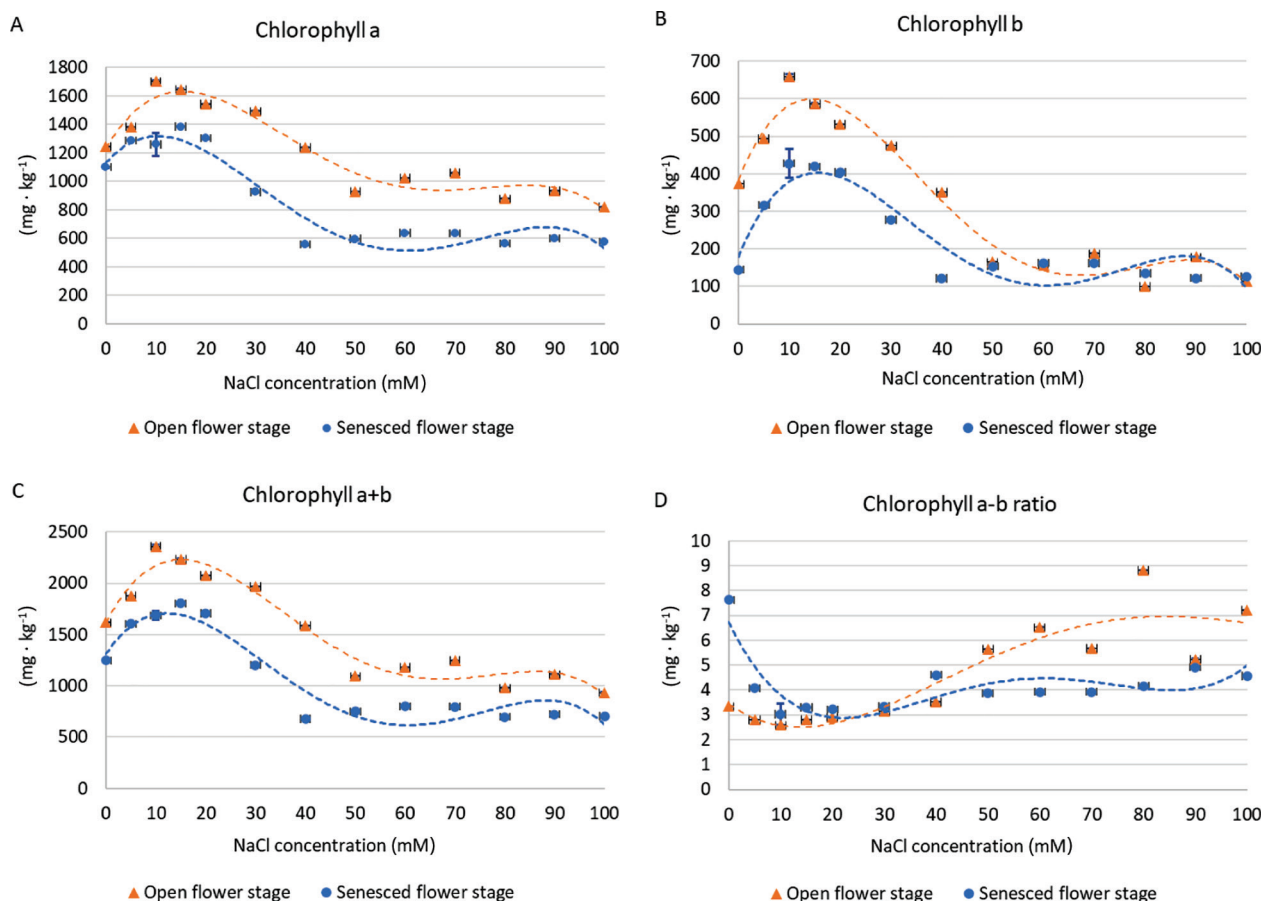


Figure 13. Chlorophyll a (A), chlorophyll b (B) content of the scapes, their sum (chlorophyll a+b) (C) and ratio (chlorophyll a+b) (D). The error bars show the standard error of means.

in 10–15–20 mM solutions, followed by a significant decrease from the 40 mM treatment onwards. However, the latter values were similar to those measured in the scapes in the control.

Comparing the two sampling times, parallel curves with almost identical slopes were obtained for chlorophyll a, with lower values in all treatments at the end of the experiment than in the middle of the experiment. In solutions with salt concentrations of >40 mM, the chlorophyll b content of scapes did not change significantly between the two samplings.

The ratio of the two chlorophyll forms varied with salt concentration. Although the amount of chlorophyll a was higher than that of chlorophyll b in all cases, the ratio was significantly higher in full flowering at concentrations of >40 mM than at the first sampling. The chlorophyll b content decreased more than the chlorophyll a content. At the end of the experiment, the highest ratio was measured in the control, while the concentration effect was not as strong in the solutions containing NaCl as it was in the previous sampling.

Both the chlorophyll a and b contents and their ratios can be fitted with a polynomial function ($R^2 = 0.72$ – 0.96).

The carotenoid content of the scapes was the highest at the first sampling (full flowering) in solutions with 10–30 mM NaCl concentrations and then varied

according to a polynomial curve ($R^2 = 0.89$). In the 10–20 mM treatments, the carotenoid content decreased significantly upon senescence. However, in the treatments with salt concentrations of >30 mM, the carotenoid content of the scapes increased significantly during flower senescence (Figure 14).

Element content

The plants took up both sodium and chlorine from the solution in the vases (Figures 15 and 16). The regression curves between the solution concentration and the increase in the sodium content of the scapes and flowers were well described by linear and second-order equations. The combined sodium content of scapes and flowers increased in linear proportion to the concentrations of the solutions in the vases (10 mM NaCl concentration increase to $2.25 \text{ g} \cdot \text{kg}^{-1}$ of the sodium content at flowering and 27% more at the flower senesced stage). Among the organs, the increase in the sodium content was higher in the scapes, but sodium was also transferred from the scapes to the flowers. After the main flowering stage, the increase in salinity continued, which was very striking for flowers at high-salt concentrations (in the 100 mM NaCl solution, a threefold increase between 108 hr and 168 hr).

