# Bulb Growth Parameters of Wild Geophyte, Giant Snowdrop (*Galanthus elwesii* Hook. f.) in Different Media and Nutrient Solution Recipes

Emrah Zeybekoğlu *

**Corresponding author: emrah.zeybekoglu@ege.edu.tr*

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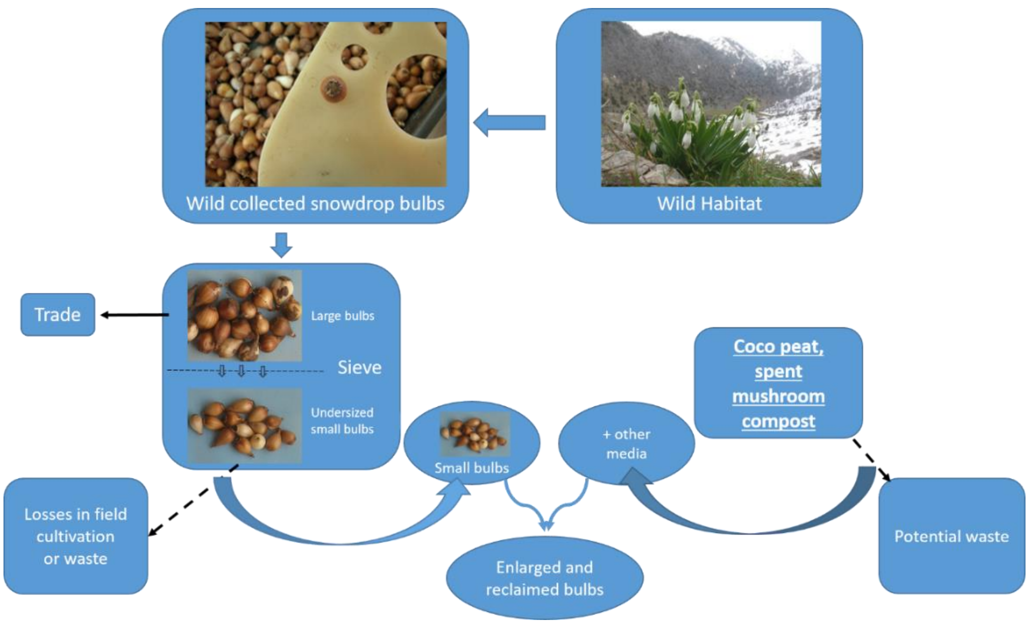
## GRAPHICAL ABSTRACT



# Bulb Growth Parameters of Wild Geophyte, Giant Snowdrop (*Galanthus elwesii* Hook. f.) in Different Media and Nutrient Solution Recipes

Emrah Zeybekoğlu *

Giant snowdrop (*Galanthus elwesii* Hook. f.) is reported on CITES lists as the most important wild-collected export flower bulb of Turkey. After the destruction caused by extensive collecting for many years, collection and trade have been controlled by the government since the late 1980's. Export quotas are annually set by a technical committee, following field inspections by scientific teams. Small bulbs (under-sized) are also unintentionally collected from nature together with marketable sized bulbs (> 4 cm). Low success rate at cultivation of field grown snowdrop and loss of these small bulbs reveals the necessity of the studies on soilless culture. This study aimed to select the suitable growing media and mineral nutrition for snowdrop bulb production. Under-sized (unmarketable) bulbs of *Galanthus elwesii* Hook. f. were cultivated in four different growing media (perlite, coco-peat, soil, or spent mushroom compost + perlite) with four different nutrient solutions. The growing media affected most of the investigated parameters (sprouting time, sprouting ratio, total weight and increase ratio, number of harvested bulbs, and bulb grades). No significant effect of nutrient solutions was determined on the parameters. Spent mushroom compost + perlite appeared to be the most effective growing media.

