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Vase Life Evaluation of Three Greek Tulip Species Compared with a Commercial Cultivar

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Abstract: Aiming at evaluating new candidate species for the cut flower market of Greece and beyond, in this study, the vase life of three Greek tulip plant species, *Tulipa cretica* 'Hilde' (CRH, local endemic of Crete, Greece), *T. clusiana* 'Chrysantha' (CLC, naturalized in Chios Island, Greece), and *T. australis* (AUS, native in the Mediterranean and Greece), was investigated in comparison to the commercial tulip hybrid Île-de-France (IDF). To this end, pre-cooled at 4 °C bulbs of the abovementioned Greek tulip plant species were bought from Dutch nurseries and grown in pots placed in unheated greenhouses located at two different climatic conditions in Northern Greece. The plants were uprooted when the flowers reached a slightly open stage. Half of the flowering stems were immediately placed into bottles with deionized water, while the rest were placed in a preservative solution containing citric acid 5% and sulfuric acid 1% and then remained under laboratory conditions until the entire tepal wilted (end of vase life). The measurements performed concerned: (a) flower stem length and flower maximum diameter, (b) fresh weight (FW) of initial stems, leaves, flowers, and bulbs and at the end of vase life, (c) flower color parameters (L, a, b, c, and H) in all treated flowers, (d) leaf chlorophyll content (SPAD values), and (e) initial and final water volume after removing the flowering stems. The aforementioned measurements showed that CRH cut flowers may exhibit consistent floral opening patterns and were associated with a long mean vase life of 5.7 days, which can be further prolonged to 6.5 days by carefully selecting a cultivation location with proper climatic conditions. The vase life of CLC cut flowers was significantly affected by the climatic parameters (temperature) of the area where the plants were cultivated. The immersion of cut flowering stems in a preservative solution with citric and sulfuric acids did not yield a notable increase in the longevity of cut flowers during the postharvest period. Moreover, this treatment did not have any significant impact on leaf chlorophyll content or flower color at the end of the flowers' vase life. The data of this work show that cut flowers from the native species *T. cretica* and *T. clusiana* have satisfactory vase life, especially when plants were grown in favorable climate condition; the latter is an important criterion for their entry into the cut flower market.

Keywords: Tulipa; Greek flora; Liliaceae; biodiversity; cut flowers; postharvest handling; preharvest climatic conditions; phytogenetic resources

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1. Introduction

Floriculture is probably the most competitive sector of agriculture since many different plant species are produced and marketed [1,2]. To stand the global competitiveness and

meet consumers' demand for cut flowers, the ornamental industry frequently introduces new flower crops with special features [1,2]. Typically, the native flora of different regions serves as a reservoir from which new floricultural species originate, and annually, hundreds of new wild plant species are evaluated worldwide for their potential to compete in the ornamental plant market. Noteworthy efforts to assess the sustainable exploitation potential for the ornamental sector of neglected and underutilized local endemics originating from selected Mediterranean regions have taken place recently, resulting in the identification of both opportunities and extant gaps [3]. Native tulips originating from the Balkans and Central Asia are a typical example of wild plant species from which many commercial tulip varieties were developed [4,5]. Although the utilization of endemic and native species offers many benefits, such as new interesting ornamental features in combination with reduced crop requirements due to natural adaptation to climatic conditions and inherent resistance to pests and diseases [3,6,7], cut flowers from wild-growing plants cannot be placed directly into the flower market [8]. The high level of variability in yield, the unbalanced architecture of the flowering parts (shoot length, foliage shape, number, and size of the flowering buds), and irregular time of flowering accompanied by their short postharvest life may undermine and reduce their aesthetic value and concomitant marketability [1,9]. Preharvest and postharvest factors are strongly affecting the abovementioned features of cut flowers [10,11]. Genetic/varietal factors, plant age, climatic conditions during the growing period, plant health, cultivation practices, and the harvesting stage are among the most important preharvest factors [12], which are responsible for creating a product with good quality (large flower with desired coloring, high water and carbohydrates content). In addition, bulb size and bulb weight of bulbous plants play a significant role both on geophytes flower quality and their postharvest vase life [13–15]. On the other hand, postharvest treatments mainly aim to maintain the cut flowers' quality characteristics for as long as possible in order to extend their vase life. For this purpose, appropriate storage conditions and handling are applied to reduce transpiration, maintain a high concentration of carbohydrates in plant tissues, limit microbial infection, and inhibit ethylene biosynthesis and action.

To achieve the abovementioned objectives, flower preservative solutions, with both surfactant and antimicrobial effects, are usually used to prolong the postharvest life of cut flowers, particularly when flowers cannot be kept at controlled temperature and relative humidity conditions to decrease their respiration and dehydration [16]. Specific preservative solutions containing substances with antimicrobial activity, such as sodium hypochlorite [17], silver nitrate [18], physan 20, 8-hydroxyquinoline [19], silver thiosulfate [18], and chlorine dioxide [20], can prevent the growth of microbes inside the flowering stem, which are responsible for occlusions of shoots vessels. Thus, the addition of these substances in the preservation solution facilitates the absorption of water and increases the vase life of the flowers. The extended postharvest life of flowers guarantees customer contentment and fosters sustained product purchase, supporting the entire flower production network and trade chain.