Similar to the sodium content, the chlorine content was also higher in the scapes than in the flowers (at the

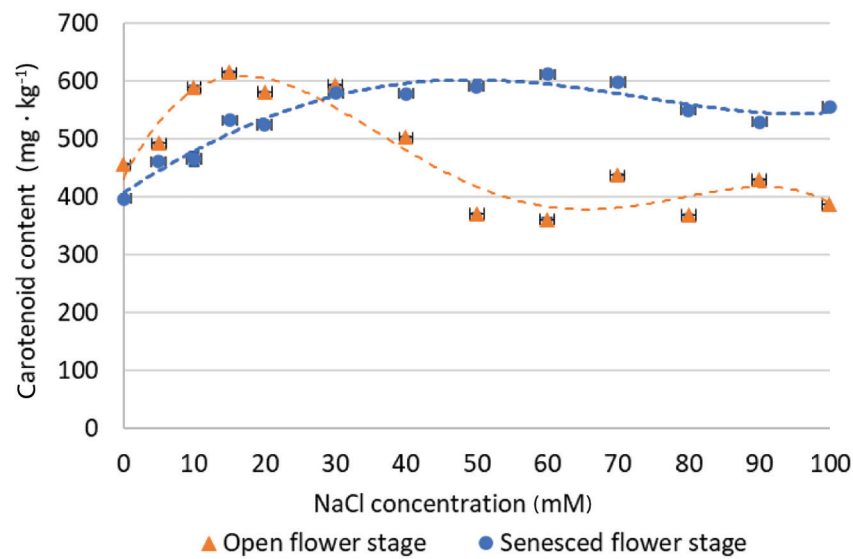


Figure 14. Carotenoid content of the scapes. The error bars show the standard error of means.

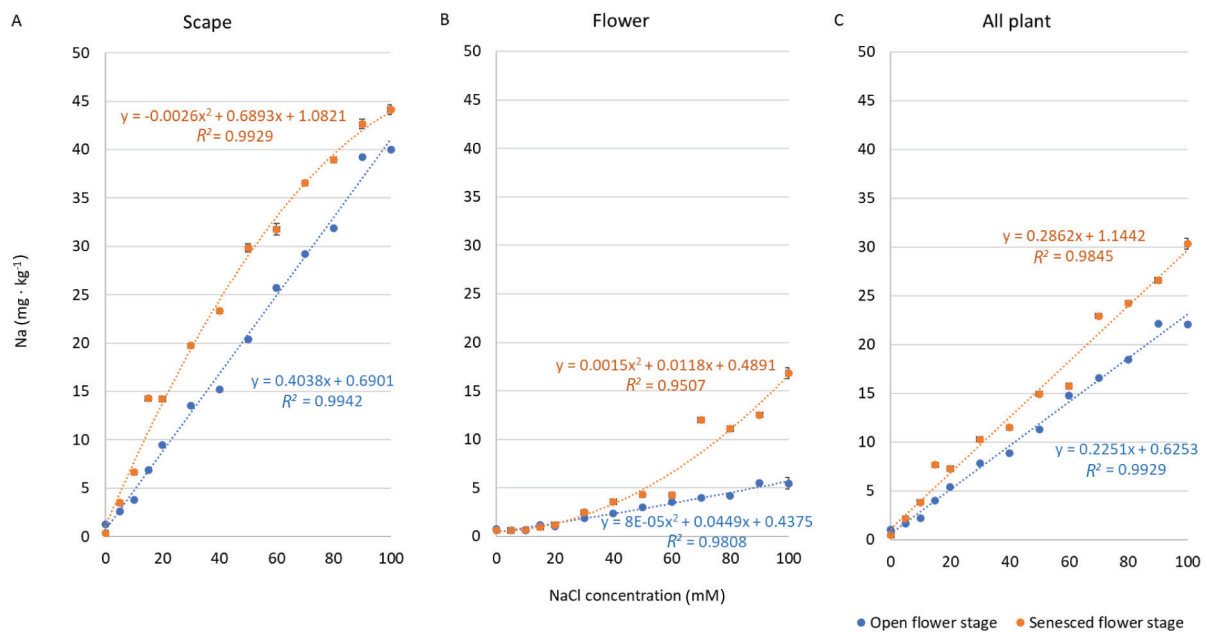


Figure 15. Sodium content of the plant parts (A: scape, B: flower, C: scape + flower). The error bars show the standard error of means.

end of the experiment in the 100 mM NaCl solution, the chlorine content in the scapes was 2.7 times higher value than that in the flowers). The chlorine content in the scapes increased steadily with the increase in the solution concentration, and there was a large difference between the two samplings in case of treatments with concentrations of >30 mM, i.e. the chlorine content also increased significantly during senescence. In the flowers, there was no significant difference between the values in the 30–70 mM range at full flowering, but

the values measured after senescence increased almost steadily. In the 100 mM solution, however, there was no significant difference between the two samplings; the flowers almost reached the maximum chlorine content at the full flowering stage. Similar to the sodium content, a polynomial regression was well fitted to the curves for the chlorine content.

The potassium content was much higher in the flowers than in the scapes (Figure 17). In the latter, the potassium concentration decreased significantly with

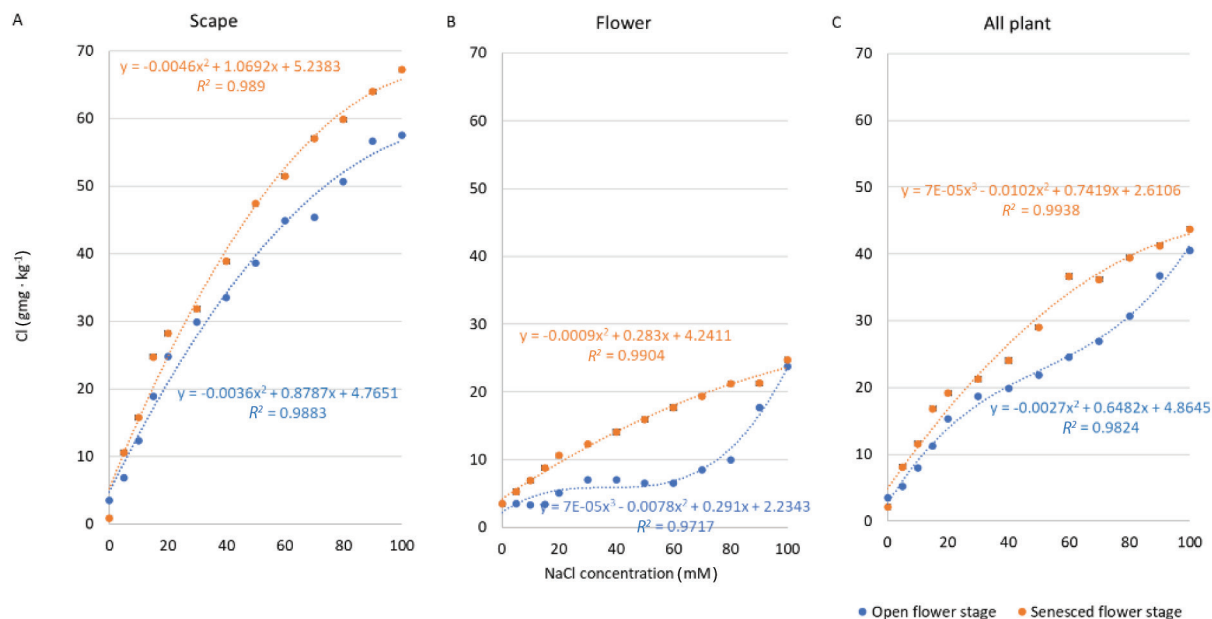


Figure 16. Chlorine content of the plant parts (A: scape, B: flower, C: scape + flower).