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*Contact information: Department of Horticulture, Faculty of Agriculture, Ege University, Box 35100, Bornova İzmir, Turkey; *Corresponding author: emrah.zeybekoglu@ege.edu.tr*

## INTRODUCTION

Snowdrops (*Galanthus* spp.) are tunicated bulbous perennials belonging to the Amaryllidaceae family of the subclass *Monocotyledonae*. The genus has been reported to have 20 species (Zubov and Davis 2012) and is native to Caucasus, Near East, Asia Minor, and various parts of Europe. The Caucasus represents the centre of species diversity (Davis 1999; Baktır 2010). Snowdrop is a popular garden plant and has a limited use as cut flower or pot plant. The species of *Galanthus* L. are included in the lists of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). Most cultivated snowdrops are from wild-collected bulbs and are the world's most traded wild ornamental bulb genus (Ronsted *et al.* 2013). The Netherlands is the largest snowdrop importing country, mostly from Turkey and Georgia, which are the primary exporting countries (Davis 1999; Benschop *et al.* 2010; Ronsted *et al.* 2013). Large quantities, in the case of *G. elwesii* near 40 million bulbs per year, of wild-collected bulbs was exported annually from those countries at the beginning of the 1990's.

Extensive collecting in the wild over many years and endangering the natural resources has increased human sensitivity for wildlife (Oldfield 1989; Davis 1999; Kamenetsky and Okubo 2012). In this regard, a quota system for collecting the snowdrop bulbs from the wild was established in Turkey. Bulbs have been collected for legal trade purposes within the limits determined by also taking into consideration the CITES convention. In this regard, the amount of wild-collected bulbs showed a marked decrease. The export limit of the wild collected *G. elwesii* bulbs determined by Turkish Ministry of Agriculture and Forestry for 2023 was 2.2 million bulbs.

Restriction of the bulb supply from natural resources has amplified the importance of developing professional cultivation. The use of quick and controlled propagation and growing techniques for snowdrops has become essential, rather than collecting them from the wild (Tıpırdamaz *et al.* 1999; Özhatay 2013). The plants propagated by seeds may need approximately 4 to 5 years to grow to blooming size. In addition to the length of this growth period, the loss of small bulbs (under-sized) that are unintentionally collected from nature together with marketable sized bulbs (> 4 cm) is a critical threat for snowdrop populations. Studies on the enlargement of the under-sized bulbs either from field or nature will be beneficial in terms of reducing removal from nature. Results of relevant studies show that the ratios of marketable-sized bulbs are generally lower than that of commercially planted species. The average weight increase for *G. nivalis* was only 18.0% (Wallis 1975), and for *G. elwesii* it was 18.5% (Arslan *et al.* 1997) after an annual cycle. In addition to the average weight increase, one of the most important objectives of bulb production is to obtain a high number of marketable size bulbs, which should be > 4 cm in circumference for a snowdrop. A limited number of the bulbs (6 to 42.7%) reached to upper grades (> 4 cm) in different studies (Arslan and Sarıhan 1998; Arslan *et al.* 1998, 2002; Zencirkıran 1998). A total of 75% of the wild collected under-sized bulbs (3 to 4 cm) replanted in organic fertilized plots reached to marketable-size (> 4 cm) after an annual growth (Gökçeoğlu and Sukatar 1986). In another study, 51.7% of the small bulbs reached marketable size after two years of cultivation at field conditions with high amounts of bulb loss (Baktır 1996). Snowdrops, which are small and delicate bulbous plants, have a poor growth in commercial field-scale cultivation (Selby *et al.* 2005).

Exporting companies have stated that growing at field scale with under-sized bulbs (< 4 cm) generally gives unsatisfactory results with a high amount of bulb losses and infections by soil-borne pests (personal communication, Yas Co Foods and Agricultural Products Ltd.). An effective cultivation targets a maximum rate of healthy bulbs that reach to upper grades in a short cultivation duration. In field conditions, small bulbous geophytes, such as snowdrops, face problems including soil-borne pests, diseases, weeds, and harvest difficulties. In this regard, it appears that soilless culture can be used as a promising cultivation technique for geophytes.

To the best of the authors' knowledge, there is limited body of literature on the cultivation and nutrition of snowdrops from the 2000's onward (Le Nard and De Hertogh 1993). Therefore, research on nutrition and new cultivation techniques of snowdrops have importance. The objective of this study was to examine the effects of four different growing media and different mineral nutrition rates on the growth and nutrient status of snowdrop bulbs. Coco peat, a material originating from coconut (*Cocos nucifera* L.) husk, was one of the media used in the experiment. Other media used in the experiment were perlite, spent mushroom compost + perlite mixture, and soil.

