Technical Article

Assessing native germplasm for extensive green roof systems of semiarid regions[1]

NATALIA CÁCERES[2]*, LELIA IMHOF[2], MARIO SUÁREZ[2], EMMANUEL C. HICK[2], LEONARDO GALETTO[3]

ABSTRACT

Extensive green roofs (EGR) spaces constitute harsh and stressful growing environments, and consequently a limited range of plants species that can be routinely used there. The habitat template hypothesis suggests that EGR can be analogous as natural environments, what makes native plants as an alternative for these conditions. This paper aimed to assess the potential use of 15 native plants from Córdoba Province (Argentina) for green roofs, based on cover ability, survived rates and health status observations during a period of 414 days. *Sedum acre* L. was used as the control. *Glandularia* x *hybrid*, *Phyla nodiflora* (L.) Greene, *Melica macra* Nees, *Eustachys retusa* (Lag.) Kunth and *Grindelia cabrerae* Ariza kept up a 60% of coverage during all the period of study. The first two species had an outperformed green coverage (at 72th day; 95% and 98% respectively) in relation to the control species (*Sedum acre*; 87%). *Eustachys retusa* and *Grindelia cabrerae* grew progressively and kept their coverage constant proximally to 65%. *Sedum acre*, *Grindelia cabrerae*, *Hysterionica jasionoides* Willd, *Melica macra*, *Phyla nodiflora*, stood out in plant survival rates; but *S. acre* suffered changes in health status throughout the evaluation period, especially with low temperatures or at high humidity conditions. It is necessary to underline the reseeding potential of *Eustachys retusa*, a process that could guarantee perpetuation of the species on EGR.
Keywords: habitat templates, native taxa, performance, plant cover, roofscape.

RESUMO

Avaliação de germoplasma nativo para sistemas extensivos de telhados verdes em regiões semiáridas

Os telhados verdes extensivos (EGR) são ambientes de agressivos e estressantes para o desenvolvimento de plantas, o que significa que uma variedade limitada de espécies de plantas pode ser usada rotineiramente. A hipótese do modelo de habitat sugere que o EGR pode ser análogo aos ambientes naturais, o que torna as plantas nativas uma alternativa para essas condições. Este trabalho descreve a caracteriza de 15 plantas nativas da Província de Córdoba (Argentina), avaliando-se a capacidade de cobertura, taxa de sobrevivência e observações do estado de sanitário durante 414 dias. *Sedum acre* L. foi a espécie usada como controle. *Glandularia* x *hybrid*, *Phyla nodiflora* (L.) Greene, *Melica macra* Nees, *Eustachys retusa* (Lag.) Kunth e *Grindelia cabrerae* Ariza cabrerae conservaram 60% da cobertura durante todo o período de estudo. As duas primeiras espécies tiveram uma cobertura verde superada (aos 72 dias; 95% e 98% respectivamente) em relação a espécies de controle *Sedum acre* (87%). *Eustachys retusa* e *Grindelia cabrerae* cresceram progressivamente e mantiveram sua cobertura constante em aproximadamente 65%. *Sedum acre*, *Grindelia cabrerae*, *Hysterionica jasionoides* Willd, *Melica macra*, *Phyla nodiflora*, destacaram-se na taxa de sobrevivência de plantas; mas *S. acre* sofreu mudanças no estado de sanitário durante o período de avaliação, especialmente com baixas temperaturas ou em condições de alta umidade. É necessário ressaltar o potencial de ressemeadura da *Eustachys retusa*, processo que poderia garantir a perpetuação da espécie.
Keywords: cobertura vegetal, desempenho modelos de hábitat, roofscape, táxons nativos