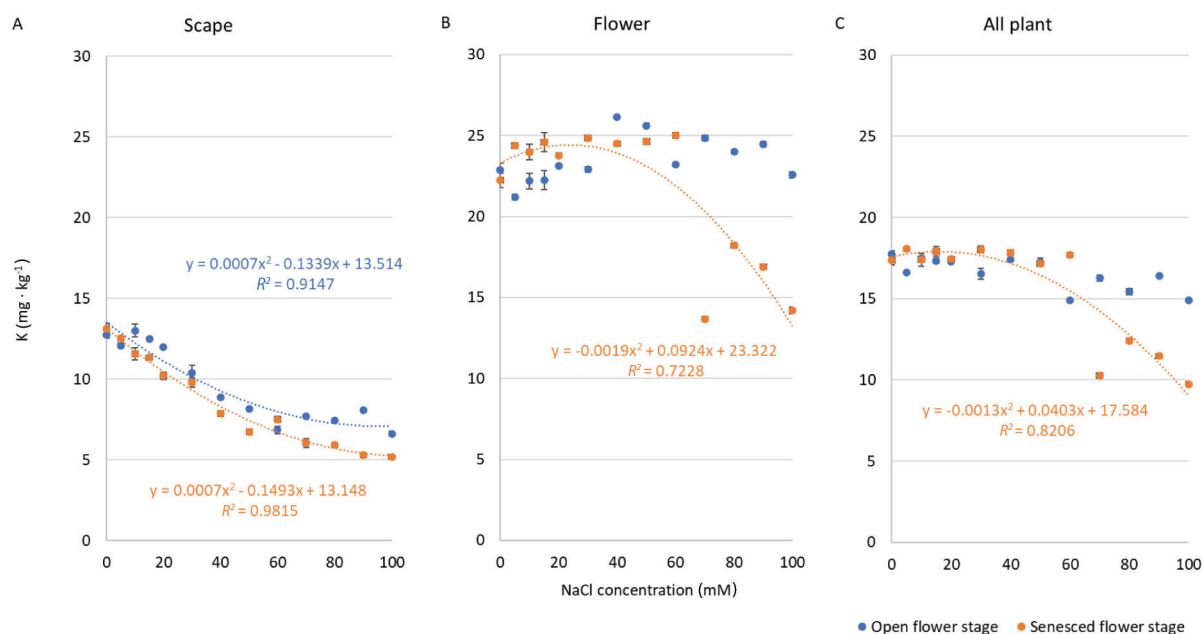


Figure 17. Potassium content of plant parts (A: scape, B: flower, C: scape + flower). The error bars show the standard error of means.

the increase in the salt concentration (well characterised by a second-order polynomial curve). The combined potassium content of stems and flowers did not show a close correlation with the salt concentration. However, in the senesced flowers, the value decreased significantly in flowers kept in solutions with high concentrations (>60 mM).

There was a negative correlation between the sodium and potassium contents of the scapes. As the salinity of

the solution increased, the potassium content decreased proportionally (Figure 18). The increase of 10.0 mg · kg⁻¹ Na content in the scape resulted in a decrease of 1.63 mg · kg⁻¹ potassium content at flowering, and 1.87 mg · kg⁻¹ at the end of the experiment. In molecular terms, a 10 mmol · g⁻¹ increase in the Na content was associated with a 0.96 mmol · kg⁻¹ decrease in the K content at flowering and a 1.10 mmol · kg⁻¹ decrease at senesced flowers.

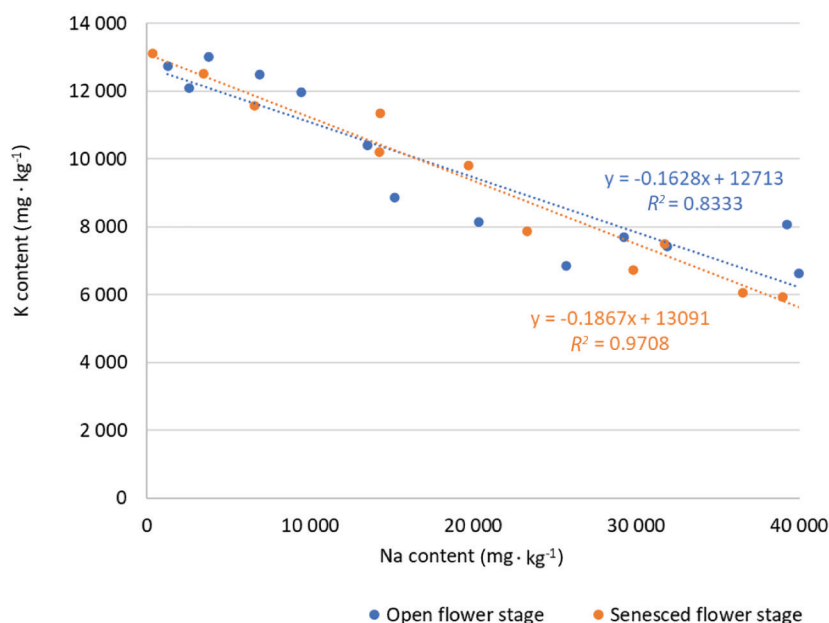


Figure 18. Relationship between the Na and K contents of the scapes. The error bars show the standard error of means.