## EXPERIMENTAL

### Materials

Wild collected under-sized (< 4 cm) snowdrop (*G. elwesii* Hook. f.) bulbs that were obtained from a Turkish exporting company (Yas Co Foods and Agricultural Products Ltd.) were graded, and the 3 to 4 cm (circumference) ones were planted. Four different growing media [perlite, coco peat, soil, and spent mushroom compost + perlite mixture (1:1; v/v)] were used (M1, M2, M3, and M4). Some chemical characteristics of the growing media are given in Table 1. In addition, four different nutrient solutions (S1, S2, S3, and S4) were applied (Table 2). The pH of the solutions was kept constant at 6.0 to 6.5.

**Table 1.** Some Chemical Characteristics of the Growing Media Used

| | pH | Total N (%) | Available (mg.kg$^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | P | K | Ca | Mg | Na | Fe | Zn | Mn | Cu |
| M1 | 8.11 | 0.02 | 0.11 | 10.74 | 120.31 | 40.82 | 72.34 | 0.05 | 0.18 | 0.15 | 0.06 |
| M2 | 6.81 | 0.09 | 3.12 | 227 | 132.33 | 90.41 | 170.40 | 0.72 | 0.36 | 0.41 | 0.10 |
| M3 | 7.46 | 0.13 | 3.96 | 608 | 6534.0 | 314.43 | 174.82 | 8.83 | 4.40 | 1.22 | 4.26 |
| M4 | 7.34 | 0.08 | 1.96 | 206 | 710.0 | 61.52 | 220.11 | 0.23 | 0.47 | 0.28 | 0.11 |

**Table 2.** Nutrient Concentrations of the Nutrient Solutions Used (mg L$^{-1}$)

| | N | P | K | Ca | Mg | Fe | Zn | Mn | Cu | B | Mo |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S1 | 60.0 | 20.0 | 80.0 | 100 | 20 | 2.0 | 0.50 | 1.0 | 0.1 | 0.1 | 0.01 |
| S2 | 120.0 | 40.0 | 160.0 | 150 | 40 | 4.0 | 1.00 | 2.0 | 0.2 | 0.2 | 0.05 |
| S3 | 180.0 | 60.0 | 240.0 | 200 | 60 | 6.0 | 1.50 | 3.0 | 0.3 | 0.3 | 0.1 |
| S4 | 60.0 | 60.0 | 240.0 | 150 | 40 | 4.0 | 1.00 | 2.0 | 0.2 | 0.2 | 0.05 |

### Methods

The study was conducted in a greenhouse of the Horticulture Department-Agriculture Faculty - Ege University (İzmir, Turkey). The greenhouse was covered with polyethylene, not heated, and it had top and side ventilations. Plastic pots were 72 × 21 × 17 cm$^3$ in size with drainage holes at the bottom. One hundred bulbs were planted in each pair of pots (each plot) in October at a depth of 5 cm. Plants were irrigated with tap water for one month, then nutrient solutions were given for fertigation (Ruamrungsri *et al.* 2004; Bala *et al.* 2018). Solutions were applied *via* drip irrigation using a fertigation dosing unit (Netajet, Netafim™, Israel). The amount of applied nutrient solution was adjusted according to the ratio of drain water / applied volume, which was kept constant approximately at 20 to 25%.

At the beginning of the experiment, the total weight (g) of the bulbs (weight of 100 bulbs) was determined. After planting, sprouting time (days from planting to beginning of the sprouting) and duration (from the beginning to completion of sprouting) were recorded, and the sprouting ratio was calculated (number of sprouted bulb / number of planted bulb × 100). Bulbs were harvested at the end of May. Total weight (TW) (g) of the bulbs, harvested from each plot and weight increase ratio of bulbs (WIR, %) [(Average weight of harvested bulb - average weight of planted bulb) / average weight of planted bulb × 100] were determined. The number of bulbs harvested from each plot (NHB) and the ratios incorporated to different bulb grades (in terms of circumference (cm)) and ratio of marketable-sized bulbs (> 4 cm) (RMSB) (%) were stated. Then, bulb samples were washed with distilled water and dried at 65 to 70 °C under forced aeration until constant weight. Total nitrogen (N) was determined by Kjeldahl digestion method (Kacar and Inal, 2008). After wet digestion with a mixture of $HNO_3$:$HClO_4$ (4:1), phosphorus (P) was quantified according to the Vanadomolibdo phosphoric-yellow colour method by spectrophotometer (Varian Cary-100 Bio-UV/VIS Spectrophotometer, Australia). In addition, potassium (K), calcium (Ca), and sodium (Na) quantified with flame photometer (Eppendorf 5243-elex 6361, Germany); iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu) by Atomic Absorption Spectrophotometer (Varian Spectra AA-220 FS, Australia) (Kacar and Inal 2008) in wet digested samples.

