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PROPAGATION OF ATLANTIC CLIMATE NATIVE SPECIES OF THE GENUS *SEDUM* FOR USE IN EXTENSIVE GREEN ROOFS

Running Head: ***Propagation of native species of the genus*** **Sedum**

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ABSTRACT

In this study, we evaluated the rooting potential of herbaceous cuttings of Atlantic climate native species of Sedum which can be interesting for use in extensive green roofs. The species are native of Galicia and León (NW Spain), which have an Atlantic climate. The following native species were considered: S. album, S. alpestre, S. anglicum, S. brevifolium, S. hirsutum and S. acre. A commercially available species, S. rupestre (S. reflexum), was used as a control for comparison with the native species. The trial was established in June 2011 in a greenhouse equipped with a fog-system and bottom heat. The cuttings used in the trials were harvested from mother plants established from wild populations collected in coastal and inland areas of Galicia and grown in a growth chamber. The cuttings were inserted directly (i.e. without prior hormonal treatment) into individual cells. The rooting media consisted of a mixture of Sphagnum peat moss, pine bark compost and vermiculite (1:1.5:2.5, v/v/v). A split plot design with 5 replicates per species-origin and evaluating date and 7 cuttings per replicate was used. Rooting percentage, visual rooting score and number of primary roots were determined 15 and 30 days after cutting. The quality of roots was evaluated as total root length and number of root tips, with a Delta-T Scan system. The length and dry weight of the shoots were determined 90 days after cutting. The mean rooting percentage was 87% on the first evaluating date and 95% on the second. The rooting percentage differed significantly between species, with the lowest values obtained for S. hirsutum of coastal origin (68%) 15 days after cutting. For the other species, the rooting percentages were similar, varying between 94 and 100% at 30 days after cutting. Root development also differed significantly between species and origins. In general, S. anglicum (from inland locations), S. album (from inland locations) and the control species (S. rupestre) developed larger root systems within the shortest space of time. The findings showed the propagation performance of Atlantic climate native species of Sedum was good. The plants can be propagated on a commercial scale from cuttings within a short time, varying between 1 and 2 or 3 months depending on the species.

Keywords: *Sedum album, S. alpestre, S. anglicum, S. brevifolium, S. hirsutum, S. acre*

INTRODUCTION

Green roofs are increasingly common, environmentally responsible building in Europe and worldwide. They represent a growing market for the field of horticulture and report numerous benefits: environmental, economic, recreational and aesthetic (Snodgrass and Snodgrass, 2006). Among the various different types of green roof systems, extensive green roofs are characterized by shallow growing media, usually less than 15 cm deep (Bousselot *et al*., 2010; Snodgrass and Snodgrass, 2006). In Spain, interest in extensive green roof systems has increased considerably in recent years (Fernández-Cañero and Emilsson, 2008). These systems represent a new and growing market for the horticulture field. However, the currently available information applies to north-western Europe (NW) where most green roofs have been installed, and where the climatic conditions are very different from the prevailing conditions in NW Spain. The available information must therefore be adapted to the particular conditions of the geographical area where the green roof will be installed. Careful selection of plants is particularly important, because the conventional criteria used to select plants for growing in soil will not work on a roof.

Research on species that can survive and thrive on extensive green roofs has revealed that succulents, predominantly of the genus *Sedum*, outperform most non-succulents (Durham *et al*., 2007; Getter *et al*., 2009; Monterusso *et al*., 2005; Rowe et al., 2006; Sendo and Uno, 2007; VanWoert *et al*., 2005) as they can survive in a wide range of conditions (Snodgrass and Snodgrass, 2006). They are very tolerant to extreme temperatures, low fertility and the limited water supply under the prevailing dry climate of the green roof. Succulents are categorized as crassulacean acid metabolism (CAM) plants, in which water use efficiency is higher than in other plants (Sendo and Uno, 2007; VanWoert *et al*., 2005). The ability of *Sedum* to withstand extended drought conditions makes it an ideal plant for use in extensive green roofs with shallow substrates (VanWoert *et al*., 2005).