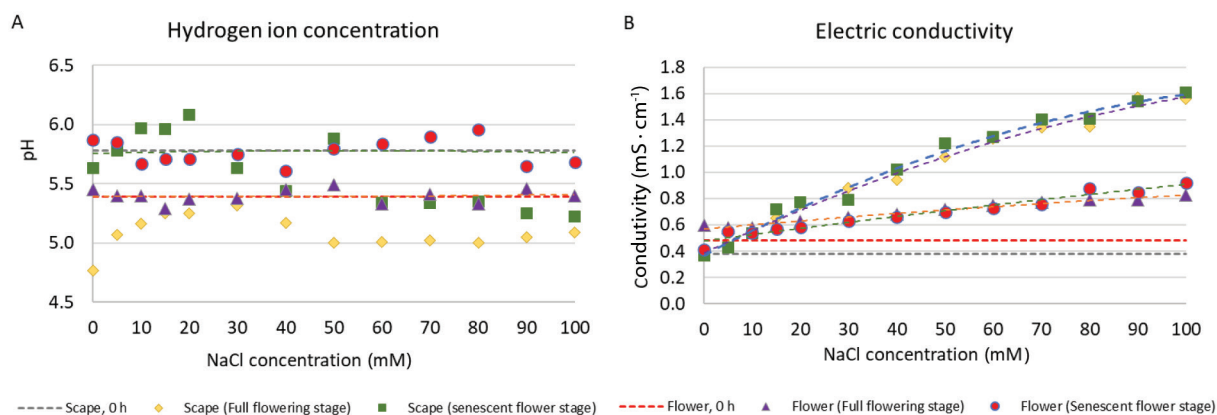


Figure 19. Hydrogen ion concentration (pH) (A) and electrical conductivity (EC) (B) of the plant water extracts.

Hydrogen ion concentration (pH) and EC values of plant water extracts

The pH of the water extracts did not show any correlation with the concentration of the salt treatments (Figure 19). However, it was observed that all scape samples collected at full flowering had lower pH than the initial sample. For the flowers collected at the end of the experiment, pH was higher than that of the initial sample (regardless of the salt treatment). Mean pH values and their corresponding standard deviations (13 treatments) are given as follows:

- scapes: open flower stage: 5.09 ± 0.14 ; wilted stage: 5.61 ± 0.30 ,
- flowers: open flower stage: 5.40 ± 0.06 ; wilted stage: 5.77 ± 0.11 .

The EC value of the water extracts increased in both plant parts (at both sampling times) as a function of salt concentration and was well described by both linear and second-order polynomial functions ($R^2 = 0.95\text{--}0.98$). The results of the two samplings were almost the same. In treatments with a concentration of >15 mM, the EC of the water extract of the scapes was higher than that of the flowers, and the difference between the EC of the extract of the scapes and flowers became higher with the increase in the salinity of the solution in the vases.

Hydrogen ion concentration (pH) and EC values of the salt solutions in the vases

In all treatments, the pH level of the saline solutions in the vases was lower than the initial value at the first measurement (54 hr after the start of the experiment), but no effect of the saline solutions was detected.

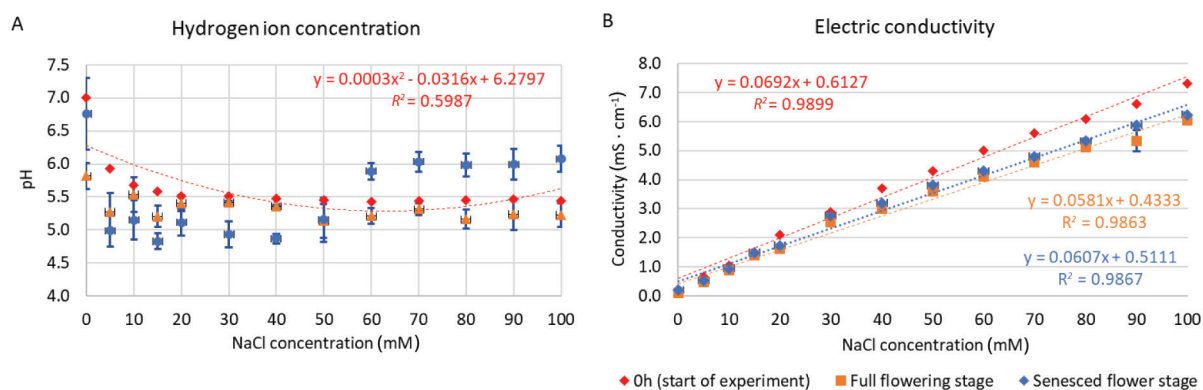


Figure 20. Hydrogen ion concentration (pH) (A) and electrical conductivity (EC) (B) of the salt solutions in the vases. The error bars show the standard error of means.

Overall, the mean value for the salt treatments was 5.29 compared to a mean value of 5.53 for the control. The pH measured at the end of the experiment decreased further at lower concentrations (<60 mM), while values above concentrations of 50 mM increased. However, no difference was found in the 60–100 mM range as a result of the change in salt concentration. The mean value of the treatments in the higher concentration range was 5.99 mM, while in the 5–50 mM treatments, it was 5.01 (Figure 20).

The EC value of the vase solutions was well described by a linear trend with increasing concentrations. The differences in coefficients of the slope (x) of the linear function fitted to the data also indicate that the initial (0 hr) values and those measured during the water usage of plants at higher salt concentrations differed significantly. Comparing the values with the initial data, the EC value of the solution decreased by $1.23 \text{ mS} \cdot \text{cm}^{-1}$ (17%–19%) at the highest concentrations (90–100 mM) compared to the time of the first measurement. However, there was no significant difference between the values of the open flowers and the senesced flowers.

After 168 hr from the start of the experiment, the refractive index (Brix) value of the solutions in the vases and the salt concentrations showed a linear correlation (Figure 21). The correlation was close ($R^2 = 0.996$), with a 10 mM concentration increase lifting the Brix value to 0.093. The effect of a 20 mM concentration change was generally clearly distinguishable with the instrument used in the experiment (0.1 precision). All treatments showed higher values at the end of the experiment than at the start. The linear function fitting the two data series was steeper for the data measured near the end of the experiment than that of the initial data series.

DISCUSSION

The subject of the experiment, the use of saline water as a vase solution to model the use of poor quality (high Na and Cl content) vase water, is a sparsely researched topic.

Armitage and Laushman (2003) stated about the basic chemical properties of the vase solution that the buffering capacity of the water or its pH value (alkalinity) is more important than the saline conditions. However, they did not note that the salt sensitivity of different plant species varies. Researchers tend to focus on the effects of saline irrigation water usage during the cultivation phase of a plant (flower) (Veatch-Blohm et al., 2013; Wang et al., 2019; QuanChao et al., 2019; Moghadam et al., 2020). Nejad and Nazarian (2013) pointed out chlorine toxicity, but the sensitivity was cultivar-dependent, and chlorine toxicity symptoms were detectable on rose leaves.

One of the roles of additives commonly used to increase the vase life is to protect scapes from bacterial contamination (i.e. to reduce bacterial growth in water). In many cases, chlorine-containing compounds are used for this purpose (Macnish et al., 2008; Nejad and Nazarian, 2013; Lee et al., 2014). In addition, the water usually used in vases initially contains chlorine, sodium and other salts. Thus, cut flowers may be affected by different forms of salt stress.