This study aimed to assess the vase life of three Greek tulip species, *Tulipa cretica* 'Hilde', *T. clusiana* 'Chrysantha', and *T. australis*, with shorter flower stem length, smaller flower size and leaf area, as well as greater adaptability to the Mediterranean climate in comparison to a commercially cultivated hybrid variety Île-de-France. The investigation sought to determine their suitability for potential introduction in the cut flower market of Greece in a sustainable way, with vase life serving as a crucial evaluation criterion.

2. Materials and Methods

2.1. Cultivation Conditions and Sampling

In February of 2022, three-month pre-cooled (at 4 °C) bulbs from three Greek native tulip plant species, i.e., *T. cretica* 'Hilde' (local endemic of Crete, Greece), *T. clusiana* 'Chrysantha' (naturalized in Chios Island, Greece), *T. australis* (native in the Mediterranean region including Greece), and the tulip hybrid Île-de-France (Figure 1), were planted in 3.6 L pots. Plants were grown in unheated greenhouses covered with plastic film, which were installed

in Northern Greece in the Institute of Plant Breeding and Genetic Resources (Hellenic Agricultural Organization Demeter) located in Thermi and in commercial greenhouses (Thermokipia Athina) located in Epanomi (Figure 1). The experiments were conducted in the framework of the research project TULIPS.GR. The substrate where plants were grown was a mixture of peat and sand (4:1, *v*:*v*). Plants were drip-irrigated regularly on a weekly basis with adequate amounts of water, similar to commercial practice. All plants in both locations received integrated fertilization with a complete mix of nutrients, similar to popular commercial fertilization regimes. A total of 658 pots with flowering plants from the different species (Table 1) were transported to the Laboratory of Floriculture and Landscape Architecture of the University of Thessaly, Greece, during March and April 2022 for postharvest evaluation.

Figure 1. Greek tulip plant species investigated in this study with views of their experimental cultivation. (**A**) *Tulipa cretica* 'Hilde' (local endemic of Crete, Greece); (**B**) *T. clusiana* 'Chrysantha' (naturalized in Chios Island, Greece); (**C**) *T. australis* (native in the Mediterranean region including Greece); (**D**) Tulip hybrid Île-de-France; (**E**) Experimental cultivation in unheated research greenhouse (Thermi, Northern Greece); (**F**) Experimental cultivation in a commercial greenhouse (Epanomi, Northern Greece).

Table 1. Number of plants from each cultivation location harvested at different days and placed in deionized water with and without the preservative for the four studied tulip species (*Tulipa cretica* 'Hilde' (CRH), *Tulipa australis* (AUS), *Tulipa clusiana* 'Chrysantha' (CLC), and tulip hybrid Île-de-France (IDF)).

Cultivation Location	With Preservative				Total
	CRH	AUS	CLC	IDF	
Epanomi	58	16	32	51	157
Thermi	42	29	46	58	175
	Without Preservative				
Epanomi	51	24	17	64	156
Thermi	39	33	39	59	170
Total	190	102	134	232	658

2.2. Sample Preparation

All plants were uprooted when flowers were at a slightly open stage (Figure 2, Stage 1). The bulbs were separated, and half of the flowering stems from each species were placed directly into 0.5 L plastic bottles containing a pre-weighed amount of deionized water, while the other half of flowering stems were placed in the bottles after pulsing for 10 s within a preservative solution containing citric acid 5%, sulfuric acid 1%, and water 94%. The flowering stems were placed in a room with natural lighting. The room temperature and relative humidity were recorded in real time.

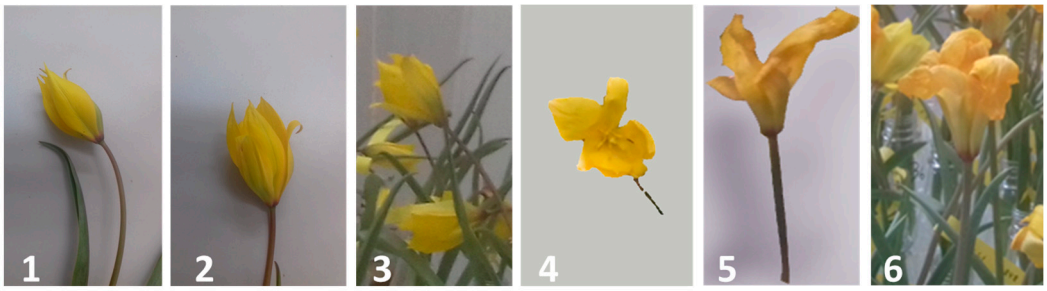

Figure 2. Postharvest stages of *Tulipa australis* flowers as defined during postharvest evaluation: (**1**) slightly open; (**2**) half-opened; (**3**) fully opened; (**4**) slightly wilted at the tepal edge; (**5**) whole tepal wilted; (**6**) whole tepal severely wilted with abscission.

2.3. Measurements

After the separation from the bulb, the flower stem length and maximum diameter were recorded.

In addition, the study also involved the measurement of certain parameters every two days. These included (a) flower color parameters such as L, a, b, c, and H, which were measured in three different tepals in each one of all treated flowers using a PCE-CSM-1 colorimeter (PCE Instruments), and (b) leaf greenness, as indicated by SPAD values, was measured on the abaxial surface of three fully expanded leaves, utilizing the CCM-200plus Chlorophyll Content Meter, following the methodology outlined by Khan et al. [21].