The use of native plants on green roofs has attracted considerable attention in recent years. Scientific arguments are based on maintenance requirements, habitat creation and the potential for plants to become invasive (Butler *et al*., 2012). Several species of *Sedum* that are native to Galicia (Baltasar Merino, 1986; Castroviejo, 1986-2010), which have Atlantic climate, could be

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selected for use in the implementation of extensive green roofs under local conditions. The species selected should be growing in environments similar to those where the green roofs will be installed.

Sedum comprises a wide range of species, including herbaceous perennials, evergreens and monocarps. Many of the herbaceous perennial *Sedum* species can be raised from seeds. Propagation by division is used in the mat-forming species and cuttings can be inserted directly in containers as many species root very readily (Hartmann *et al*., 2002; Thompson, 1989; Zaharia, 2004). Plugs, essentially cuttings with established root systems, offer a compromise between cost and flexibility. However, there is little scientific information about propagation conditions and the rooting ability of different *Sedum* species. Some research into the rooting of cuttings of *Sedum* spp. has shown that there may be great differences between species, with rooting percentages ranging between 60 and 100% depending on the species (Zaharia, 2004).

Extensive green roof systems have not been scientifically evaluated in Galicia, and research is therefore needed to adapt the systems to local conditions. The main objective of this study was to evaluate the potential rooting of cuttings of several native *Sedum* species from Galicia (*S. album, S. anglicum, S. brevifolium, S. hirsutum, S. acre*) and *S. alpestre* from León (which borders with south-eastern Galicia) in order to produce plugs for use in extensive green roof systems. The potential rooting of the cuttings depends on variables such as the percentage of rooting, the quality of the root systems, as well as the time needed to obtain them, which would guarantee the survival and the proper development of the plants. The wild populations from which plants were established were growing under harsh conditions in coastal and inland areas of Galicia. Two species (*S. anglicum*, *S. hirsutum*) of plants from both types of environments were finally selected.

MATERIALS AND METHODS

Collection of wild populations

We began field sampling of different species of *Sedum* in February 2011. All species were growing in rocky areas, on walls or roofs. Individual specimens were collected by removing whole plants from different areas of each site to prevent damage to the existing populations of *Sedum* spp. The specimens were collected on several dates in February, March and April 2011.

Establishment of mother plants and identification

The specimens were placed in an insulated box for transportation to the laboratory where they were transferred to trays filled with a substrate consisting of Sphagnum peat moss, pine bark compost and vermiculite (1:1.3:1.0, v/v/v). A slow release fertilizer (Osmocote Plus Mini, 16-8-

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11 + TE) was added at a dose of 1.5 g L^{-1}. Vermicompost was also added as organic fertilizer (1.6 L per 100 L). The trays were placed in a growth chamber (22ºC day and 16ºC night, photoperiod 16 h day and 8 h night and 80% relative humidity) to promote plant growth and flowering, as the flowers are essential for species identification. We consulted "Flora Ibérica" (Castroviejo, 1986-2010) to identify the wild species and "Flora Ornamental Española" (Sánchez de Lorenzo Cáceres, 2003) to identify the commercial species.

The plants were drenched every 2 weeks with 2.5 ml L^{-1} metilpirimifos (Zeneca Actellic 50E 12.240/10®, 50% Liquid) and 2g L^{-1} captan + triadimifon (Bayer Bayleton CA 14524/00®, 75% wettable powder) to control aphids and rust disease.

Plant material and cutting propagation

Propagation trials were carried out to compare the rooting performance of seven different species of *Sedum* (Table I) with that of the commercial species *S. rupestre* (*S. reflexum*) as a control. The trials were carried out in a greenhouse between June 2012 and September 2012. The cuttings used in the trials were harvested on 7 June 2012 from mother plants established from wild populations collected in coastal and inland areas of Galicia and grown in a growth chamber in the spring of 2011. Cuttings of 2-5 cm length, depending on the species, were obtained from herbaceous shoots.

