

# Establishment of five new hybrids of Mediterranean sage species (*Salvia* spp.) on an urban green roof, as affected by irrigation frequency

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## Abstract

This study investigated the effect of irrigation frequency on establishment of five new hybrids of sage (*Salvia*) species native to Greece (*S. fruticosa*, *S. officinalis*, *S. pomifera* ssp. *pomifera*, *S. tomentosa* and *S. ringens*) in an urban Mediterranean extensive green roof, aiming to evaluate their drought tolerance. Rooted cuttings were planted in April 2021 in plastic containers with a green roof infrastructure fitted (moisture retention and protection of the insulation mat, drainage layer and filter sheet) and placed on a second floor roof. The substrate used was grape marc compost:perlite:pumice (3:3:4, v/v) and had 10 cm depth. Two irrigation frequencies were applied, starting from every 3 days (normal) and 5 days (sparse) and followed (after the end of May) by every 2 and 4 days, respectively. Two months after planting all plants had survived. The type of hybrid affected all growth parameters, whereas irrigation frequency affected only plant diameter and total axillary shoot length. Plants irrigated normally had greater diameter and greater total axillary shoot length, compared to those irrigated sparsely. Hybrids *S. officinalis* × *S. tomentosa* and *S. pomifera* × *S. ringens* had shorter foliage height (10.5-12.5 cm) than the others (20.6-24.5 cm), but when height of the inflorescences was included, *S. pomifera* × *S. ringens* was the tallest of all (90.0 cm). Hybrids *S. officinalis* × *S. pomifera* and *S. officinalis* × *S. tomentosa* had the greatest diameter (24.5 cm), when irrigated normally, while they produced more axillary shoots (14.4-18.3) of greater total length (126.4-180.8 cm) too. Only in hybrids *S. officinalis* × *S. tomentosa* and *S. pomifera* × *S. ringens*, almost all plants flowered producing 5-10 flowering shoots plant<sup>-1</sup>, whereas in others, 16.7-75% of plants flowered producing 1.0-2.2 flowering shoots plant<sup>-1</sup>.

**Keywords:** green roof technology, native xerophytic ornamentals, *Salvia* hybrids, drought stress, soilless substrate, grape marc compost, pumice

## INTRODUCTION

Mediterranean *Salvia* species being drought resistant could be ideal for use in xeriscaping, valuable as bee-friendly plants, as well as suitable for use on extensive type urban green roofs. In order to introduce new drought-resistant species with interesting floricultural characteristics in the floricultural industry, interspecific crossbreeding between five sage species native to Greece (*S. fruticosa*, *S. officinalis*, *S. pomifera* ssp. *pomifera*, *S. tomentosa* and *S. ringens*) has been done and some hybrids were selected for their ornamental traits (Papafotiou et al., 2021).

The need of planning more sustainable cities leads to a wider use of extensive green roofs, as they provide significant environmental, social and economic advantages to the urban environment, which mitigate the adverse effects of urbanization and make cities more safe, sustainable and resilient to climate change (Whittinghill and Rowe, 2012; Berardi et al., 2014; Caneva et al., 2015; Shafique et al., 2018).

The adaptation of many Mediterranean plants to drought stress and their floristic

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diversity constitutes them ideal for use in green roofs (Caneva et al., 2015; Papafotiou et al., 2016; Tassoula et al., 2021). From the Mediterranean *Salvia* species, mainly *S. officinalis* (Savi et al., 2013; Raimondo et al., 2015; Papafotiou et al., 2017), but also *S. fruticosa* (Kokkinou et al., 2016) have been tested on an extensive green roof. Besides, the five hybrids, used in the present study, have already been evaluated regarding their drought tolerance, along with *S. fruticosa*, under greenhouse conditions (Papafotiou et al., 2021).

Aim of this study was to investigate the effect of irrigation frequency on establishment of five new hybrids (*S. fruticosa* × *S. ringens*, *S. officinalis* × *S. ringens*, *S. officinalis* × *S. pomifera* ssp. *pomifera*, *S. officinalis* × *S. tomentosa*, *S. pomifera* ssp. *pomifera* × *S. ringens*) of sage species native to Greece on an urban Mediterranean extensive green roof, in order to evaluate their drought tolerance.