The experimental design was a split plot in randomized blocks. The growing media was the main plot and the nutrient solutions (mineral nutrition) were the subplots, performed in three replications. In total, there were 48 plots (4 growing media × 4 nutrient solutions × 3 replications). Each plot had two pots (100 bulbs). The data obtained from the experiment were subjected to an analysis of variance using the statistical package program IBM® SPSS® Statistics 19 (IBM, Armonk, NY, USA). Significant differences were determined by Duncan's multiple range tests.

## RESULTS AND DISCUSSION

### Sprouting Time, Duration, and Ratio

The sprouting time was significantly affected by the growing media. The earliest sprouting was determined in the treatment M4 (27.8 days) and the latest in M1 (38.9 days) and M3 (38.1 days). There was no significant effect of the media on the sprouting duration and ratio (Table 3). In a study, conducted with four freesia cultivars, the earliest sprouting time (22.2 days) was determined from spent mushroom compost media (Ali *et al.* 2011), which was similar to the results presented above. Lyngdoh *et al.* (2015) indicated that hybrid lilies sprouted earlier on coconut peat-based media. The present and the previous studies stated that organic or organic-based media, such as mushroom compost and coco peat, have positive effects on early sprouting of bulbs.

**Table 3.** Sprouting and Yield Parameters of the Bulbs

| Treatments | | Sprouting | | | Yield Parameters | | | |
|---|---|---|---|---|---|---|---|---|
| | | Time (days) | Duration (days) | Ratio (%) | NHB (number) | TW (g) | WIR (%) | RMSB (%) |
| Media (A) | M1 | 38.9 a | 81.8 | 97.0 | 94.3 a | 185.0 b | 88.8 b | 58.1 b |
| | M2 | 32.4 ab | 83.6 | 96.8 | 91.1 ab | 149.1 c | 59.6 bc | 39.2 c |
| | M3 | 38.1 a | 90.3 | 93.8 | 80.6 c | 125.9 c | 52.7 c | 33.5 c |
| | M4 | 27.8 b | 82.4 | 98.0 | 89.9 b | 236.0 a | 156.9 a | 77.9 a |
| Solutions (B) | S1 | - | - | - | 89.9 | 166.8 | 86.4 | 50.2 |
| | S2 | - | - | - | 87.6 | 181.9 | 99.2 | 55.2 |
| | S3 | - | - | - | 90.3 | 178.4 | 90.4 | 54.0 |
| | S4 | - | - | - | 89.0 | 168.8 | 82.1 | 49.8 |
| A | | ** | ns | ns | * | * | * | * |
| B | | - | - | - | ns | ns | ns | ns |
| A×B | | - | - | - | ns | ns | ns | ns |
| Within a column, values followed by different letters are significantly different at p≤0.05 (*) or p ≤ 0.01(**) according to Duncan's test; n.s. indicates non-significant differences | | | | | | | | |

## Number of Harvested Bulbs

In terms of NHB, significant differences were determined among the growing media. M1, M2, and M4 had higher number of bulbs (94.3, 91.1, 89.9) while the soil (M3) had the lowest (80.6). No differences were found for the nutrient solutions (Table 3). It can be said that the number of bulbs that could not sprout or could not survive after sprouting was higher in M3 than in the other media (Table 3). These results may be related to the structure and structural changes of the soil in the pot. Baktır (1996) stated significant loss and damage in *G. elwesii* bulbs grown in soil. In another study, the positive effect of media was highlighted on the harvested number of saffron (Turhan *et al.* 2007).