TABLE I: Native species of Sedum selected and locations of origin. All locations are in Galicia (north-west Spain) except San Isidro, which is in León (region bordering south-eastern Galicia)

Species	Origin	Geographic coordinates /Elevation
S. album	inland - Carbedo - Lugo	42º 38' 07.5'' N, 07º 07' 28.0'' O/Elevation: 992 m
S. anglicum	inland-Seoane - Lugo	42º 39' 35.7'' N, 07º 07' 25.1'' O/ Elevation: 705 m
	coast- San Pedro - La Coruña	43º 22' 43.5'' N, 08º 26' 14.7'' O/ Elevation: 122 m
S. alpestre	inland - San Isidro - León	43º 03' 35.6'' N, 05º 22' 33.3'' O/Elevation: 1487 m
S. brevifolium	inland -Lugo	43º 00' 27.0'' N, 07º 32' 05.0'' O/Elevation: 390 m
S. hirsutum	inland- Lugo	43º 00' 27.0'' N, 07º 32' 05.0'' O/Elevation: 390 m
	inland-Seoane - Lugo	42º 39' 35.7'' N, 07º 07' 25.1'' O/Elevation: 705 m
	coast-Marcés – La Coruña	43º 14' 51.9'' N, 08º 16' 41.6'' O/Elevation: 91 m
S. acre	inland-Carbedo- Lugo	42º 38' 07.5'' N, 07º 07' 28.0'' O/Elevation: 992 m

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The bases of the cuttings were inserted into individual cells (3.5 x 3.5 x 5 cm) filled with rooting media consisting of Sphagnum peat moss, pine bark compost (Dermont) and vermiculite (1:1.5:2.5, v/v/v). The rooting bed was initially heated from below with an average temperature of 15,7 to 18,8 ºC. The bench was equipped with a fog system. Fog cycles were adjusted during the day to allow the foliage to dry before misting: they generally lasted 20 s and occurred every 15 min between 11:00 AM and 19:30 PM every day. The temperature (ºC) of the substrate and relative air humidity were recorded daily with data-loggers. Anti-fungal treatments were not required.

Experimental design

A split plot design with 5 replicates per species-origin and evaluating date and 7 cuttings per replicate was used. The main plots included 10 species of different origins, while the subplots represented the three evaluating dates.

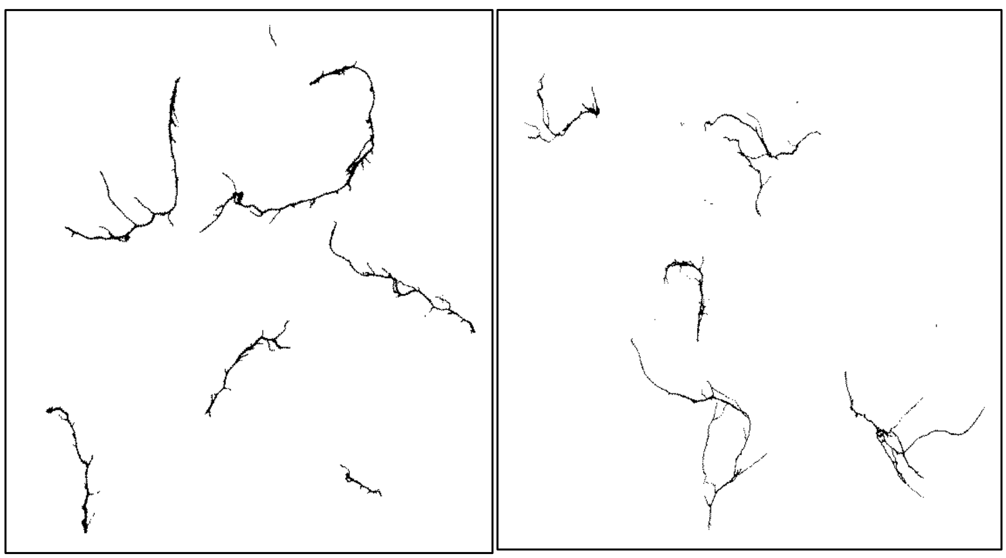
Percentage of cutting rooted, visual rooting score and number of primary roots

A total of 700 cuttings (10 species-origin x 7 cuttings x 2 evaluating dates x 5 replicates) were evaluated at two different times, i.e. 15 days (22 June) and 30 days (7 July) after cutting, to determine the percentage of cuttings that had rooted. A visual rooting score was also determined according to the following scale: 0 = dead, 1 = no callus or roots, 2 = roots present. The *Sedum* spp. cuttings did not develop any callus, and thus the corresponding values were not considered here. The visual rooting score was calculated to provide information about the proportion of rooted cuttings and about the proportion of surviving and dead cuttings. The number of primary roots was counted by hand in the rooted cuttings.