Flower quality was evaluated every second day by four different observers (floriculture laboratory staff) using a scale ranging from 1 to 6 according to tepal senescence [22]. Figure 2 shows the flower quality corresponding to the evaluation scale from 1 to 6. Similar senescence stages for tepals based on the degree of wilting and abscission were followed for the cut flowers of all tulip species treated in this experiment.

In this study, the vase life of cut flowers was considered as the number of days between harvest day and the time when the entire tepal of the flower has withered (Figure 2, stage 5), leading to the loss of its commercial quality. To estimate the period during which 50% of cut

flowers of CRH, CLC, AUS, and IDF reached stage 5, the plants of each treatment (Table 1) were divided into four groups. Each of these groups contained 4 to 17 plants depending on the available number of plants. The flowering stems were gradually removed from the bottles when flowers reached the 5th stage (Figure 2). After removing the flowering stems from the bottle, the FW of the flowering stems and leaves were measured separately. The preservation period (number of days) and the weight of the preservative solution that remained in each bottle were recorded.

2.4. Statistical Analysis

The obtained featured values, as the average, were statistically verified by means of variance analysis method (ANOVA). The difference among the means was compared by Multiple Range Tests, Kruskal–Wallis, and Friendman Tests at the 95.0% confidence level by using STATGRAPHICS computer package. Differences among treatments were considered significant only when $p \leq 0.05$.

3. Results and Discussion

The native tulip plant species CRH, CLC, AUS, as well as the tulip hybrid Île-de-France grown in both Epanomi and Thermi, showed flower stem height and flower diameter similar to those reported from botanical and hybrid tulip bulb producers (https://www.farmergracy.co.uk/collections/botanical-tulips and https://www.gardenia.net/plant/tulipa-ile-de-france-triumph-tulip, respectively, accessed on 2 August 2023) as shown in Figure 3.

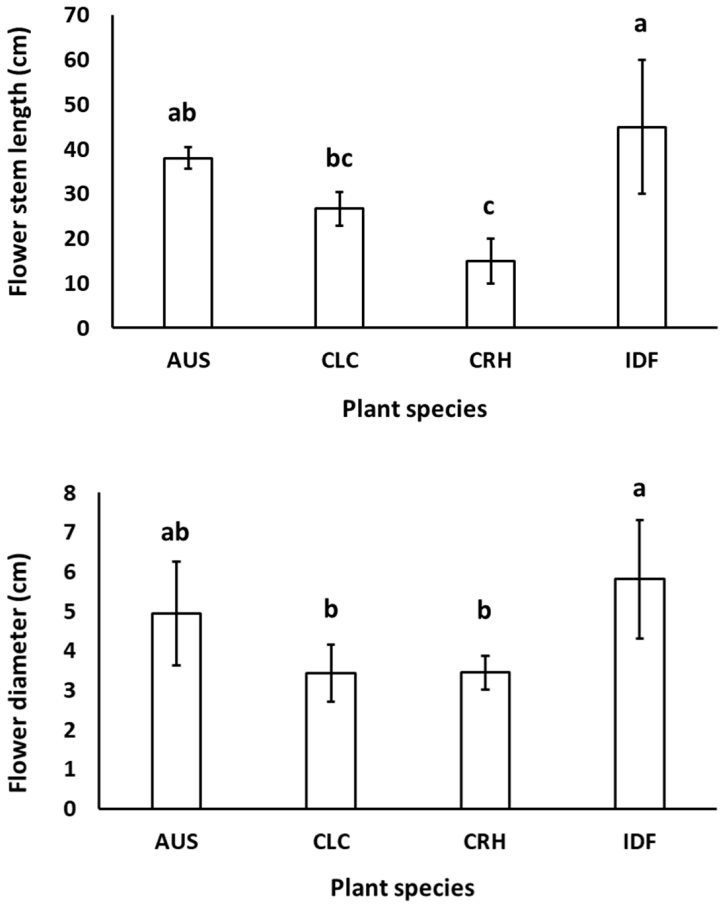

Figure 3. Mean flower stem length and flower diameter of *Tulipa australis* (AUS), *Tulipa clusiana* 'Chrysantha' (CLC), *Tulipa cretica* 'Hilde' (CRH), and tulip hybrid Île-de-France (IDF) harvested from plants grown in Epanomi and Thermi. Different lowercase letters indicate statistically significant differences ($p \leq 0.05$). The vertical bars indicate standard deviation (SD).

The temperature and humidity inside the laboratory where the experiments were conducted varied from 18.8 to 25 °C and from 31 to 55%, respectively (Figure 4). The average air temperature and relative humidity were 20.4 (±1.5) and 44.6 (±5.9), respectively. The abovementioned values were similar to those measured from several researchers inside the Mediterranean residents during March and April [23–25]. The photosynthetic active radiation (PAR) above the cut flowers ranged from 4.6 to 5.31 μmol/m^2/s, and the photoperiod was the natural one for the period when the experiments were conducted (11 h and 30 min to 12 h and 30 min, respectively).