Our experiment shows that almost all vase life indices change unfavourably with the increase in the NaCl content. The variation in most parameters can be described by linear or polynomial regression curves, but for most properties, concentrations of 5–15 mM do not cause a significant effect, but concentrations above this level do. The concentration range of 5–15 mM NaCl contained $109\text{--}327 \text{ mg} \cdot \text{L}^{-1}$ sodium and $168\text{--}504 \text{ mg} \cdot \text{L}^{-1}$ chlorine, resulting in $0.67\text{--}1.50 \text{ mS} \cdot \text{cm}^{-1}$ EC values. According to the WHO (2022), the human taste limits ($200 \text{ mg} \cdot \text{L}^{-1}$ sodium and $250 \text{ mg} \cdot \text{L}^{-1}$ chloride) are still within this range, but these limits can be exceeded in drinking water and do not apply to irrigation water. In the case of irrigation water, the water source can have a wide range of salinity, and in many cases (especially in past or present seawater-influenced areas), Na and Cl contents fall into the concentration range where experimental results indicate that vase life is already impaired.

Based on the effect of increasing salt concentration compared with the response of other plant species

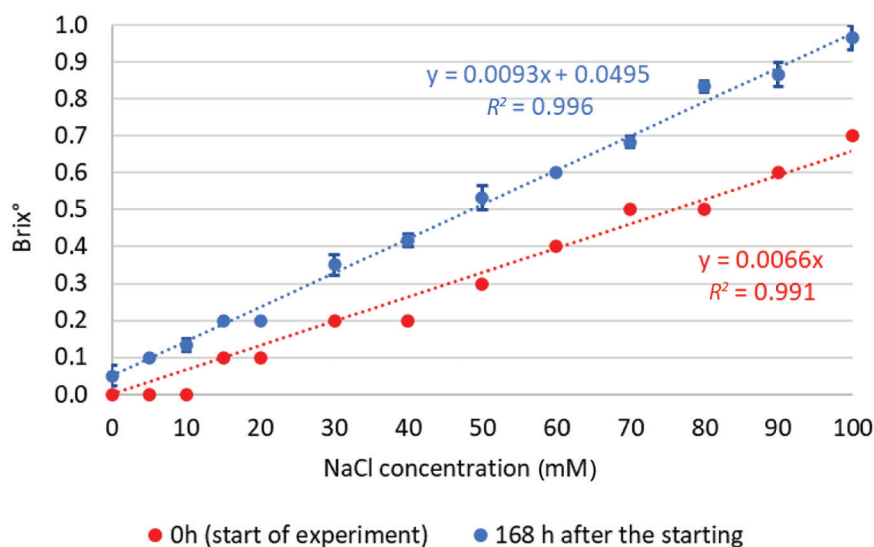


Figure 21. Refractive index value of the salt solutions in the vase. The error bars show the standard error of means.

(Ahmad et al., 2013; Carlson and Dole, 2013), our experimental results show that *N. poeticus* cut flowers are moderately salt-tolerant.

In addition to the vase life of flowers, the effect of salt was also observed in several other parameters.

The ornamental value scoring system developed for the evaluation of vase length results (Jezdinská Slezák et al., 2022) proved to be a suitable tool for making a sophisticated evaluation of vase length in several aspects. The scores calculated from 12-hr recordings allow the instantaneous condition to be monitored, and the cumulative scores can be used to describe the suitability of the use as cut flowers in general in a single number and to compare the overall firmness effect of different treatments.

The increase in the chlorophyll content at low salinity and then a significant decrease at higher concentrations is a trend similar to that observed by Chinese researchers in a pot experiment with *N. pseudonarcissus*. When salt was applied *via* a root medium, they observed an increase in the chlorophyll content at a concentration of 100 mM, followed by a significant decrease when using solutions of 300–500 mM (Wang et al., 2019). The difference in the range of harmful concentrations in our case is mainly due to the application of the salt. The cut flowers were in contact with saline water directly through the scapes without any major selective or tissue transmission system, and there was no surrounding medium (such as the organic root medium in the pot experiments) to attenuate the salt effect. Likewise, a substantial difference in experimental conditions explains the results obtained by Moghadam et al. (2020), who showed that the chlorophyll content in leaves decreased at 30% field capacity when irrigated with a concentration of 60 mM NaCl in a field experiment with *N. tazetta*.

In our experiment, the results of the first sampling of the carotenoid content showed a trend similar to the chlorophyll content, while in the second half of the experiment, the carotenoid content of the scapes increased in the treatments with high salt concentrations. Increases in the carotenoid content under NaCl-induced salt stress have been shown by other researchers in cultivation experiments with other plant species. In experiments with seedlings of *Fagopyrum esculentum*, Lim et al. (2012) found that saline solutions of 50 mM NaCl and 100 mM NaCl sprayed on plants increased the carotenoid content of the plants compared to a 0 mM control. Using the same concentrations, Abdallah et al. (2016) showed an increase in β -carotene and lutein in *Solanum nigrum*. However, in field-grown *N. tazetta*, regularly applied irrigation water containing 60 mM NaCl reduced the carotenoid content of green leaves. The conclusion of the same experiment was, however, that up to EC of $3 \text{ mS} \cdot \text{cm}^{-1}$ the salinity of irrigation water had no negative effect if irrigated at 70% field capacity, i.e. if the water supply is adequate. Their results showed that the carotene content decreased only when high salt stress was combined with drought (irrigation at 30% field capacity) (Moghadam et al., 2020).

In relation to carotenoid and chlorophyll degradation, it was shown in the 1960s, when dried and ensiled green fodder was examined, that even in drying hay, carotenoid synthesis can continue for a short time after cutting (i.e. after the interruption of water supply and active photosynthesis). In addition, under anaerobic conditions (silage making), chlorophyll and carotenoid decomposition proceed differently, with chlorophyll often not occurring (Ihász, 1963). This fact may explain why in our experiments, the part of the scapes immersed in the solution remained green even at salt

concentrations where the aerial part of the scapes turned yellow, or even dried out.

In addition to the accumulation of Na and Cl, the scape yellowing and drying we observed at high salt concentrations, as well as the rapid flower withering, were also due to the decomposition of the tissues at the basal end of the scape (the water absorption surface), which inhibited water uptake. The highly decomposing scapes caused a slight increase in the pH of the vase solutions, which, according to experience with the preservation of cut flowers, can be an important factor because it creates more favourable conditions for microorganisms attacking the scapes, leading to further decomposition.

No data on the accumulation of Na and Cl in the scapes and flowers were found in the literature, but Bian and Pan (2018) in the case of *N. tazetta* seedlings treated with NaCl solutions *via* root and leaf application found that the Na and Cl content in the leaves increased in both methods. Similar to our results, the K:Na in their experiments decreased significantly when NaCl was used.