Computerized analysis of root length and number of root tips

All the rooted cuttings were analyzed to determine the quality of the root system on two evaluating dates, i.e. 15 and 30 days after cutting. The total all rooted cutting was 300 in the first date and 325 in the second one. In the third date, i.e. 90 days after cutting, a randomized sample of 140 rooted cutting (14 cuttings per species-origin) was analyzed. Delta-T Scan (Delta-T Devices Ltd.) software was used to analyze root length and number of root tips. The software was installed in a Pentium PC coupled to a flatbed scanner (HP ScanJet 6300, Hewlett-Packard Co., USA). Individual root systems of the cuttings were washed and separated from the substrate by hand; the white roots were stained with a solution of methyl violet (0.01%) for 30 minutes to enable them to be distinguished from the background. The primary roots were then cut at the base of the cuttings. The root segments were spread on to a glass tray for flatbed scanning from below. The stained roots were arranged as randomly as possible to achieve a uniform distribution of orientations of root segments (Fig. 1) (Richner *et al.*, 2000). Furthermore, in the longest root systems two samples were required to avoid overlapping of root pieces. The scanner resolution was 300 dpi. A black & white threshold was used for root recognition. The roots were counted by hand and threshold correlations between this data and the Delta-T Scan data were determined. The digital image resolution (threshold) used varied between 20- 35 depending on the width of the roots of the different species.

Figure 1: Two scanned black and white images of stained samples of root cuttings of *S. anglicum* (coast- San Pedro) (a) and *S. brevifolium* (b) used to measure root length and number of root tips by the Delta-T scan procedure. The scanner resolution was 300 dpi and the digital image resolution (threshold) 25



Length and dry weight of shoots

Growth of the cuttings was evaluated as length and dry weight of the shoots on the third evaluating date, i.e. at 90 days after cutting. After measuring the root lengths, the shoots were removed, weighed and then dried at 65º C for 48 h for dry weight determination.

Data analysis

The rooting percentages and visual rooting scores were examined by analysis of variance (PRO ANOVA SAS, SAS Institute, 2009), with separation of means by the Newman-Keuls test ($P<0.05$). Percentage data were subjected to arcsin transformation before analysis, following the procedure described by Snedecor and Cochran (1980). The percentage data shown in the tables are not transformed. The data on rooted cuttings (number of primary roots, root length, number of root tips, length and dry weight of shoots obtained) were examined by a generalized linear model for unbalanced data (PRO GLM SAS, SAS Institute, 2009).

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RESULTS AND DISCUSSION

Percentage rooting and visual rooting score

The percentage rooting success differed significantly between species and between evaluating dates (Table II). *Sedum hirsutum* yielded the lowest mean rooting percentage, with values between 68.1 and 81.4 % depending on the origin. For the other species, the values varied between 87.1 and 100% of rooted cuttings. The differences in rooting percentage between species shown in Table 2 paralleled the differences in visual rooting score. Delaying the harvesting date until 30 days after cutting yielded a significant increase in the global rooting percentage of *Sedum* species (from 87.1 to 95.0%). Rooting percentage and visual rooting score displayed a low degree of variability, with coefficients of variation of 14 and 11% respectively. The statistical analysis did not reveal any interaction between species and evaluating date, except for the visual rooting score.