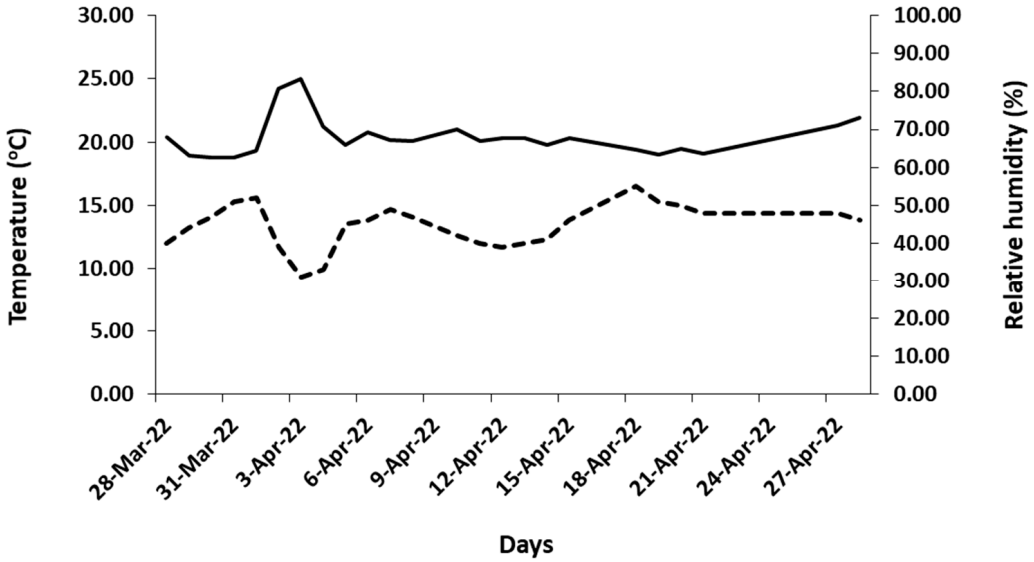

Figure 4. Indoor air temperature (°C) (—) and relative humidity (%) (- -), where the harvested flowering stems of studied tulips were placed to experimentally assess their vase life.

Under similar to the above-described climate conditions, the vase life of the cut flowers of the commercial cultivar IDF, which is a member of Triumph tulips group and cultivated both for field and greenhouse cut tulip production in many different climatic zones, ranged from 3.5 to 8 days depending on the bulb maturity stage [22,26,27]. The measurements conducted on the average vase life of the cut flowers revealed statistically significant differences among the four tulip species, irrespective of the growth location and the use of preservatives. Specifically, the average vase life (days) of cut flowers of IDF measured in this experiment was in agreement with those measured in the abovementioned studies [22,26,27]. The cut flowers of IDF reached the 5th stage (Figure 2) after 4.0 days (±1.7) from harvest (Figure 5). The flowers of the native species *T. cretica* 'Hilde' (CRH) presented the highest average vase life (5.7 days ±1.5), followed by *T. australis* (AUS), which had slightly lower preservation period (5.1 days ±2.82). In addition, the *T. cretica* flowers had almost half the SD value compared to that of *T. australis* flowers, probably due to lower genetic homogeneity. These characteristics can become important in selecting a plant species as a candidate ornamental plant for cut flower production [28–30], since they promote uniformity of the floral opening and, thus, increased marketability. Additional studies have evaluated *T. cretica*, showing high potential for the ornamental sector concerning the suitability for targeted floricultural sub-sectors (e.g., pot/patio plants, home gardening, landscaping, and xeroscaping) coupled with an adequate level for sustainable exploitation feasibility [3]. The third examined species, namely *T. clusiana* 'Chrysantha' (CLC), had shorter vase life (3.5 days ±1.19) compared to all other tulip species used in this study. This postharvest life of CLC was under the minimum acceptable standard for vase life of cut tulips, which is perceived to be 5 to 6 days [31]. From the evaluation of the worldwide electronic trade of Greek botanical tulips, the ex-situ conservation of different Greek species and the sustainable exploitation challenges of Greek tulips have revealed that

both well-established value chains and research gaps exist in the market of tulips, raising significant concerns regarding the effectiveness of ex-situ conservation [32]. Nevertheless, the current study contributes to the creation of a sustainable value chain for the Greek tulips. For *T. cretica*, in particular, its previously defined readiness timescale for sustainable exploitation in the long term [3] could be upgraded based on the results of the current work as achievable in the short term after bridging of previously extant research gaps regarding its cultivation and postharvest vase life.