1. INTRODUCTION

Attending to conventional roofs provide cities with 20%-30% of impervious surfaces; there is a globally growing effort to restore ecological functions, goods and services into urbanized areas by strengthening them with green infrastructure (PALLA et al., 2010; FRANCIS and LORIMER, 2011; BUTLER et al., 2012; LUNDHOLM, 2015). Green technology main purposes, founded on principles of urban sustainability (LUNDHOLM, 2015), are to reestablish partially some biosphere goods and prevent cities from global and local threats through technological solutions (e.g. reducing the urban heat island effect (UHI) and run-off water management) (JANSSON, 2013; RAZZAGHMANESH et al., 2014; THURING and DUNNET, 2014; DUSZA et al., 2016). Landscaping roofs (green roof) is a significant opportunity of these constructed ecological designs, shaped to serve as bridges and balance through an interaction between nature and artificial environments providing multiple urban ecosystem services

DOI: http://dx.doi.org/10.14295/oh.v24i4.1225

[1] Received in 18/05/2018 and accepted in 05/11/2018

[2] IRNASUS (Universidad Católica de Córdoba-CONICET, Facultad de Ciencias Agropecuarias) Córdoba, Argentina.

[3] Instituto Multidisciplinario de Biología Vegetal, Departamento de Diversidad Biológica y Ecología, Universidad Nacional de Córdoba-CONICET, Córdoba, Argentina.

(i.e., control storm water quality and quantity, reduced heat island effect, building energy, reduced noise impact, increase biodiversity), critical to face current climate changes (FRANCIS and LORIMER, 2011; LUEDERITZ et al., 2015; SUTTON, 2015; BEICHLER et al., 2017). Given the stressful conditions that characterize these systems, particularly the extensive ones, there are some obstacles to take into account when selecting suitable plants to grow there as tolerant to drought, hot, cold and windy weather. Supporting shallow root depths, less nutrient dependency and resistance to diseases are also vital challenges for the survival of plants in these kinds of sustainable structures (DURHMAN et al., 2004; LI and YEUNG, 2014; VAN-MECHELEN et al., 2014). In consequence, plant selection for roofscaping includes multiple interrelated factors, ranging from building infrastructure to microclimate, culture medium, as well as plant functional and utilitarian features (VAN-MECHELEN et al., 2014; ARABI et al., 2015; NOYA et al., 2017). Therefore, the preliminary challenge of these technologies is limited by the success of the vegetation layer (EMILSSON and ROLF, 2005).

Vegetation establishment, a permanent green coverage surface, high survival rates, and self-regeneration are crucial traits to achieve plant viability over time and drive-on the functional urban benefits associated with living roofs. Even more, selecting suitable vegetation improves their aesthetic appearance and public acceptance and parameters related to the quality of life (BOIVIN et al., 2001; DURHMAN et al., 2004; MONTERUSSO et al., 2005; GETTER and ROWE, 2006; RAZZAGHMANESH et al., 2014). According to the German Green Roof Guidelines (FLL, 2008), living roofs have to achieve a green plant surface area greater than 60% after one or two years of installment. Other characteristics that can enhance the stability over time of vegetated roofs are center on plant size, growth potential, flowering period, the presence of pollinating agents and their capability of re-seeding (VAN-MECHELEN et al., 2014). It is well known that the species used by excellence worldwide corresponds to the genus *Sedum*, mainly for its supreme characteristics of adaptability to water stress conditions. Unfortunately, these conditions are not always fulfilled in arid or semiarid climates, making it essential that vegetation meet certain abilities to cope with these stressful situations. Therefore, it is necessary to evaluate new species able to tolerate these types of stressful environments (EMILSSON and ROLF, 2005; MONTERUSSO et al., 2005; DVORAK and VOLDER, 2010; VAN- MECHELEN et al., 2014).