## MATERIALS AND METHODS

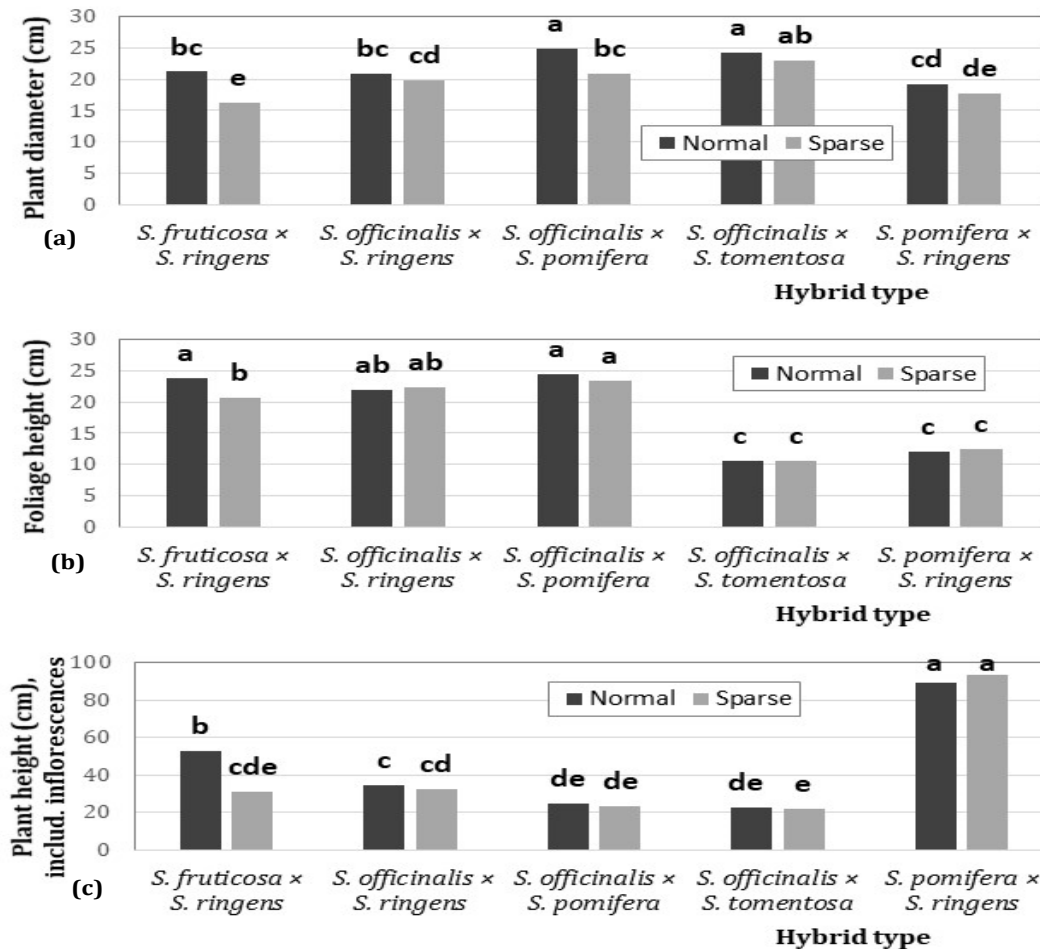
Rooted cuttings of the new sage hybrids *S. fruticosa* × *S. ringens*, *S. officinalis* × *S. ringens*, *S. officinalis* × *S. pomifera* ssp. *pomifera*, *S. officinalis* × *S. tomentosa* and *S. pomifera* ssp. *pomifera* × *S. ringens* were planted in April 2021 in plastic containers 40×60×22 cm (two plants per container, six containers per treatment) with a green roof infrastructure fitted (moisture retention and protection of the insulation mat FLW-500, drainage layer Diadrain-25H and filter sheet VLF-150) (Landco Ltd., Diadem Green Roof Systems, Athens, Greece) and placed on a fully exposed second floor flat roof at the Agricultural University of Athens. The substrate used was grape marc compost:perlite:pumice (3:3:4, v/v) and had 10 cm depth. Grape marc compost was produced locally, as described in Papafotiou et al. (2016). The soil contained 17.3% clay, 32.2% loam, 50.5% sand and 19.68% CaCO<sub>3</sub>, and it had a pH of 7.66, EC 1900 μmhos cm<sup>-1</sup> and a resistance of 525 Ohm. The properties of the substrates are given by Tassoula et al. (2015). Two irrigation frequencies were applied, with individual drippers of constant supply (4 L h<sup>-1</sup>) for 60 min, starting from every 3 days (normal), when substrate moisture was 16-22% v/v, and every 5 days (sparse), when substrate moisture was 7-11% v/v, which were followed (after the end of May) by every 2 and 4 days, respectively.

Their growth was evaluated monthly, measuring foliage and plant height (from substrate surface to the tallest plant part), foliage diameter (average value of greater horizontal diameter and its perpendicular), axillary shoot number and total length and number of inflorescences plant<sup>-1</sup>.

The completely randomized design was used, the significance of the results was tested by one- or two-way analysis of variance (ANOVA) and treatment means were compared by Student's *t* test at  $p \leq 0.05$ .

## RESULTS AND DISCUSSION

Two months after planting all plants had survived. The type of hybrid affected all growth parameters, whereas irrigation frequency affected only plant diameter and total axillary shoot length. Plants irrigated normally had greater diameter (Figures 1a and 2) and greater total axillary shoot length (Figure 3a), compared to those irrigated sparsely. Hybrids *S. officinalis* × *S. tomentosa* and *S. pomifera* × *S. ringens* had shorter foliage height than the others (Figure 1b), but when height of the inflorescences was included, *S. pomifera* × *S. ringens* was the tallest of all (Figure 1c). Hybrids *S. officinalis* × *S. pomifera* and *S. officinalis* × *S. tomentosa* produced more axillary shoots of greater total length (Figure 3a, b) and had the greatest diameter (Figures 1a and 2), when irrigated normally. Only in hybrids *S. officinalis* × *S. tomentosa* and *S. pomifera* × *S. ringens*, almost all plants flowered producing 5-10 flowering shoots plant<sup>-1</sup>, whereas in others, 16.7-75% of plants flowered producing 1.0-2.2 flowering shoots plant<sup>-1</sup> (Figure 3c, d).



Significance	Foliage height	Plant height	Foliage diameter
$F_{\text{hybrid type}}$	**	**	**
$F_{\text{irrigation frequency}}$	NS	NS	**
$F_{\text{hybrid type} \times \text{irrig. frequency}}$	NS	**	NS
$F_{\text{one-way ANOVA}}$	**	**	**

Figure 1. Effect of hybrid type and irrigation frequency on foliage height and diameter (cm), as well as plant height including inflorescences (cm) of *Salvia* hybrids, two months after establishment on an extensive green roof system ( $n=12$ ). NS or \*\*, non-significant at  $P \leq 0.05$  or significant at  $P \leq 0.01$ , respectively.