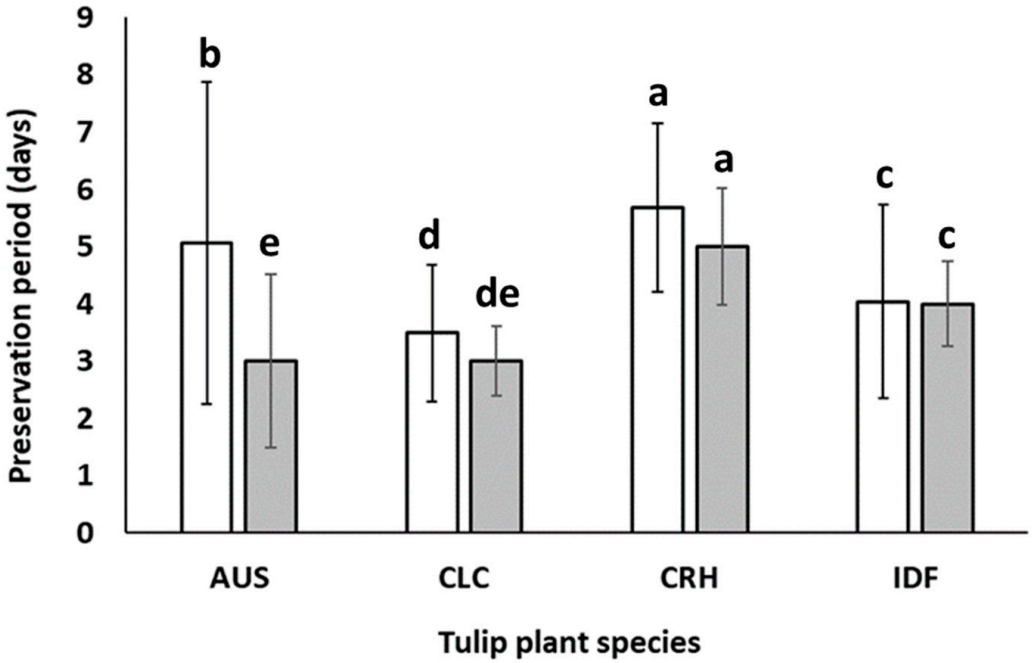

Figure 5. Vase life (□) and the period (■) that 50% of the flowers of *Tulipa australis* (AUS), *Tulipa clusiana* 'Chrysantha' (CLC), *Tulipa cretica* 'Hilde' (CRH), and tulip hybrid Île-de-France (IDF) reached stage 5. Measurements concern flowers harvested from plants grown both in Epanomi and Thermi and remained in solution with and without the preservative. Different lowercase letters indicate statistically significant differences ($p \leq 0.05$). The vertical bars indicate standard deviation (SD).

To further enhance the assessment of the aesthetic value of the studied tulip species, we estimated the timeframe in which 50% of the cut flowers of CRH, CLC, AUS, and IDF reached stage 5 (as depicted in Figure 5). According to the obtained results, 50% of cut flowers of CRH reached stage 5 in five days after harvesting, which is almost equal to their vase life (5.6 days being the period that the average number of all CRH flowers reached the same senescence stage). In other words, all treated cut flowers of CRH appear to lose their aesthetic value almost at the same time, which strengthens the hypothesis for strong genetic homogeneity among the cultivated individuals of this species, as well as enhances the ability of its commercial exploitation for the production of cut flowers in Greece. The flowers of CLC also showed a similar pattern, while the senescence of AUS flower stems continued for another two days after 50% of the flowers of this species had reached stage 5 (Figure 5). As observed in the aforementioned graph, it is evident that all cut flowers of the commercial cultivar IDF underwent a simultaneous decline in their aesthetic value.

The climatic conditions where plants were grown significantly affected the postharvest life of the cut flowers examined for each studied species. In specific, apart from AUS (in which no statistically significant differences were observed), the vase life of cut flowers from plants from each species grown in Epanomi was longer than those grown in Thermi, as shown in Figure 6. This is probably due to the higher temperatures of the area of Thermi area compared to those of Epanomi during the growth period of the plants. The outdoor temperature difference ranged from 0.5 °C during January to 1.1 °C during

April. It has been reported in several studies that preharvest high temperatures promote an elevated respiration rate and decrease carbohydrate reserves, and thus ultimately limiting the quality of flowers and their vase life [33–35]. However, the possible interaction of temperature with other factors, such as the sufficiency or deficiency in nutrients, complicates the understanding of temperature effects on vase life [35].

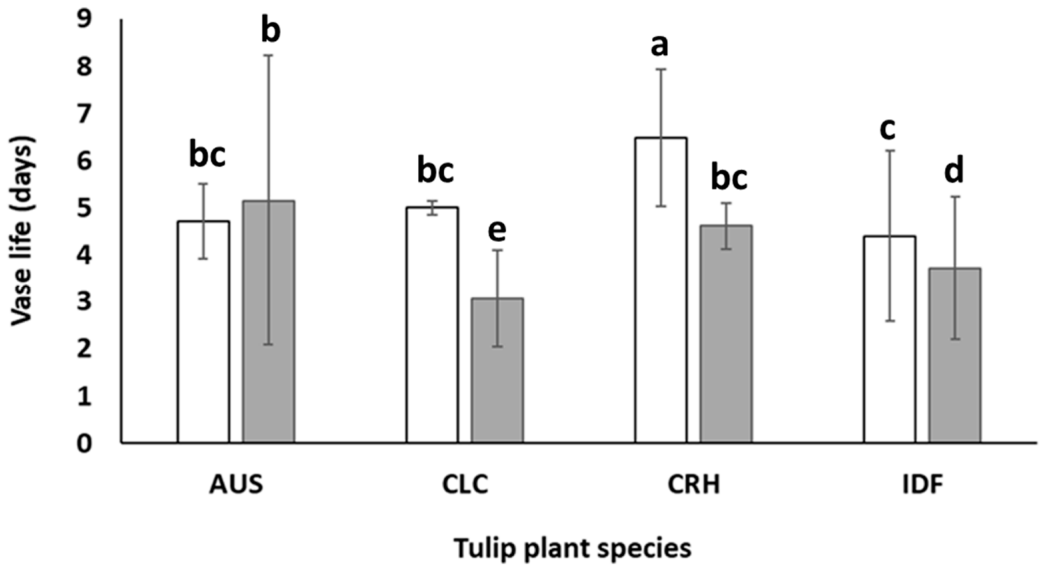

Figure 6. Vase life of cut flowers of *Tulipa australis* (AUS), *Tulipa clusiana* 'Chrysantha' (CLC), *Tulipa cretica* 'Hilde' (CRH), and tulip hybrid Île-de-France (IDF) harvested from plants grown in Epanomi (□) and Thermi (■). Different lowercase letters indicate statistically significant differences ($p \leq 0.05$). The vertical bars indicate standard deviation (SD).