TABLE II: Average rooting percentage and visual rooting score of cuttings of Sedum species on two different evaluating dates: two weeks (22 June) and one month (7 July) after cutting

Species (origin)	Rooting percentage (%)	Visual rooting score
S. anglicum (coast- San Pedro)	100 a[1]	2.00 a
S. anglicum (inland-Seoane)	97.1 a	1.97 a
S. hirsutum (coast- Marcés)	68.1 c	1.68 c
S. hirsutum (inland- Lugo)	80.0 b	1.80 b
S. hirsutum (inland-Seoane)	81.4 b	1.81 b
S. brevifolium (inland-Lugo)	87.1 ab	1.87 ab
S. alpestre (inland- León)	98.5 a	1.99 a
S. acre (inland-Carbedo)	100 a	2.00 a
S. album (inland-Carbedo)	100 a	2.00 a
Sedum rupestre (commercial species)	100 a	2.00 a
Significance ($p<0.05$)	0.0001	0.0001
Harvest date		
22 June	87.1 b	1.87 b
7 July	95.0 a	1.95 a
Significance ($p<0.05$)	0.0011	0.0018
Species (origin) x Date		
Significance ($p<0.05$)	0.0758	0.0377

[1]Mean values indicated with the same letter are not significantly different according to the Newman-Keuls test ($P<0.05$).

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In general, *Sedum* species had rooted well at 15 days after cutting, with on average 63 to 100 % of the cuttings producing roots (Table 3). However differences were observed between species: the lowest rooting percentage occurred in *S. hirsutum* from both sampling locations (coastal-Marcés and inland-Lugo). For the other species, the rooting percentage peaked at between 86 and 100% and was similar to that of the commercial species *S. rupestre*.

Delaying evaluating to 30 days after cutting led to a significant increase in the rooting percentage of *S. hirsutum*, to 94%, i.e. to a level similar to that achieved in the other species, except in the *S. hirsutum* of coastal origin, in which the rooting percentage was lowest (73%). The delay in evaluating also increased the visual rooting score in this species (except in the specimens of coastal origin), in parallel with the higher rooting percentage (Table III).

TABLE III: Rooting percentage and visual rooting score of several species and origins of Sedum evaluated on two dates: June and July 2011 (15 and 30 days after cutting)

Species (origin)	Rooting percentage (%)		Visual rooting score	
	22 June	7 July	22 June	7 July
S. anglicum (coast- San Pedro)	100 a[2]	100 a	2.00 a	2.00 a
S. anglicum (inland-Seoane)	94 a	100 a	1.94 a	2.00 a
S. hirsutum (coast- Marcés)	63 c	73 b	1.63 b	1.73 b
S. hirsutum (inland- Lugo)	66 bc	94 a	1.66 b	1.94 a
S. hirsutum (inland-Seoane)	68 ab	94 a	1.68 b	1.94 a
S. brevifolium (inland-Lugo)	86 a	89 a	1.85 a	1.87 a
S. alpestre (inland- León)	97 a	100 a	1.97 a	2.00 a
S. acre (inland-Carbedo)	100 a	100 a	2.00 a	2.00 a
S. album (inland-Carbedo)	100 a	100 a	2.00 a	2.00 a
S. rupestre (commercial species)	100 a	100 a	2.00 a	2.00 a
Significance	0.0001	0.0032	0.0001	0.0032
Overall mean ± RMSE[1]	87± 12 B	95± 10 A	1.87±0.12 B	1.95± 0.10A
Significance (p<0.05)	0.0011		0.0018	

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[1]Root mean square error.

[2]Mean values for each date indicated by the same letter are not significantly different according to the Newman-Keuls test (P<0.05). Overall mean values, capital letters indicate differences between dates for each variable.

Root and shoot growth parameters

Regarding the quality of the root system, there were significant differences in the number of primary roots, the number of root tips and the total root length per rooted cutting for the species and origin evaluated, including the commercial species (*S. rupestre*) (Table IV). The number of primary roots, the total root length and the number of root tips were also highly variable. In general, *S. anglicum* (inland-Seoane) yielded the largest root system 15 and 30 days after cutting, while *S. hirsutum*, *S. brevifolium* and *S. alpestre* had the smallest root system on both dates. The total root length per rooted cutting was similar in *S. anglicum* (Seoane) and the commercially available *S. rupestre*.