In front of this, green roofs technology could be based on the "habitat template hypothesis" (LUNDHOLM, 2006; VAN-MECHELN et al., 2015). This hypothesis stands that built spaces can be analogous to natural environments, such as limestone pavements, and stony or rocky habitats, which are characterized for having shallow soils, matching to those green roofs of extensive nature (NAGASE and TASHIRO-ISHII, 2018). In accordance with these characteristics and to inquire into other native and suitable taxa, multiple studies have focused their attention on indigenous plants, naturally adapted to local conditions, as alternatives occupants of the thin living layer (150-200 mm) (CANTOR and PECK, 2008; BUTLER et al., 2012; LI and YEUNG, 2014) and low availability of water resources (drought-tolerant). At South America region there is still a knowledge shortage on suitable plants green roof terms. Moreover, the use of native resources is limited by the lack of availability or nonexistence of potential materials for the market (PROVENZANO et al., 2010; LUNDHOLM et al., 2010). Consequently, a necessary first step to develop suitable plants for green roofs would be to evaluate native and naturalized germplasm under different growth condition and development, in order to have a basis to start developing efficient low maintenance technologies at local and regional level (MARTIN, 2007). A study carried out by our research team had evaluated the performance of *Glandularia* (Verbenaceae) hybrids, a native species from Argentina on EGR under non-irrigated conditions, giving optimal results of coverage and survival rates at experimental green roof conditions. We hypothesized that local plants from semiarid Northwest region of Córdoba, Argentina, might provide a novel alternative for EGR owing to their adaptability to these stressful environments. In order to achieve this objective, we first look at a characterization based on their cover ability quantification, survival rates, and health status observations. In this way, through the assessment of these variables, particularly coverage area parameter, we finally ranked them and selected the best candidate species to be recommended for EGR systems.

2. MATERIALS AND METHODS

The trial was carried out (31°28′ S, 64°13′ W) for a period of 414 days, from October 12, 2016 to November 30, 2017 Semi-arid regions of central Argentina are characterized by high thermal amplitude, hot days and cold nights; precipitations concentrated in spring-summer and dry periods and cold and strong winds (CABIDO, 1985; GIORGIS et al., 2011). The climate of this region is classified as BSh (B: arid; S: Step and h: hot arid) according to Köppen- Geiger climate classification.

Plant materials collection and green roof modules

The collection of the most promising species from the northwest and central region of Córdoba Province was carried out. The collection period was scheduled between August and September of 2016. The fourteen native accessions were taxonomically identified (SÉRCIC et al., 2015). In addition, the research team provided two species, one of this, corresponded to a material resulted of a breeding program, *Glandularia* x *hybrid,* and the second one to *Sedum acre* L., which was used as the control due to its demonstrated performance on green roofs systems (LI and YEUNG, 2014) (Table 1).

Table 1. Species list collection, family group, plants grown form, propagule collected and initial number of plants m^{-2} per module of extensive green roof.

Species	Family	Growth form	Propagule collected	Number of plants m^{-2}
Sedum acre L.	Crassulaceae	Creeping herbaceous	Cuttings /Mats	9
Glandularia x *hybrid*	Verbenaceae	Creeping herbaceous	Cuttings	25
Phyla nodiflora (L.) Greene	Verbenaceae	Creeping herbaceous	Cuttings/ Mats	11
Eustachys retusa (Lag.) Kunth	Poaceae	Graminoides	Mats	8
Melica macra Nees.	Poaceae	Graminoides	Mats	6
Grindelia cabrerae Ariza cabrerae.	Asteraceae	Upright forbs	Cuttings/ Mats	20
Hysterionica jasionoides Willd.	Asteraceae	Upright forbs	Mats	7
Scoparia montevidensis Spreng.	Scrophulariaceae	Creeping herbaceous	Cuttings/ Mats	10
Bulbostylis sp.	Cyperaceae	Graminoides	Mats	11
Justicia squarrosa Griseb.	Acanthaceae	Upright forbs	Cuttings/ Mats	8
Senecio sp.	Asteraceae	Upright forbs	Mats	11
Heliotropium curassavicum L.	Boraginaceae	Creeping herbaceous	Cuttings/ Mats	8
Sisyrinchium sp.	Iridiaceae	Graminoides	Mats	11
Nama undulatum Kunth.	Boraginaceae	Creeping herbaceous	Mats	11
Adesmia sp.	Fabaceae	Creeping herbaceous	Mats	11
Schizachyrium condensatum (Kunth.) Nees.	Poaceae	Graminoides	Mats	6

*Growth form. Creeping herbaceous: plants that spread out along the ground, have not succulent leaves and are not superior to 20 cm of height; Creeping succulents: plants that spread out along the ground, have succulent leaves and are not superior to 20 cm of height; Grasses type: graminoide or lanceolate leaves as turf; Upright forb: erect forbs with a height equal or superior to 25 cm.