Great differences were observed in growth of sage hybrids in an extensive green roof, which were determined by the characteristics that each one inherited from its parents, as described by Papafotiou et al. (2021). For instance, the hybrids *S. officinalis* × *S. tomentosa* and *S. pomifera* ssp. *pomifera* × *S. ringens* were the shortest (Figure 1b), since they inherited low height from both parents the first and from *S. ringens* the second. Besides, *S. pomifera* ssp. *pomifera* × *S. ringens* produced extremely long flowering shoots (Figure 1c), as both parents do, which contrasts with the low foliage of this hybrid. All hybrids provided satisfactory vegetation cover of the container two months after establishment (Figures 1a and 2), especially *S. officinalis* × *S. pomifera* ssp. *pomifera* and *S. officinalis* × *S. tomentosa*, which produced more axillary shoots too (Figure 3b). The poor flowering of some hybrids does not allow us to draw conclusions about their flowering, but it does indicate possible differences in their photoperiodic requirements for flowering. The hybrid *S. pomifera* ssp. *pomifera* × *S. ringens* most probably inherited the easiness to flower from both of its parents, which have the tend to flower on annual shoots, even during summer (personal observation).

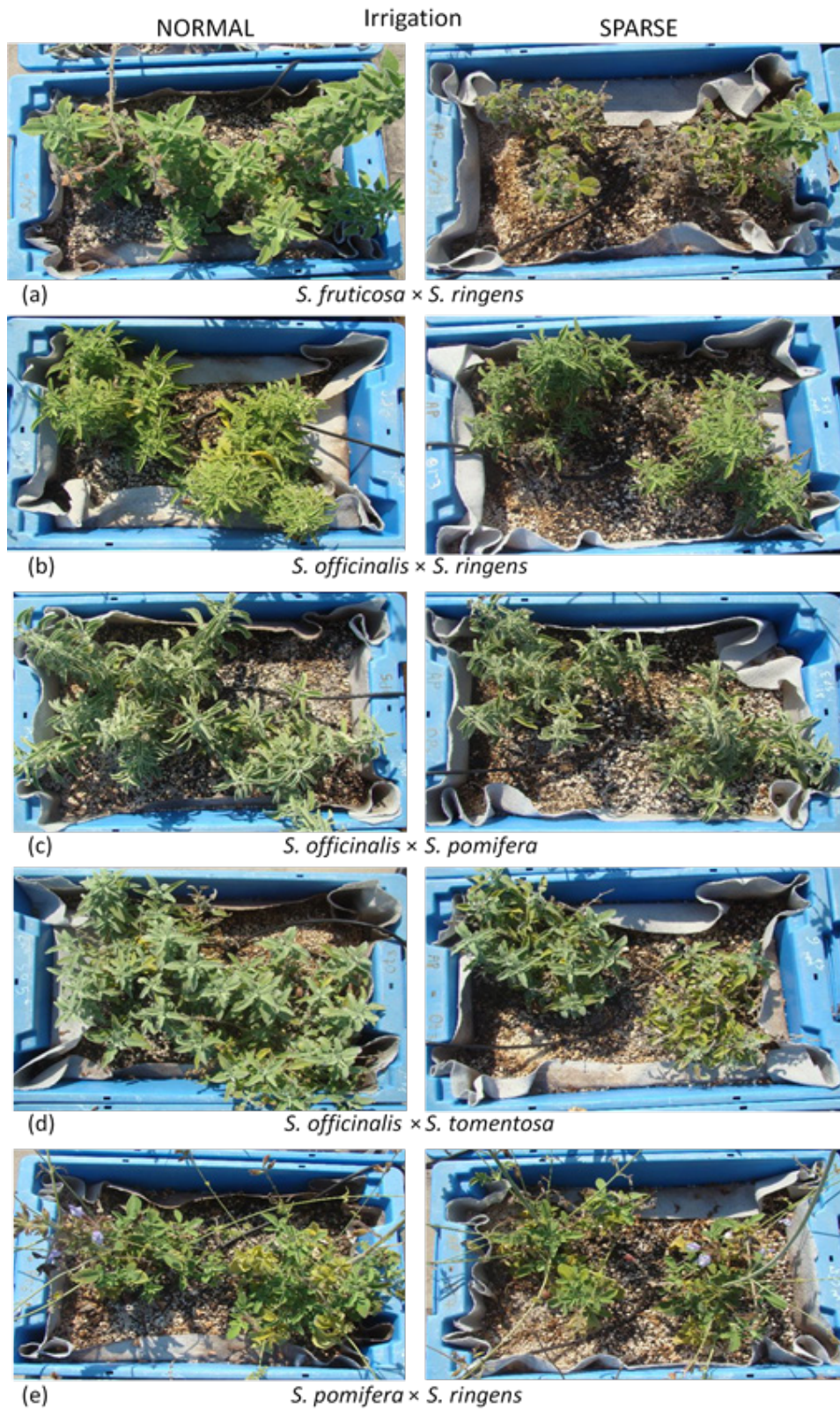
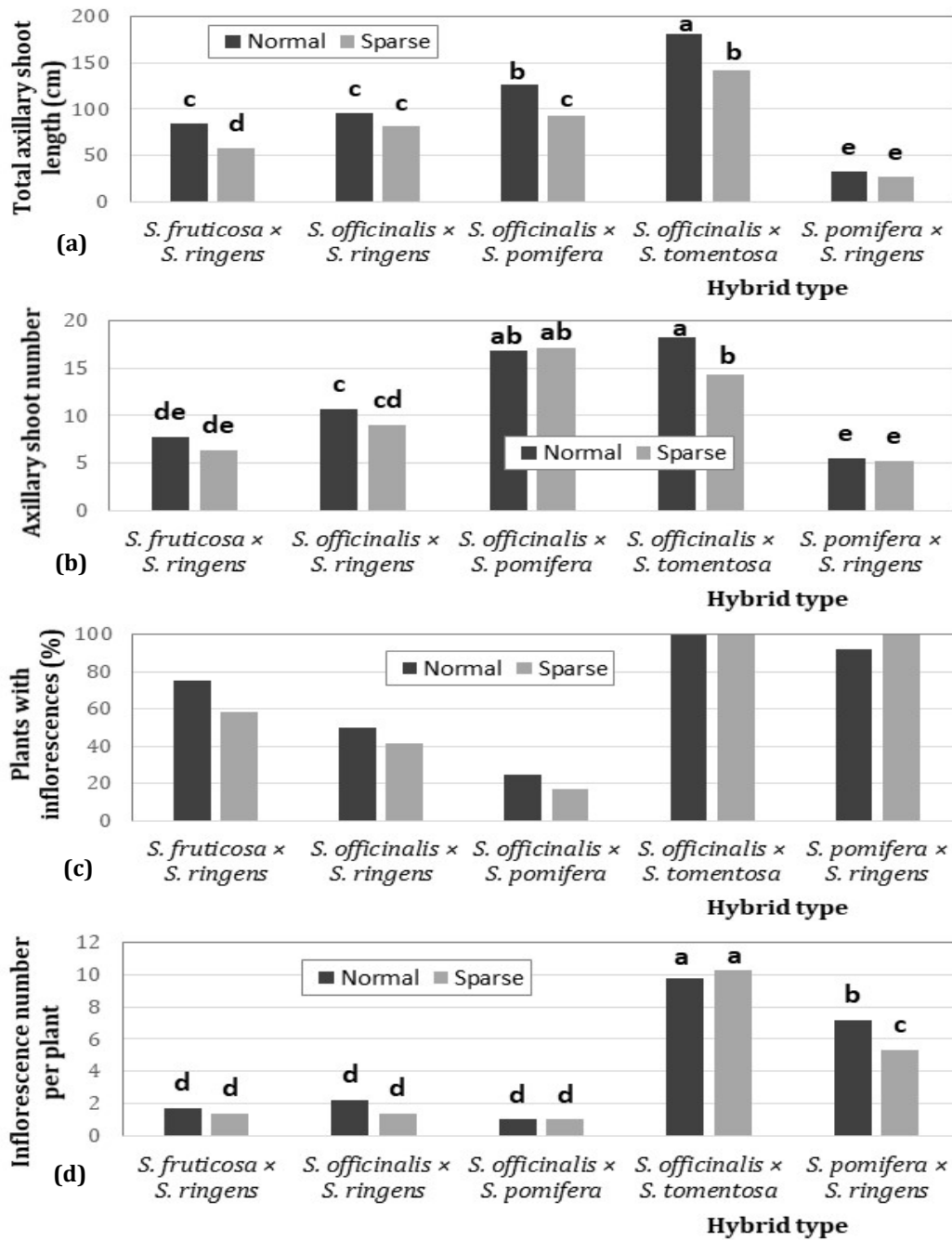