## Total Weight of Bulbs (TW)

The total weight of the bulbs harvested from the plots was significantly affected by the growing media ($p \leq 0.01$). The heaviest total weight of the bulbs (236.0 g) was obtained from M4, followed by M1, M2, and M3 in descending order (185.0, 149.1, and 125.9 g). No differences were determined among nutrient solutions (Table 3). In this regard, a soilless culture study conducted by Kahraman and Özzambak (2015) put forth coco peat as the most effective media on the snowdrop bulb weight, and all other three media (peat, soil, and perlite) came in the second rank. The husk of the coconut is used for manufacturing ropes, matting, and many other products (Abad *et al.* 2002). However, large quantities of coir remain unutilized and dumped as waste (Stelte *et al.* 2023). When the husk is processed for industrially valuable long fibers, a significant amount of pith tissue and short to medium length fibers are left behind. These materials can be treated as waste (Abad *et al.* 2002). Prisa *et al.* (2010), in their study with Lilium Asiatic, reported that growing media have significant effects on the growth and weight of bulblets without fertilization. In another study conducted in Hippeastrum, Jamil *et al.* (2016) indicated that growing media affected the total bulb weight, as well as mother and daughter bulb weight.

The effect of plant nutrients studied by Khan *et al.* (2006) showed that all nutrients are effective in increasing bulb and bulblet weight in tulips. However, Çığ and Çığ (2019) observed that increasing NPK applications in *Hyacinthus* Tourn. ex L. did not have a significant effect on bulb weight. Biekart, as cited in Hanks (1993), stated that a good flower and bulb yield was obtained even after three years from daffodils grown in sand culture without nitrogen fertilization. The weight of bulb and root in the onion were not significantly affected by nutrient solution compositions reported by Kane *et al.* (2006). In terms of the total bulb weight, the authors' findings are partially parallel with these studies. The fact that nutrient solutions did not affect the growth of snowdrop bulbs in the study might be due to the effect of the nutrient reserves existing in the bulbs (Rees 1972).

## Weight Increase Ratio (WIR)

In terms of the weight increase ratio of the bulbs, the difference among the treatments of the growing media was significant, and M4 gave the highest value (156.9%), which was followed by M1, M2, and M3. (88.8, 59.6, and 52.7, respectively). After an annual growth, the average weight increase determined by Wallis in *G. nivalis* was 18% (Selby *et al.* 2005) and 18.5% in *G. elwesii* (Arslan *et al.* 1997). In this trial, the weight increase ratio values obtained from all of the growing media were much higher than the results of previous studies. This parameter was not influenced by the nutrient solutions (Table 3).

### Ratio of Marketable Sized Bulbs (RMSB)

According to the number of bulbs planted, the percentage that reached marketable size (> 4 cm) varied with respect to the treatments of the growing media ($p \leq 0.01$). M4 treatment had the highest value (77.9) followed by M1 (58.1). The lowest values (39.2, 33.5) were from M2 and M3, respectively. The RMSB were not influenced by the nutrient solutions (Table 3). In an experiment conducted under field conditions, the highest ratio of marketable-sized bulbs was determined as 51.7% after two years of cultivation (Baktır 1996). In other studies, this ratio was stated between 6 to 75% (Gökceoglu and Sukatar 1986; Arslan and Sarıhan 1998; Arslan *et al.* 1998; Zencirkıran 1998). The fact that the ratio of M4 was above the ones stated in other studies indicates the significance of soilless culture as a growing media and obtaining such results at the end of a single vegetation period.

### Ratio of Harvested Bulbs in Different Grades

The treatments M3, M2, and M1 had the highest ratios in sizes 2 to 3 and 3 to 4, respectively. Bulbs harvested from M4 had significantly high values in all the upper grades (Table 4). In addition to reaching the marketable minimum bulb size (4 to 5 cm), because bulbs reach larger sizes (> 5 cm) by exceeding this size limit, it is also important in increasing the market value. In this respect, the highest performance was obtained from the M4 treatment. In the study, the nutrient solutions had no significant effect on bulb size. Uysal and Kaya (2013) reported that the increase in N doses in fertilization in *G. elwesii* and *Leucojum aestivum* L. was not effective on bulb size. Similarly, Çığ and Çığ (2019) also reported that increasing doses of NPK in *Hyacinthus* did not increase bulb size.