According to Figure 6, the cultivation of IDF, CRH, and CLC tulips exclusively in the greenhouse located in Epanomi could increase the average vase life of cut flowers at 0.3, 0.8, and 1.5 days, respectively, compared to the values presented in Figure 5. In this way, cut flowers from CLC and CRH tulips could reach a commercial vase life of 5 and 6.4 days, respectively. However, it is important to mention that IDF cut flowers produced from plants grown in Epanomi's greenhouse increased their vase life only by 0.3 days. The abovementioned results denote that there is a great potential in increasing the cut flowers' vase life of Greek tulips when a proper selection of the cultivation area is made.

No statistically significant differences in vase life were observed among cut flowers harvested from plants grown in the same location (Epanomi or Thermi) and remained in deionized water or previously dipped in preservatives (Table 2). These results are in agreement with previous studies, where it has been pointed out that tulips do not respond well to the general range of postharvest floral preservatives [31,36–38]. Cut flowers are often held in holding or vase solutions, the composition of which may vary according to the flower species [39]. Each holding solution must contain at least two components, i.e., sugar and germicides. The preservative used in this experiment that contained citric and sulfuric acids to lower the pH of the flowering stem sap as well as to control and reduce microbial proliferation is a requirement for extending quality and longevity of cut flowers [40–43]. The addition of sugar to the preservative solution was not considered necessary since sugar in tulip preservatives is not recommended [44].

Table 2. Mean vase life (days ± standard deviation) of cut flowers harvested from plants cultivated in the greenhouses of Epanomi and Thermi. The cut flowers remained in bottles of deionized water, with or without prior immersion in the preservative.

Cultivation Location	Studied Tulip Species	Vase Life (Days)	
		Without Preservative	With Preservative
Epanomi (Northern Greece)	*Tulipa australis* (AUS)	4.5 ± 1.0 ^{a}	5.0 ± 0.1 ^{a}
	Tulipa clusiana 'Chrysantha' (CLC)	4.4 ± 1.0 ^{a}	4.9 ± 0.5 ^{a}
	Tulipa cretica 'Hilde' (CRH)	6.4 ± 1.4 ^{a}	6.5 ± 1.4 ^{a}
	Tulip hybrid Île-de-France (IDF)	4.6 ± 2.0 ^{a}	4.1 ± 1.6 ^{a}
Thermi (Northern Greece)	*Tulipa australis* (AUS)	5.6 ± 3.0 ^{a}	4.9 ± 3.0 ^{a}
	Tulipa clusiana 'Chrysantha' (CLC)	3.2 ± 1.5 ^{a}	3.0 ± 0.1 ^{a}
	Tulipa cretica 'Hilde' (CRH)	4.5 ± 0.5 ^{a}	4.7 ± 0.5 ^{a}
	Tulip hybrid Île-de-France (IDF)	3.8 ± 1.5 ^{a}	3.7 ± 1.5 ^{a}

Different lowercase letters in the same row indicate statistically significant differences ($p \leq 0.05$).

Physiological wilting, which results from the inability of cut flowers to absorb water after harvesting (water stress), is a major factor contributing to cut flower senescence and, thus, dermination of their postharvest life. In cut flowers, water uptake diminishes over time [45]. The limited ability of cut flowers to absorb water is mainly due to the proliferation of microorganisms in the vase preservative solution, which gradually leads to flower stem vascular occlusion [46–49]. For this reason, measuring the amount and rate of water absorption by the cut flowers is an important indication of the possibility of their long-term preservation in the vase [50]. The results of this work showed that cut flowers from the tulip hybrid IDF absorbed three to eight times more water than those of the Greek species studied herein (Table 3). In contrast, water absorption by the cut flowers of each Greek tulip species was similar regardless of the location where the plants were grown and was not affected significantly by the use of preservatives.

Table 3. Average water uptake (mL) throughout the vase life and per day during the same period performed by cut flowers of *Tulipa australis* (AUS), *Tulipa clusiana* 'Chrysantha' (CLC), *Tulipa cretica* 'Hilde' (CRH), and tulip hybrid Île-de-France (IDF) cultivated in Epanomi (E) and Thermi (T), with or without pulsing within the preservative.

Cultivation Location	Tulip Species	Preservation	Water Uptake (mL)	
			During Vase Life	Per Day
Epanomi	AUS	No	27 ^{de}	6.3 ^{ce}
		Yes	22.6 ^{defg}	4.5 ^{ced}
	CLC	No	12.3 ^{defg}	2.7 ^{ced}
		Yes	21.5 ^{def}	4.8 ^{ced}
	CRH	No	14.0 ^{efg}	2.2 ^{e}
		Yes	14.0 ^{efg}	2.2 ^{e}
	IDF	No	79.7 ^{a}	23.2 ^{a}
		Yes	66.5 ^{b}	22.0 ^{a}
Thermi	AUS	No	24.3 ^{d}	5.3 ^{c}
		Yes	23.0 ^{de}	5.5 ^{c}
	CLC	No	7.4 ^{fg}	2.6 ^{ed}
		Yes	7.6 ^{g}	2.5 ^{ed}
	CRH	No	12.9 ^{efg}	2.7 ^{ed}
		Yes	14.9 ^{defg}	3.1 ^{ced}
	IDF	No	46.2 ^{c}	12.1 ^{b}
		Yes	44.1 ^{c}	11.6 ^{b}

Different lowercase letters in each column denote statistically significant differences ($p \leq 0.05$).