Figure 2. Typical growth of *Salvia* hybrids, in an extensive green roof, in marked irrigation frequencies, two months after establishment (June 2021).



Significance	Axillary shoot number	Total axillary shoot length	Inflorescence number/plant
$F_{\text{hybrid type}}$	**	**	**
$F_{\text{irrigation frequency}}$	*	**	NS
$F_{\text{hybrid type} \times \text{irrig. frequency}}$	NS	NS	NS
$F_{\text{one-way ANOVA}}$	**	**	**

Figure 3. Effect of hybrid type and irrigation frequency on axillary shoot number and total length (cm), as well as flowering of *Salvia* hybrids, two months after establishment in an extensive green roof ( $n=12$ ). NS or \* or \*\*, non-significant at  $P \leq 0.05$  or significant at  $P \leq 0.05$  or  $P \leq 0.01$ , respectively.

Hybrids diameter was benefited by normal irrigation during establishment, which has also been shown in *Origanum dictamnus* during the first dry period, although there were no differences in this species growth after the second dry period as regards irrigation frequency (Papafotiou et al., 2016). In cases that plants had been cultivated for a longer period, more than a year, in an extensive green roof irrigation frequency did not affect plant growth, which has been reported for *Convolvulus cneorum* and *Sideritis athena* (Tassoula et al., 2015; Papafotiou et al., 2016) and *Scabiosa cretica* (Tassoula et al., 2017). Only in *S. officinalis* × *S. tomentosa* axillary shoot number was increased by normal irrigation, which also happened in *Scabiosa cretica* (Tassoula et al., 2017). Regarding hybrids parents, *S. officinalis* is considered suitable for use in green roofs (Savi et al., 2013; Raimondo et al., 2015; Papafotiou et al., 2017), whereas *S. fruticosa* showed fast water consumption and needs irrigation at least 50% of the daily pan evaporation (Kokkinou et al., 2016). Besides, all hybrids, especially *S. officinalis* × *S. pomifera* and *S. officinalis* × *S. tomentosa*, were found to survived drought stress better than *S. fruticosa* in greenhouse conditions (Papafotiou et al., 2021).