The experiment provides new data not only on salt stress but also on the general usefulness of *N. poeticus* as a cut flower. Most authors define the final stage of vase life as the stage when half of the flowers are completely wilted (Eason, 2002; Eason et al., 2002; Clark et al., 2010; Gun, 2020). Starting from the erect white bud ('pencil') stage, the experiment reported in this article showed a vase life of 180 hr in the control and at low salt concentrations, i.e. 7.5 days, until half of the flowers were completely wilted. These results are in line with or better than those published by other authors for other narcissus species (values generally between 3 days and 6 days – Sun and Brosnan, 1999; Gul and Tahir, 2013; Whale, 2017), and with the results previously published for *N. poeticus* (Jezdinská Slezák et al., 2022). This also indicate that *N. poeticus* can be used as cut flowers in the same way as other single-flowered daffodils in this respect.

CONCLUSIONS

The poet's narcissus (*N. poeticus*) can be used as a cut flower even if the salinity (NaCl) of the water is higher than the usual limits: in room temperature, only a reduction in the vase life of 1.5–2 days can be expected at a concentration of 70–100 mM NaCl (5.6–7.3 mS · cm⁻¹ EC) compared to 7–7.5 days in the salt-free and low-salt vase water.

In addition to conventional chemical laboratory analyses, nontraditional fast detection methods, such as the Brix° value of the vase water and the EC and pH of the water extract of the plant parts, can be used to characterise changes.

In the case of most of the parameters considered, the effect of the current salt concentration can be well described by regression curves; thus, the method can be used to determine trends and calculated values associated with the intermediate concentrations.

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AUTHOR CONTRIBUTIONS

A.J. and K.J.S designed and performed experiments and analytical measurements. M.V. performed statistical analysis. A.J., K.J.S and M.V. wrote the paper. R.P. and J.U. assisted with conceptualisation, methodology and review and provided funding. A.J. and U.J. supervised the experiment.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

- ABDALLAH, B. S., AUNG, B., AMYOT, L., LALIN, I., LACHAAL, M., KARRAY-BOURAOUI, N., AND HANNOUFA, A. (2016). Salt stress (NaCl) affects plant growth and branch pathways of carotenoid and flavonoid biosyntheses in *Solanum nigrum*. *Acta Physiologiae Plantarum*, 38, 72, <https://doi.org/10.1007/s11738-016-2096-8>.
- AHMAD, I., DOLE, J. M., CARLSON, A. S., AND BLAZICH, F. A. (2013). Water quality effects on postharvest performance of cut calla, hydrangea, and snapdragon. *Scientia Horticulturae*, 153, 26–33, <https://doi.org/10.1016/j.scienta.2013.01.015>.
- ARMITAGE, A. M., AND LAUSHMAN, J. M. (2003). *Specialty cut flowers*, 2nd ed. Portland, London: Timber Press. ISBN-13: 978-0-88192-976-8.
- BARANAUSKIENĖ, R., AND VENSKUTONIS, P. R. (2022). Supercritical CO₂ extraction of *Narcissus poeticus* L. flowers for the isolation of volatile fragrance compounds. *Molecules*, 27(2), 353, <https://doi.org/10.3390/molecules27020353>.
- BIAN, A., AND PAN, D. (2018). Effects of salt stress on growth and inorganic ion distribution in *Narcissus tazetta* L. var. *chinensis* Roem. seedlings. *HortScience*, 53(8), 1152–1156, <https://doi.org/10.21273/HORTSCI13145-18>.
- BITTNEROVÁ, M., AND MARTÍNEK, J. (2007). Floristická obchodní jednotka, vedení prodeje, marketing, legislativa. In *Floristika 2*, Děčín-Libverda, CR: Střední škola zahradnická a zemědělská Antonína Emanuela Komerse. ISBN 978-80-239-8922-9.
- BLATNY, P., KVASNICKA, F., LOUCKA, R., AND SAFAROVA, H. (1997). Determination of ammonium, calcium, magnesium, and potassium in silage by capillary isotachopheresis. *Journal of Agricultural and Food*