TABLA IV: Number of principal roots, root tips and variation in total length of roots in cuttings of several species and origins of Sedum spp. evaluated on two dates: June and July 2011(15 and 30 days after cutting)

	Number of primary roots		Number of root tips		Total root length (cm)	
Species (origin)	22 June	7 July	22 June	7 July	22 June	7 July
S. anglicum (coast- San Pedro)	9.3 c[2]	8.8 bc	38.2 b	87.91b	27.9 ab	50.4 bc
S. anglicum (inland-Seoane)	15.1 a	19.5 a	38.7 b	144.7a	33.2 a	75.9 a
S. hirsutum (coast- Marcés)	2.1 d	2.6 d	4.5 c	13.8 c	2.4 d	6.6 e
S. hirsutum (inland-Lugo)	3.3 d	6.0 cd	18.4 c	33.5 c	4.6 d	20.7 de
S. hirsutum (inland-Seoane)	4.3 d	6.1 cd	9.3 c	32.0 c	8.3 d	16.6 e
S. brevifolium (inland-Lugo)	5.3 d	8.7 bc	8.2 c	32.1 c	3.5 d	15.3 e
S. alpestre (inland-León)	3.2 d	5.5 cd	17.2 c	42.4 c	6.2 d	25.6 de
S. acre (inland-Carbedo)	8.7c	13.0 b	41.2 b	94.3 b	16.3 c	47.7 bc
S. album (inland-Carbedo)	11.9 b	12.9 b	56.5 a	80.4 b	22.3 bc	35.9 cd
S. rupestre (commercial species)	12.8ab	12.6 b	50.7 ab	102.9b	27.1 ab	65.9 ab
Mean±RMSE[1]	8.1±4.6	9.8±6.5	30.4±23.6	68.7±50.1	16.4±14.1	37.3±29.8
Significance (p<0.05)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

[1]Root mean square error.

[2]Mean values for each date indicated by the same letter are not significantly different according to the Newman-Keuls test (P<0.05).

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At the end of the trials, i.e. 90 days after establishing the cuttings (Table V), the total root length per rooted cutting was similar in the commercial *Sedum* and the other species and origins, except for *S. anglicum* (inland-Seoane), in which the total root length was significantly longer. The number of root tips was also significantly higher in this species (Figure 2).

Figure 2: *Sedum anglicum* plant three months after inserting the herbaceous cutting in the medium

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TABLE V: Mean number of root tips, total root length, length and dry weight of shoots for rooted cuttings of several species and origins of Sedum spp., 90 days after cutting (7 September 2011).

	Adventitious roots		Shoots	
Species (origin)	Number of root tips	Total root length (cm)	Length (cm)	Dry weight (mg)
S. anglicum (coast- San Pedro)	530.3 b[2]	376.3 b	18.2 a	222.1 b
S. anglicum (inland-Seoane)	1061.9 a	808.9 a	20.3 a	374.4 a
S. hirsutum (coast- Marcés)	139.9 c	74.5 b	2.2 ef	54.7 cd
S. hirsutum (inland- Lugo)	419.7 bc	255.8 b	6.9 d	132.8 bcd
S. hirsutum (inland-Seoane)	550.4 b	350.7 b	3.6 ef	171.1 bc
S. brevifolium (inland-Lugo)	261.5 bc	165.3 b	4.8 def	32.7 d
S. alpestre (inland- León)	480.6 bc	329.6 b	5.5 de	39.2 d
S. acre (inland-Carbedo)	330.7 bc	180.6 b	10.2 c	80.3 cd
S. album (inland-Carbedo)	507.4 b	358.4 b	12.1 bc	139.7 bcd
S. rupestre (commercial species)	478.1 bc	322.9 b	14.3 b	173.3 bc
Mean ±RMSE[1]	480.2±323.3	325.7±299.4	9.9±3.0	143.7±115.1
Significance	0.0001	0.0001	0.0001	0.0001

[1]Root mean square error

[2]Mean values indicated by the same letter are not significantly different according to the Newman-Keuls test ($P<0.05$)

In contrast with the general performance of the root system at the end of the trials, there were significant differences in the average length and dry weights of shoots of the species evaluated for potential use in extensive green roof systems (Table V). The species that yielded the longest shoots and highest dry weight of shoots was *S. anglicum* (inland-Seoane) followed by *S. anglicum* (coast-Marcés), *S. rupestre* and *S. album*. The shortest shoots corresponded to *S. hirsutm* (inland-Seoane and coast-Marces). Significant differences in length of shoots were also

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observed between different origins of *S. hirsutum*, with the population from the interior of Lugo yielding the longest shoots in this species.