Conclusively, all sage hybrids were established successfully on an urban green roof. The only parameters that were affected by irrigation frequency were plant diameter and axillary shoot total length, which were greater under normal irrigation. Hybrids' growth should be observed for a greater period of time in order to conclude for their drought tolerance.

## ACKNOWLEDGEMENTS

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# INTRODUCTION

Mediterranean *Salvia* species being drought resistant could be ideal for use in xeriscaping, valuable as bee-friendly plants, as well as suitable for use on extensive type urban green roofs.

In order to introduce new drought-resistant species with interesting floricultural characteristics in the floricultural industry, interspecific crossbreeding between five sage species native to Greece

*S. fruticosa*



*S. officinalis*



*S. pomifera* ssp. *pomifera*



*S. ringens*



*S. tomentosa*



has been done and some hybrids were selected for their ornamental traits.

**Aim of this study**, the effect of irrigation frequency on establishment of five new hybrids of sage species native to Greece on an urban Mediterranean green roof, in order to evaluate their drought tolerance.

# MATERIALS AND METHODS

Time of planting: **April 2021**

**Plant material:** rooted cuttings of five new sage hybrids (8-week old)

*S. fruticosa* × *S. ringens* - *S. officinalis* × *S. ringens* - *S. officinalis* × *S. pomifera* - *S. officinalis* × *S. tomentosa* - *S. pomifera* × *S. ringens*



**Plastic containers:** 40 cm x 60 cm x 22 cm  
(two plants per container; six containers per treatment)  
with a green roof infrastructure fitted