- Chemistry*, 45(9), 3554–3558, <https://doi.org/10.1021/jf9606767>.
- CARLSON, A. S., AND DOLE, J. M. (2013). Postharvest water quality affects vase life of cut *Dendranthema*, *Dianthus*, *Helianthus*, and *Zinnia*. *Scientia Horticulturae*, 164, 277–286, <https://doi.org/10.1016/j.scienta.2013.09.024>.
- CEVALLOS, J. C., AND REID, M. S. (2001). Effect of dry and wet storage at different temperatures on the vase life of cut flowers. *HortTechnology*, 11(2), 199–202, <https://doi.org/10.21273/HORTTECH.11.2.199>.
- CHANDRA GARG, M., AND JOSHI, H. (2015). A review on PV-RO process: solution to drinking water scarcity due to high salinity in non-electrified rural areas. *Separation Science and Technology*, 50(8), 1270–1283, <https://doi.org/10.1080/01496395.2014.951725>.
- CLARK, E. M. R., DOLE, J. M., CARLSON, A. S., MOODY, E. P., MCCALL, I. F., FANELLI, F. L., AND FONTENO, W. C. (2010). Vase life of new cut flower cultivars. *HortTechnology*, 20(6), 1016–1025, <https://doi.org/10.21273/HORTSCI.20.6.1016>.
- CONRADO, L. L., SHANAHAN, R., AND EISINGER, W. (1980). Effects of pH, osmolarity and oxygen on solution by cut rose flowers. *Journal of the American Society for Horticultural Science*, 105, 680–683.
- DIRECTIVE (EU) 2020/2184 of the European Parliament and of the council of 16 Dec 2020 on the quality of water intended for human consumption (recast). Retrieved from <https://eur-lex.europa.eu/eli/dir/2020/2184/oj>.
- DOLE, J. M., AND WILKINS, H. F. (2005). *Floriculture: Principles and species*, 2nd ed. Upper Saddle River, NJ, USA: Pearson/Prentice Hall. ISBN 0-13-046250-0.
- EASON, J. R. (2002). *Sandersonia aurantiaca*: An evaluation of postharvest pulsing solutions to maximise cut flower quality. *New Zealand Journal of Crop and Horticultural Science*, 30(4), 273–279, <https://doi.org/10.1080/01140671.2002.9514224>.
- EASON, J. R., RYAN, D. J., PINKNEY, T. T., AND O'DONOGHUE, E. M. (2002). Programmed cell death during flower senescence: isolation and characterization of cysteine proteinases from *Sandersonia aurantiaca*. *Functional Plant Biology*, 29(9), 1055–1064, <https://doi.org/10.1071/PP01174>.
- GUL, F., AND TAHIR, I. (2013). An effective protocol for improving vase life and postharvest performance of cut *Narcissus tazetta* flowers. *Journal of the Saudi Society of Agricultural Sciences*, 12(1), 39–46, <https://doi.org/10.1016/j.jssas.2012.06.001>.
- GUN, S. (2020). Extending of vase life of *Narcissus tazetta* by AVG and antimicrobial agents. *Journal of Postharvest Technology*, 8(4), 27–34.
- HILAL, N., AL-ZOUBI, H., MOHAMMAD, A. W., AND DARWISH, N. A. (2005). Nanofiltration of highly concentrated salt solutions up to seawater salinity. *Desalination*, 184(1–3), 315–326, <https://doi.org/10.1016/j.desal.2005.02.062>.
- HOLM, G. (1954). Chlorophyll mutations in barley. *Acta Agriculturae Scandinavica*, 4, 457–471, <https://doi.org/10.1080/00015125409439955>.
- IHÁSZ, I. (1963). Takarmányok karotin és klorofil bomlásának vizsgálata. *Agrokémia és Talajtan*, 12(3), 379–390.
- JEFFREY, G. H., BASSETT, J., MENDHAM, J., AND DENNEY, R. C. (1989). *Vogel's textbook of quantitative chemical analysis*, 5th ed. New York, USA: Longman Scientific & Technical. ISBN 0-582-44693-7.
- JEZDINSKÁ SLEZÁK, K., JEZDINSKÝ, A., MAZUR, J., VACHUN, M., KAPCZYŃSKA, A., POKLUDA, R., AND UHER, J. (2022). The influence of the bud stage at harvest and cold storage on the vase life of *Narcissus poeticus* (L.) flowers. *Agriculture*, 12, 2114, <https://doi.org/10.3390/agriculture12122114>.
- KARAGIANNIS, I. C., AND SOLDATOS, P. G. (2008). Water desalination cost literature: review and assessment. *Desalination*, 223(1–3), 448–456, <https://doi.org/10.1016/j.desal.2007.02.071>.
- KŘESADLOVÁ, L., AND VILÍM, S. (2009). Encyklopedie tulipánů, hyacintů, begonii a dalších cibulnatých a hlíznatých rostlin (Encyclopedia of Tulips, Hyacinths, Begonias and other Bulbous and Tuberous Plants), 1st ed. Brno, ČR: Computer Press a.s. ISBN 978-80-251-2830-5.
- LEE, Y. M., PARK, S. K., AND KIM, W. S. (2014). Antibacterial effect of chlorine dioxide on extending the vase life of cut gerbera 'Jenny'. *Flower Research Journal*, 22(3), 161–166, <https://doi.org/10.11623/frj.2014.22.3.9>.
- LIM, J. H., PARK, K. J., KIM, B. K., JEONG, J. W., AND KIM, H. J. (2012). Effect of salinity stress on phenolic compounds and carotenoids in buckwheat (*Fagopyrum esculentum* M.) sprout. *Food Chemistry*, 135(3), 1065–1070, <https://doi.org/10.1016/j.foodchem.2012.05.068>.
- LOU, X., ANWAR, M., WANG, Y., ZHANG, H., AND DING, J. (2021). Impact of inorganic salts on vase life and postharvest qualities of the cut flower of Perpetual Carnation. *Brazilian Journal of Biology*, 81(1), 228–236, <https://doi.org/10.1590/1519-6984.221502>.
- MACNISH, A. J., LEONARD, R. T., AND NELL, T. A. (2008). Treatment with chlorine dioxide extends the vase life of selected cut flowers. *Postharvest Biology and Technology*, 50(2–3), 197–207, <https://doi.org/10.1016/j.postharvbio.2008.04.008>.
- MOGHADAM, A. N., BAYAT, H., AMINIFARD, M. H., AND MORADINEZHAD, F. (2020). Effect of drought and salinity stress on flower quality, biochemical changes and ions concentration of *Narcissus tazetta* cv. 'Shahla'. *Journal of Plant Production*, 27(1), 207–221, <https://doi.org/10.22069/jopp.2020.16138.2459>.
- NEJAD, A. R., AND NAZARIAN, F. (2013). Effects of pre-cooling and chlorine on post-harvest quality of cut roses (*Rosa hybrida* L.). *International Journal of Agriculture and Crop Sciences*, 5(4), 355–361.