The longest shoots did not always yield the highest dry weights: in *S. hirsutum* (inland-Seoane), one of the smallest species, the dry weight of shoots was similar to those of *S. rupestre* and *S. album*.

The time taken for primary roots to develop after plant cuttings are inserted in the propagation bed varies widely (Hartmann et al., 2002): in some species adventitious roots are visible after 10 days, while in others they do not appear until after three weeks. In the *Sedum* species evaluated in the present study, abundant roots were observed after 15 days in a high percentage of the cuttings.

In some species, callus formation is a precursor of adventitious root formation, while in other species excess callusing may hinder rooting. The development of adventitious root from callus tissue has been associated with difficult-to-root-species (Hartmann *et al*., 2002). In *Sedum* species, callus formation was observed prior to root development in *Sedum stahlii* (Yarborough, 1936), although in this case leaf cuttings, rather than stem cuttings, were used. In the present study, none of the species developed callus before the appearance of adventitious roots, and therefore the roots formed directly. Although there were differences between species regarding the time to maximum rooting and differences between some populations in rooting potential, the rooting percentage exceeded 60% at 15 days after cutting in all species. The species evaluated can be classified as easy-to-root as the cuttings rooted without hormonal treatment.

The observed differences in the rooting percentage in *S. hirsutum* relative to the other species at 15 days after cutting may be partly related to the type of shoot used in propagating this species. The shoots consist of thin stems in which leaves are arranged in a rosette at the distal end. The roots emerge at the base of the leaf rosettes and between the leaves. In the other species the leaves are arranged along the stem, thus providing more points for rooting, and rooting occurred faster. However, after 30 days the rooting percentage was similar in all species, except in *S. hirsutum* of coastal origin. The lower rooting percentage in this population relative to that of the inland population is difficult to explain. It may be related to the physiological status of the mother plants, which depends on the genotype and environmental growth conditions (Hartmann *et al.,* 2002) and is known to influence the rooting of cuttings. Differences in rooting percentage have also been reported for five species and cultivars of *Sedum*, with similar values, ranging between 60 and 100% (Zaharia, 2004), to those observed in the present study.

In *S. anglicum*, although the origin did not influence rooting percentage on any date, it was associated with a lower quality of root system (fewer main roots and fewer root tips) in the coastal population at 30 days after cutting. The status of the mother plant may affect root development. For example, the nutritional status of the cuttings and the carbohydrate/nitrogen levels have been identified as factors affecting rooting in different types of plants (Hartmann *et al*., 2002; Rapaka *et al*., 2005; Rowe *et al*., 2002; Tsipouridis, 2006).

The variability in the quality of the root systems detected at each harvesting time may be explained by differences between individual cuttings some of which take longer to root than others (Hartman *et al.*, 2002).

The differences in length of the shoots between species at the end of the trial (90 days after cutting) may be related to the size and growth habit of the different species. Differences in shoot length between *S. hirsutum* of different origins can be explained for a more compact habit observed in wild populations from inland (Seoane) and coastal (Marcés) areas than in the inland population from Lugo.

The findings showed that the native species of *Sedum* evaluated can be successfully propagated by herbaceous cuttings as all species rooted well under the trial conditions. High rooting percentages and good quality root systems, similar or better than those yielded by commercial species, were obtained.

The different time-to-rooting observed between species affected the time required to obtain a well-established plant for use in extensive green roof systems. The species that rooted fastest - *S. anglicum*, *S. rupestre* and *S. album* - can be produced in one or two months. For the more slowly rooting species - *S. hirsutum* and *S. brevifolium* - cuttings with well-established root systems were obtained within three months. We recommend selecting mother plants of native species by taking into consideration their rooting ability and growth, as there may be important differences between populations of the same species.

Although cuttings or plugs can be used, plug tray systems are recommended for species that root and grow slowly. However, further field trials are necessary to investigate the best installation method for the species studied.

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