**Substrate:** grape marc compost: perlite: pumice (3: 3: 4, v/v),  
10 cm depth



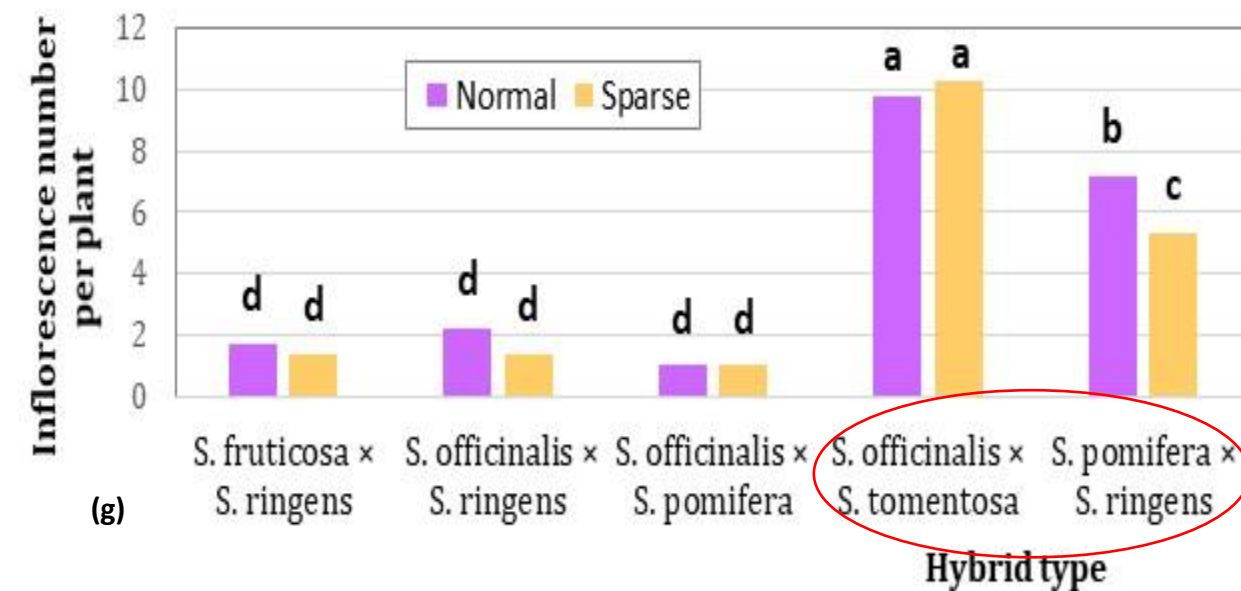
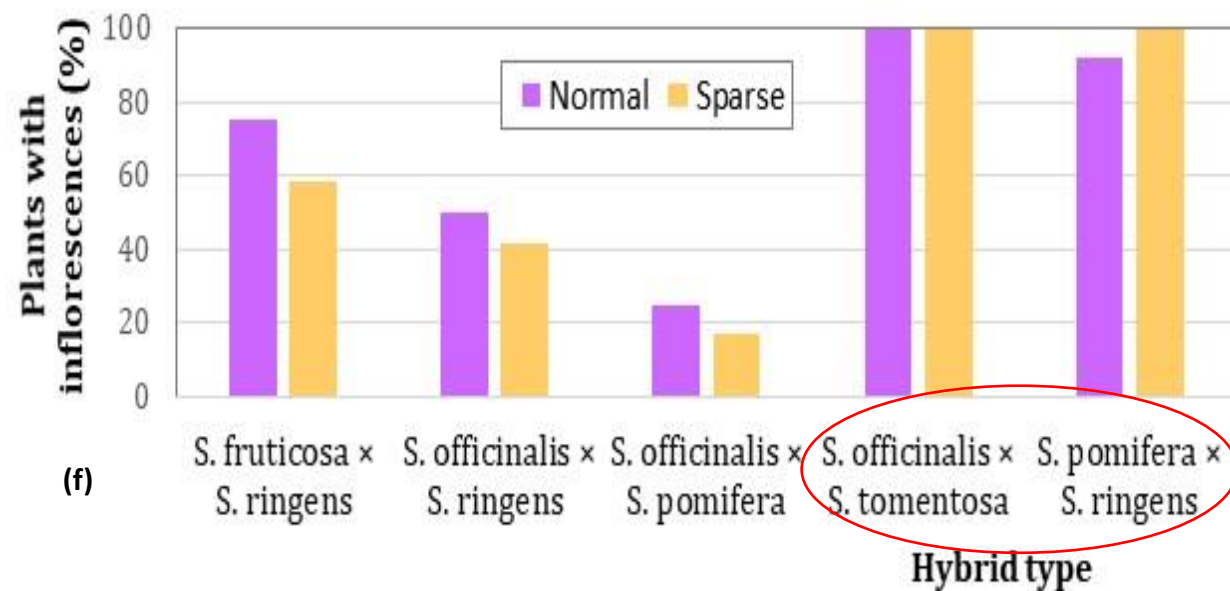
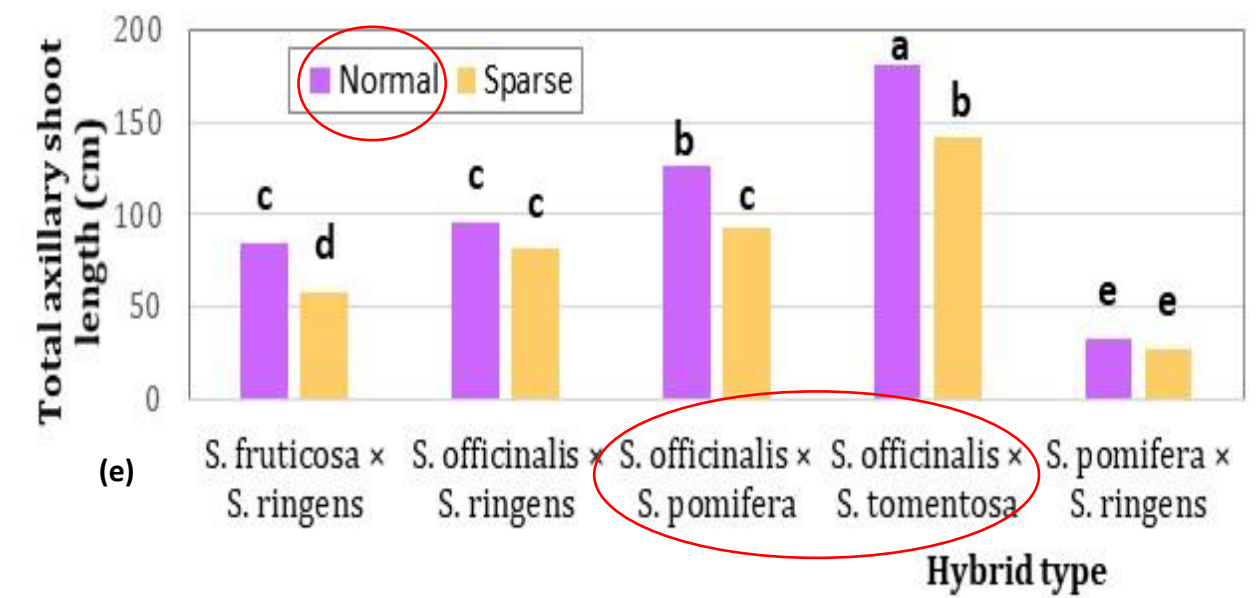