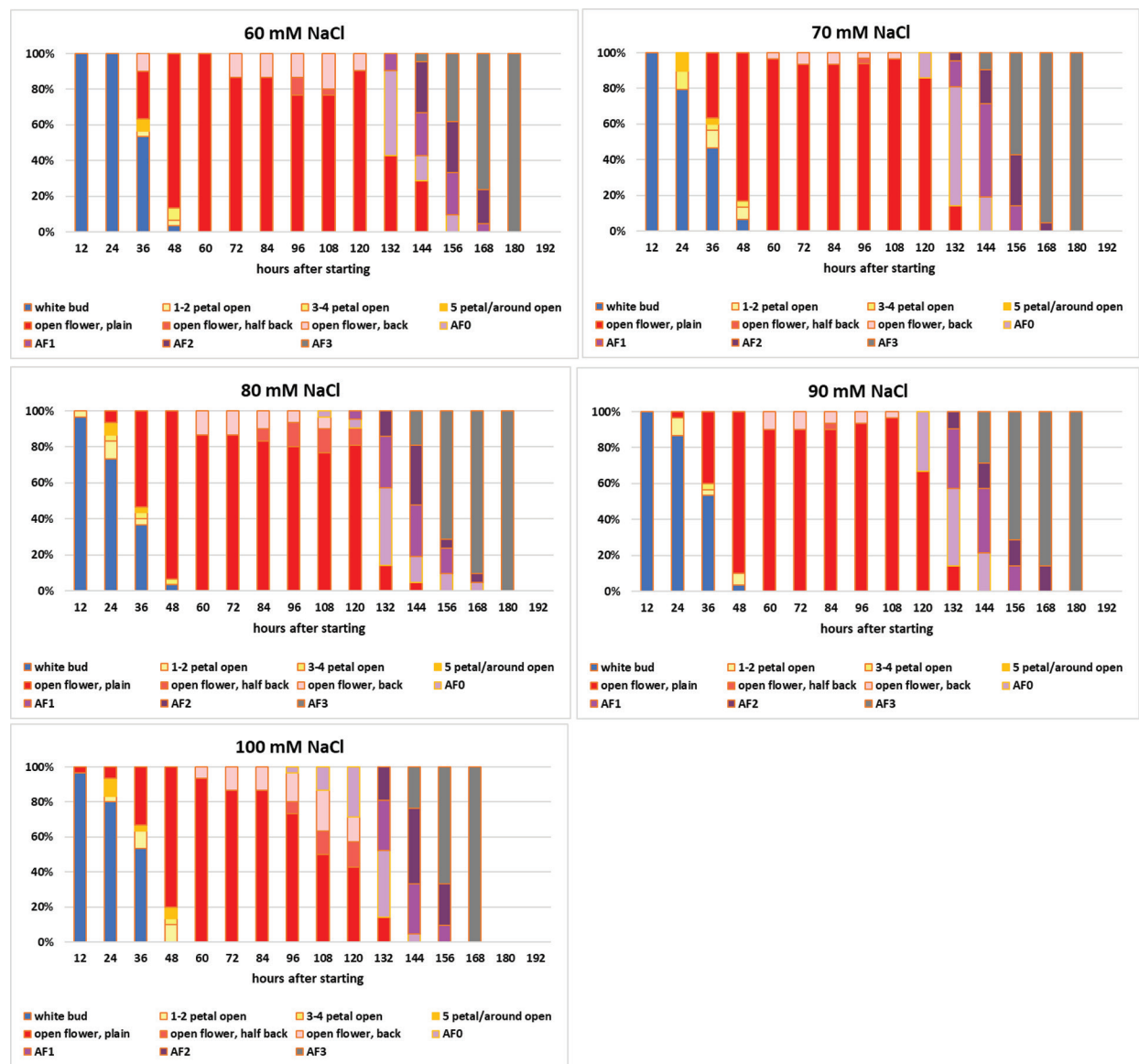
- QUANCHAO, L., YANG, L., YAOYU, X., LING, L., SHAOBING, H., AND XIAOJING, C. (2019). Responses of physiological property and chlorophyll fluorescence characteristics of narcissus to salt stress. *Journal of Fujian Agriculture and Forestry University (Natural Science Edition)*, 2, 161–167.
- RABIZA-ŚWIDER, J., SKUTNIK, E., JĘDRZEJUK, A., AND SOCHACKI, D. (2020). Effect of preservatives on senescence of cut daffodil (*Narcissus* L.) flowers. *The Journal of Horticultural Science and Biotechnology*, 95(3), 331–340, <https://doi.org/10.1080/14620316.2019.1679042>.
- REDZIĆ, S., HODZIĆ, N., AND TUKA, M. (2005). Plant pigments (antioxidants) of medicinal plants *Malva silvestris* L. and *Malva moschata* L. (Malvaceae). *Bosnian Journal of Basic Medical Sciences*, 5(2), 53–58, <https://doi.org/10.17305/bjbms.2005.3284>.
- REID, M. S., AND JIANG, C. (2013). Postharvest: Cut flowers and potted plants. In R. Kamenetsky and H. Okubo (Eds), *Ornamental Geophytes* (pp. 333–361). Boca Raton, USA: CRC Press. ISBN 978-1-4398-4924-8.
- REMY, C. H. (2002). Narcissus in perfumery. In G. R. Hanks (Ed.), *Narcissus and daffodil. The genus narcissus*, 1st ed (pp. 392–398). London, UK: Taylor & Francis. ISBN 0-415-27344-7.
- SALEEM, S., BYTEŠNÍKOVÁ, Z., RICHTERA, L., AND POKLUDA, R. (2021). The effects of *Serendipita indica* and guanidine-modified nanomaterial on growth and development of cabbage seedlings and black spot infestation. *Agriculture*, 11, 1295, <https://doi.org/10.3390/agriculture11121295>.
- SAPPA, G., ERGUL, S., FERRANTI, F., NGALYA SWEYA, L., AND LUCIANI, G. (2015). Effects of seasonal change and seawater intrusion on water quality for drinking and irrigation purposes, in coastal aquifers of Dar es Salaam, Tanzania. *Journal of African Earth Sciences*, 105, 64–84, <https://doi.org/10.1016/j.jafrearsci.2015.02.007>.
- SHAMMI, M., RAHMAN, M. M., BONDAD, S. E., AND BODRUD-DOZA, M. (2019). Impacts of salinity intrusion in community health: A review of experiences on drinking water sodium from coastal areas of Bangladesh. *Healthcare*, 7, 50, <https://doi.org/10.3390/healthcare7010050>.
- SUN, D. W., AND BROSNAN, T. (1999). Extension of the vase life of cut daffodil flowers by rapid vacuum cooling. *International Journal of Refrigeration*, 22(6), 472–478, [https://doi.org/10.1016/S0140-7007\(99\)00011-0](https://doi.org/10.1016/S0140-7007(99)00011-0).
- VAN DOORN, W. G. (2012). Water relations of cut flowers: an update. *Horticultural Reviews*, 40, 55–106.
- VAN MEETEREN, U., VAN GELDER, H., AND VAN IEPEREN, W. (2019). Reconsideration of the use of deionized water as vase water in postharvest experiments on cut flowers. *Postharvest Biology and Technology*, 17(3), 175–187, [https://doi.org/10.1016/S0925-5214\(99\)00050-2](https://doi.org/10.1016/S0925-5214(99)00050-2).
- VEATCH-BLOHM, M. E., CHEN, D., AND HASSETT, M. (2013). *Narcissus* cultivar differences in response to saline irrigation when application began either pre- or postemergence. *HortScience*, 48(3), 322–329, <https://doi.org/10.21273/HORTSCI.48.3.322>.
- WANG, J. Y., QIAO, Q., AND TAO, J. H. (2019). The physiological response of three *Narcissus pseudonarcissus* under NaCl stress. *American Journal of Plant Sciences*, 10, 447–461. <https://doi.org/10.4236/ajps.2019.103032>.
- WHALE, S. (2017). *Cut flowers*, 3rd ed. Birmingham, UK: Jago Publishing Ltd. ISBN 978-0-9568713-3-6.
- WHO (World Health Organization). 2022. *Guidelines for drinking-water quality, Fourth edition incorporating the first and second addenda* (583 p). Geneva, Switzerland: World Health Organization. ISBN 978-92-4-004506-4.
- YASEMIN, S., KÖKSAL, N., AND KARIMI ANSARI, B. (2022). A cut flower cultivation under saline conditions: *C. morifolium* Ramat ‘Bacardi’. *Polish Journal of Environmental Studies*, 31(2), 1901–1907, <https://doi.org/10.15244/pjoes/141858>.

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SUPPLEMENTARY MATERIALS



Supplementary Figure S1. Continued.



Supplementary Figure S1. Flower stage distribution with 12-hr recordings.