**Table 4.** Distributions of the Bulbs Harvested from Different Growing Media (%)

| Growing Media | Number of Harvested Bulbs at Different Circumferences | | | | | |
|---|---|---|---|---|---|---|
| | 2/3 | 3/4 | 4/5 | 5/6 | 6/7 | 7/8 |
| M1 | 2.4 b | 33.2 b | 47.1 a | 11.1 b | 0.4 ab | 0.0 |
| M2 | 6.6 ab | 45.2 a | 33.5 bc | 5.6 b | 0.1 b | 0.0 |
| M3 | 11.6 a | 35.5 b | 25.6 c | 7.9 b | 0.0 b | 0.0 |
| M4 | 1.9 b | 10.1 c | 38.6 ab | 35.3 a | 3.9 a | 0.2 |
| | * | ** | ** | ** | ** | Ns |

Within a column, values followed by different letters are significantly different at $p \leq 0.05$ (*) or $p \leq 0.01$(**) according to Duncan's test; n.s. indicates non-significant differences

### Mineral Content of Bulbs

Results showed that the mineral contents of the bulbs excluding Na was affected by the media. In this regard, the effects on the N, Zn, Cu, and Mn contents were significant (Table 5). The significant mineral nutrients that bulbs contain in high amounts in M1, M2, M3, and M4 media were respectively as follows: N, Ca, Cu, Mn (M1); N, P, K, Ca, Fe, Zn (M2); P, K, Ca, Cu, Mn (M3); P, K, Fe, Zn, Cu, Mn (M4). Nutrient solutions affected the N, Zn, Cu, and Mn contents and these minerals were the lowest at S1, while they were close to each other in S2, S3, and S4. Kane *et al.* (2006) stated that onions grown in two different nutrient solutions differ in terms of Mg, Ca, and Zn contents, but not in other elements. It was reported that in *Hyacinthus*, enhanced doses of NPK fertilization increased the N content but did not have a significant effect on K and P contents (Bintaş *et al.* 2020).

**Table 5.** Mineral Content of the Bulbs

| Treatments | | N (%) | P (%) | K (%) | Na (ppm) | Ca (%) | Fe (ppm) | Zn (ppm) | Cu (ppm) | Mn (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|
| Growing Media (A) | M1 | 1.44 a | 0.16 b | 0.59 b | 540.5 | 0.44 a | 27.7 c | 25.5 b | 5.50 a | 13.8 a |
| | M2 | 1.26 ab | 0.22 ab | 1.11 a | 498.3 | 0.34 ab | 49.7 a | 32.5 a | 3.51 b | 6.1 b |
| | M3 | 1.19 b | 0.25 a | 1.08 a | 452.8 | 0.32 ab | 33.0 bc | 27.1 b | 6.99 a | 15.1 a |
| | M4 | 1.18 b | 0.24 a | 1.08 a | 473.8 | 0.25 b | 42.0 ab | 28.7 ab | 5.16 ab | 14.9 a |
| Solutions (B) | S1 | 1.17 b | 0.21 | 0.90 | 470.3 | 0.32 | 36.3 | 25.3 c | 4.59 b | 10.8 b |
| | S2 | 1.24 ab | 0.21 | 0.93 | 485.8 | 0.34 | 37.2 | 27.3 bc | 5.13 ab | 12.1 ab |
| | S3 | 1.30 ab | 0.22 | 0.99 | 498.5 | 0.34 | 39.6 | 29.4 ab | 5.60 a | 12.7 ab |
| | S4 | 1.36 a | 0.23 | 1.04 | 510.8 | 0.36 | 39.3 | 31.7 a | 5.84 a | 14.30 a |
| A | | ** | * | ** | ns | ** | ** | * | ** | ** |
| B | | * | ns | ns | ns | ns | ns | * | * | ** |
| A×B | | ns | ns | ns | ns | ns | ns | ns | ns | Ns |

Within a column, values followed by different letters are significantly different at p≤ 0.05 (*) or p≤0.01(**) according to Duncan's test; n.s. indicates non-significant differences

## CONCLUSIONS

Based on the results obtained in this study, it can be concluded that:

a) In comparison to other soilless growing media used, and being better alternative to soil, spent mushroom compost + perlite was found to be the most effective media for growing bulbs of *Galanthus elwesii* to an upper grade and marketable size.

b) Different nutrition solutions had no effect on the growth of *G. elwesii* bulbs, possibly due to the nutrient reserves present in the bulbs. Finally, it can be concluded that a low concentration of nutrient solution and an appropriate soilless culture could be a sustainable way of cultivating *G. elwesii* and reducing snowdrop bulb collection from nature.

## ACKNOWLEDGMENTS

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