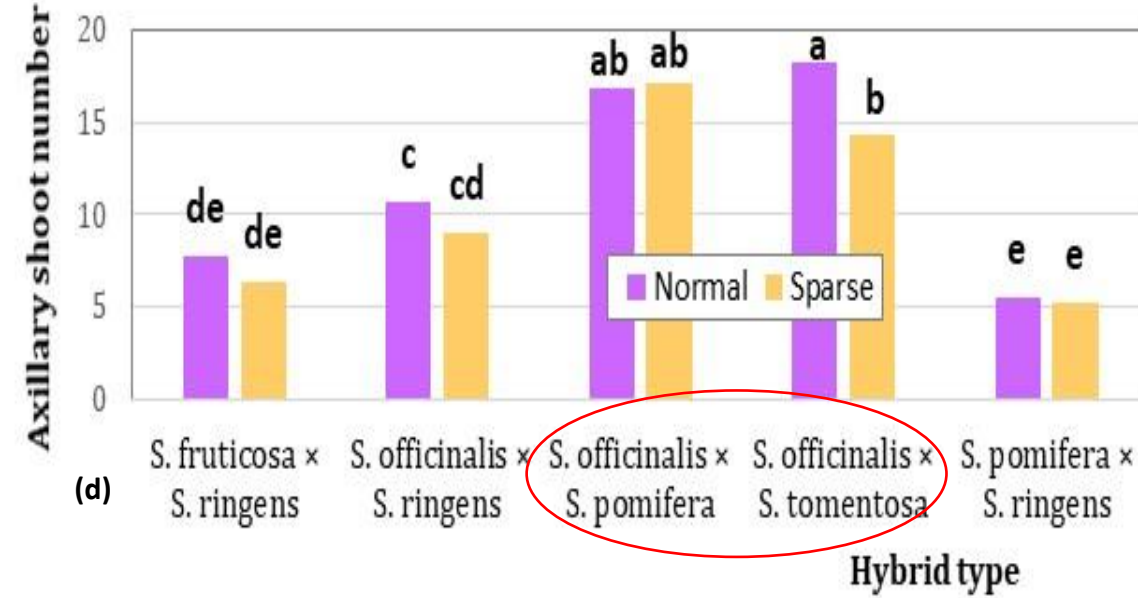
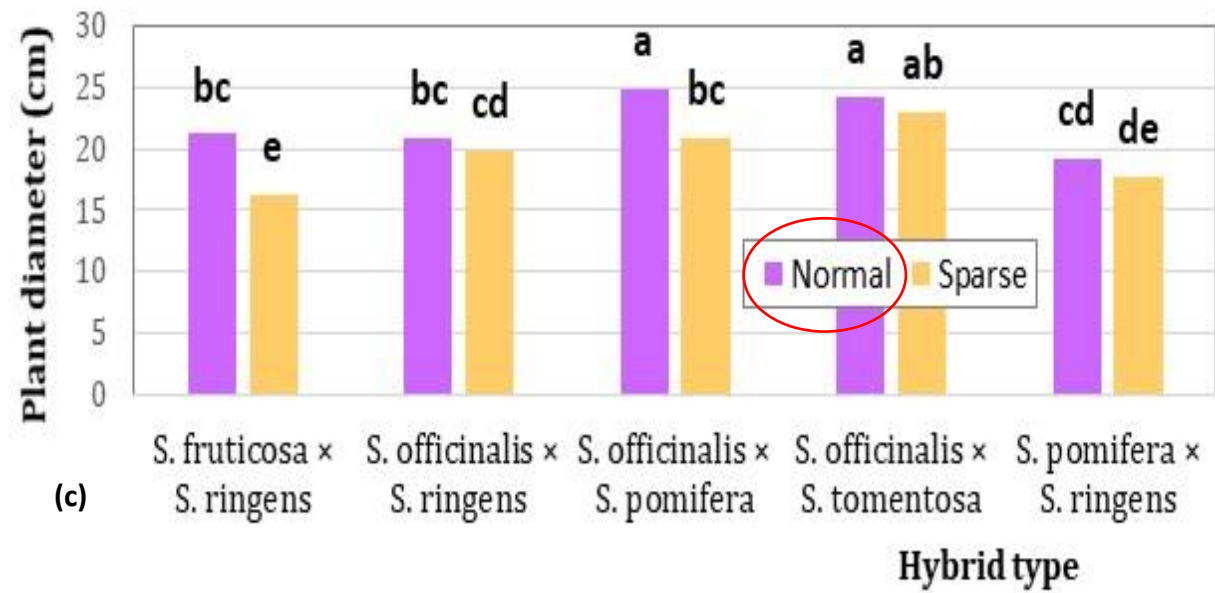
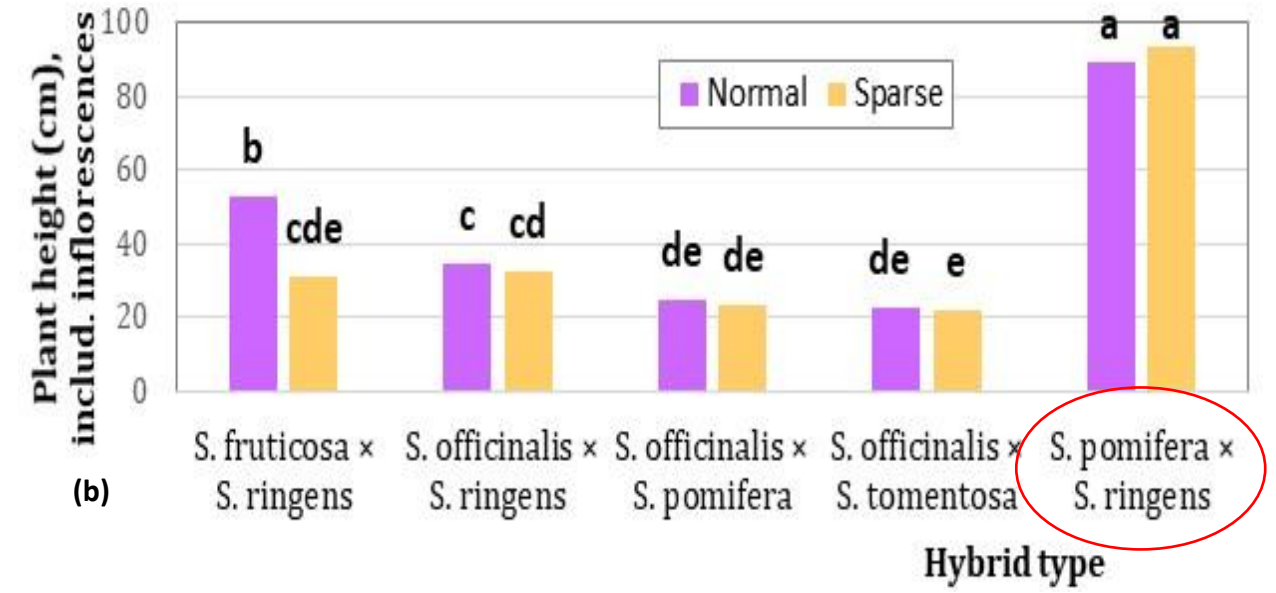
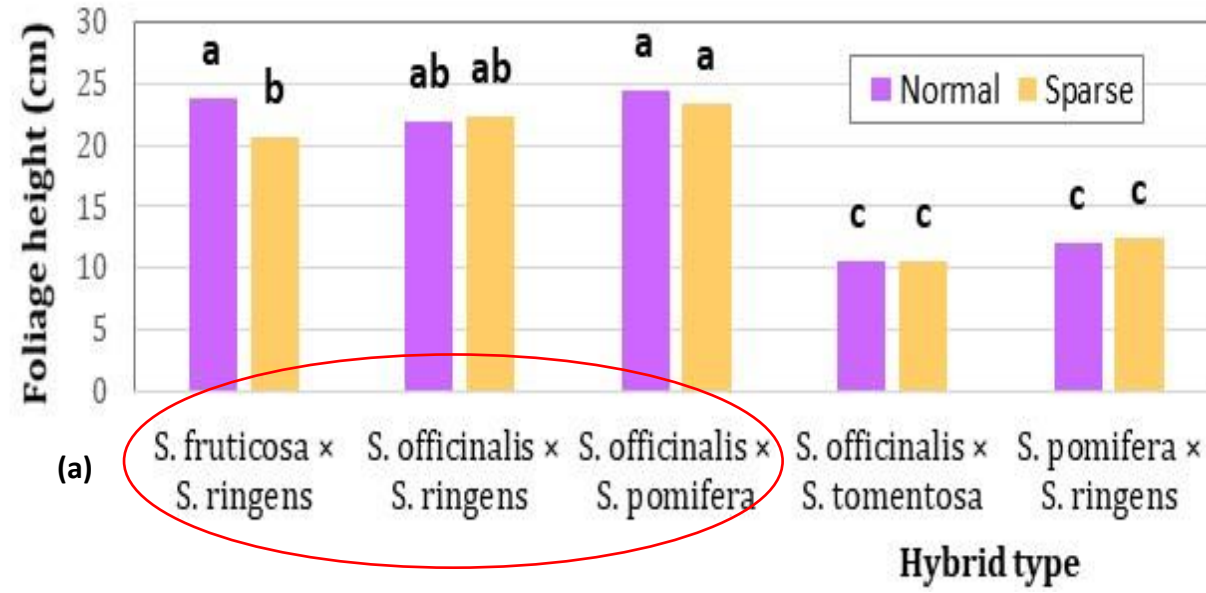
**Irrigation frequencies:**