This pattern remained almost the same when the measurements were normalized by estimating the average amount of water absorbed by cut flowers per day of their vase life. Even though the cut flowers of Greek tulip species (AUS, CLC, and CRH) did not show a statistically significant difference regarding water absorption, CLC and CRH tulips showed the longest vase life and tended to absorb the least amount of water (Table 3). However, cut flower water balance depends on the water uptake and transpiration rate. Impaired water uptake may be due to bacterial growth and/or physiological processes (production of polyphenolic compounds) and, therefore, an increased resistance of water flow through xylem vessels. The transpiration rate (apart from climatic conditions) is reported to be affected significantly by plant species [51,52] since it depends on morphological characteristics, such as the number and size of stomata across the epidermis. The much higher water uptake of IDF's cut flowers compared to those of the Greek plant species (AUS, CLS, and CRH) should probably be attributed to the higher leaf mass and longer flowering stems of IDF, resulting in an average FW of 14.2 g (±4.8) compared to the AUS, CLS, and CRH leaves FW (3.9 g ±1.1, 1.7 g ±0.4, and 2.3 g ±0.88, respectively). The latter was also confirmed from the linear correlation with high R^2 = 0.99 between the FW of different species' leaves and the absorbed water measured (Figure 7).

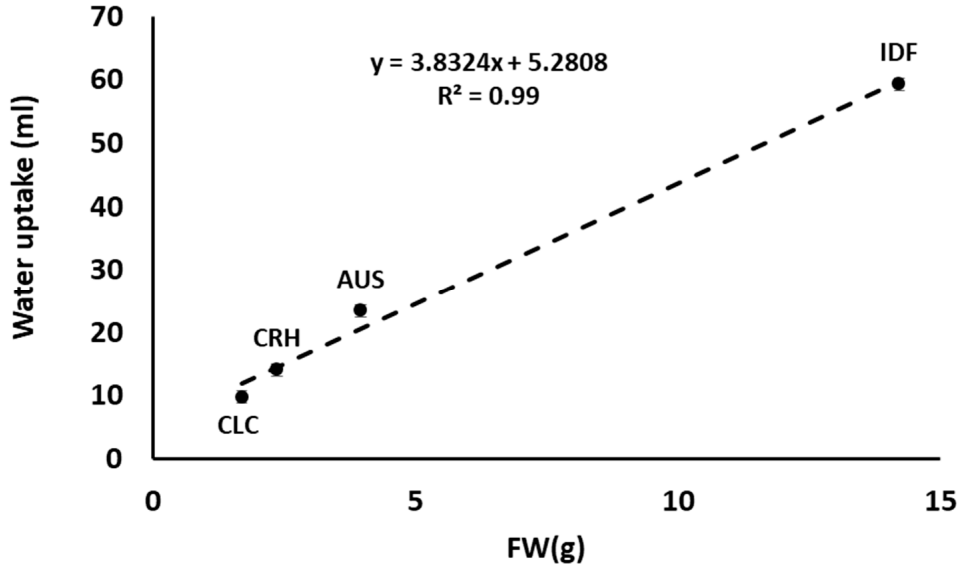

Figure 7. Correlation between the fresh weight (FW) of leaves and flowering stems from *Tulipa australis* (AUS), *Tulipa clusiana* 'Chrysantha' (CLC), *Tulipa cretica* 'Hilde' (CRH), and tulip hybrid Île-de-France (IDF) associated with the amount of water (mL) absorbed during vase life.

However, it is well established that not only the negative water balance causes wilting symptoms on leaves and flowers, but also biocides used as preservatives can affect the wilting of leaves [47,53], their photosynthesis and membrane permeability, as well as cut flower's quality physiology and flower opening [46,47,54]. When citric acid is used as a preservative, it may reduce chlorophyll fluorescence and increase ion leakage during the last days of vase life as membrane permeability decreases [42]. However, the effect of citric acid on the physiological responses of cut flowers has not been adequately studied as additive in flower preservative solutions. The results of this work showed that the use of citric acid as a preservative for the cut flowers of AUS, CLC, CRH, and IDF, which were cultivated in the same location (Epanomi or Thermi), did not cause significant alteration in leaf greenness (SPAD values) (Table 4). The above is in agreement with the results of other researchers [55] regarding the effect of citric acid as an additive in cut flower preservatives since a concentration of 100 to 200 ppm citric acid can improve the chlorophyll content of tulip cut flowers to overcome the loss of photosynthetic activity caused by citric acid absorption [56]. However, the addition of citric acid in the preservative solution did

not appear to affect anthocyanin leakage [57] and, consequently, the color of flowers. In specific, in experiments concerning the preservation of cut tulip flowers [58], the addition of 100 ppm citric acid to the preservation solution, instead of 50 ppm used in the present work, resulted in an increased flower vase life, solution uptake, chlorophyll content, flower diameter, and their fresh and dry weight, whereas at the same time, delayed senescence initiation and stem bending.

Table 4. Mean leaves SPAD values and L,a,b,c, and H color parameter values of cut flowers harvested from *Tulipa australis* (AUS), *Tulipa clusiana* 'Chrysantha' (CLC), *Tulipa cretica* 'Hilde' (CRH), and tulip hybrid Île-de-France (IDF) plants grown in Epanomi (E) and Thermi (T) location, with or without pulsing within the preservative.