starting from every **3 days (normal)**  
and **5 days (sparse)**

followed (after the end of May) by  
every **2 days (normal)**  
and **4 days (sparse)**

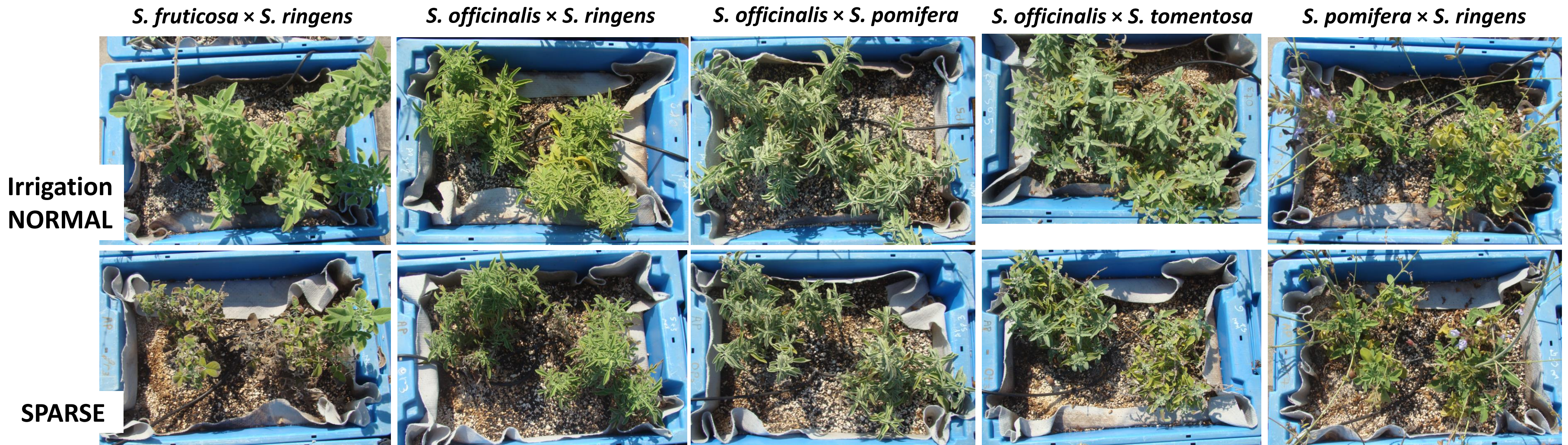
# RESULTS AND DISCUSSION

Survival two months after planting:  
**100%** for all hybrids



# CONCLUSIONS

- All sage hybrids were established successfully on an urban green roof.
- Diameter and total axillary shoot length were greater under normal irrigation.
- Hybrids' growth should be observed for a greater period in order to conclude for their drought tolerance.



Typical growth of Salvia hybrids two months after establishment (June 2021).

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