Cultivation Location	Tulip Species	Preservative	SPAD	Color Parameters				
				L	a	b	c	H
Epanomi	AUS	No	34.9 ^{f}	69.3 ^{b}	5.5 ^{e}	88.0 ^{a}	88.2 ^{a}	86.5 ^{b}
		Yes	35 ^{ef}	72.2 ^{b}	4.3 ^{e}	69.7 ^{b}	69.8 ^{b}	86.4 ^{b}
	CLC	No	35.3 ^{f}	62.8 ^{c}	9.1 ^{b}	63.8 ^{b}	64.4 ^{b}	81.7 ^{b}
		Yes	36.8 ^{f}	62.3 ^{c}	8.9 ^{d}	63.5 ^{b}	64.8 ^{b}	80.3 ^{c}
	CRH	No	64.1 ^{ce}	80.1 ^{ab}	0.8 ^{g}	12.4 ^{ef}	12.8 ^{g}	83.6 ^{bc}
		Yes	60.7 ^{ce}	74.3 ^{b}	1.6 ^{g}	13.9 ^{e}	14.3 ^{g}	82.6 ^{bc}
	IDF	No	72.5 ^{ab}	33.7 ^{d}	27.4 ^{b}	10.2 ^{f}	29.6 ^{e}	23.5 ^{e}
		Yes	68.1 ^{abc}	27.6 ^{d}	28.3 ^{b}	8.3b ^{f}	29.8 ^{e}	19.4 ^{ef}
Thermi	AUS	No	36.2 ^{f}	65.3 ^{c}	5.2 ^{e}	85.2 ^{a}	81.2 ^{a}	83.2 ^{bc}
		Yes	36.7 ^{f}	64.7 ^{c}	4.8 ^{e}	67.1 ^{b}	64.5 ^{b}	85.6 ^{b}
	CLC	No	37.2 ^{f}	64.8 ^{bc}	16.3 ^{c}	40.5 ^{c}	44.8 ^{c}	65.5 ^{d}
		Yes	53.5b ^{cdef}	69.3 ^{c}	16.5 ^{c}	56.4 ^{bc}	58.5 ^{bc}	73.7 ^{d}
	CRH	No	76.0 ^{a}	77.1 ^{b}	1.0 ^{g}	19.9 ^{d}	20.1 ^{f}	91.2 ^{a}
		Yes	45.4 ^{cdef}	76.4 ^{b}	0.92 ^{g}	18.7 ^{d}	20.8 ^{f}	90.4 ^{a}
	IDF	No	55.8 ^{ef}	30.4 ^{d}	31.8 ^{ab}	15.1 ^{e}	34.0 ^{d}	18.6 ^{f}
		Yes	28.1 ^{fg}	36.0 ^{d}	33.3 ^{a}	11.4 ^{ef}	35.3 ^{d}	18.8 ^{f}

Different lowercase letters in each column denote statistically significant differences ($p \leq 0.05$).

In addition, in almost all treatments, no variation of the color parameters (L, a,b,c, and H) was observed. Only in the case of AUS cultivated both in Epanomi and Thermi, b and c flowers' color parameters showed higher values when no preservative was used (Table 4). Higher values of b indicate more intense yellow coloration of the flower, while higher values of parameter c indicate higher brightness. According to the results shown in Table 4, the use of citric acid reduced the coloring and brightness of the color in flowers harvested from AUS plants grown in Epanomi and Thermi.

4. Conclusions

Measurements regarding the average vase life of the cut flowers showed that there were statistically significant differences between the three Greek tulip species, *T. cretica* 'Hilde', *T. clusiana* 'Chrysantha', *T. australis*, and the commercialized tulip hybrid Île-de-France, regardless of the cultivation location and the use of preservatives. Cut flowers from *T. cretica* were characterized from a long vase life of 5.7 days, which can be extended to 6.5 days if a location with proper climate conditions is selected for plant cultivation. In addition, they are characterized by uniformity of the flower opening. These are basic criteria for selecting a potential plant species as a candidate for cut flower production, and therefore, *T. cretica* could serve as a potential candidate ornamental plant for cut flower production. In addition, cut flowers from *T. clusiana* showed similar characteristics to *T. cretica*, but their vase life was probably affected to a greater extent by the climate parameters of the area where the plants were grown. The vase life of the flowers harvested from the tulip hybrid Île-de-France, cultivated in Epanomi (the location with favorable conditions for the growth of *T. cretica* and *T. clusiana*), showed the same or shorter vase life compared to

the other Greek species studied. However, the cut flowers of the tulip hybrid Île-de-France absorbed almost three times more the amount of water from the vase that *T. cretica* and *T. clusiana* cut flowers absorbed in the comparative experiment performed herein due to their larger flower stems and leaves.

Pulsing cut flowering stems within a preservative containing 5% citric acid and 1% sulfuric acid did not significantly increase the postharvest lifetime of the cut flowers in any of the herein studied tulips and did not affect the green color of leaves and the color of flowers at the end of their vase life. However, according to the results of relative experiments, the increase of citric acid content to 10% could improve flower characteristics measured in this experiment. The above data furnished herein show that the native species *T. cretica* and *T. clusiana* have sufficient vase life, which is an important criterion for their entry into the cut flower market. These data may be used to pave the road for the facilitation of the sustainable exploitation of the Greek tulip species with high ornamental value.

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