The sixteen plant materials were conditioned and propagated asexually by stem cuttings or mat division, and were grown under greenhouse conditions for about 30 days. Once all propagules were rooted, the transplant was carried out to the experimental plots.

The plant material was cultivated on experimental units of extensive green roofs modules on two rows to avoid edge effects (1m above the ground level; 15 cm depth; 100 x 100 cm size; total area: 10,000 cm^2). The planting design was planned using one taxa per module (monoculture, without repetitions). At the beginning of the experiment, all modules started with a different number of seedling (see Table 1) to reach comparable plant coverage (10% to 15%).

The growing medium consisted on a mixture of construction waste soil, perlite, peanut shell and equine compost (proportions by volume 3:1:1:1). The portion of soil used was recycled from a removal of land used for the construction of a sport field of the University. Additional fertilization was not applied during the cultivation period.

It was a rigorous watering regime during the first 45 days to kept soil moisture at field capacity and ensure good establishment of the different plant materials. After this first stage, supplementary irrigation was provided through the observation of vegetation needs. Hand weeding activity was carried out every 15 days, which allowed a better measurement take. Substrate dry weight was 80 kg m^{-3} and its saturated weight was 110 kg m^{-3}. Chemical indicators of the substrate were tested, resulting pH (1:10), determine in water, was 7.4 and CE (1:10) 0.39 ds m^{-1}. Some physical parameters were as well determinate: water holding capacity 41.4%, total porosity (77%), air-filled porosity 35.6%, pore/solid ratio 3.35, substrate density 0.57 g cm^{-3} and particle density 1.35 g cm^{-3}.

To characterized plants performance the following characters were considered: green coverage area (Ca; %), survival percentage (S; %), health status (HS Range: 5 to 1). The measurements were taken with the fortnightly frequency.

Green Coverage Area (GCA)

The GCA of each species was calculated as the percentage of the green surface, defined as the living area layer of the plant, and was estimated by digital photographs taken directly overhead. The camera (Canon Power Shot Sx700HS) was positioned horizontally, placing it at the same height and position (center) above the module. It was also a requirement to take the images at the same hour range, in order to avoid shadows and differences in the contrasts between green coverage and the module surface. To processing each photography, an image analysis software was used, FIJI Image J Tool (National Institute of Health, MD, USA). From the coverage values obtained, species were divided into three groups: Group I: ≥ 60%, Group II: 59%-45%, and Group III ≤ 44%. The following step was to rank the materials on a table according to the number of days in which maximum coverage values were reached and on their aptitude to maintain them upper to 60% until the final day of the study period. Additional information such as minimum and maximum of green coverage area were also showed on a table. From this data, a selection of the best performers (Group I) was effectuated, and coverage models were explored to outlook graphically plant cover variation over time and to compare if there were similarities in growth velocity with those of the control. Coverage growth patterns were visualized by adjusting the following models: linear and non-linear regression. Infostat Software was applied to the obtained the growth curves (DI RENZO et al., 2011).

Survival percentage and Health Status

Plant survival percentage (S %) was determined by counting life plants at the time of implantation (day 0) to the end of the study (day 414). Health Status (HS) was determined as a visual quality, following the methodology proposed by MONTERUSSO et al. (2005) through the relative appearance of each plant on a categorized scale (range from 1 to 5). Score 1 = for dead materials; score 2 = for materials that showed marked stress (wilt and browning symptom); score 3 = for plants with very low growth rates; score 4= healthy plants, without stress; score 5 = fullness growth and flowering, the presence of new seedlings. There was calculated the mode statistic on each accession and the value was registered on a table. Supplementary parameters such as (qualitative characters): flowering period, reseeding ability and observation of new seedling grown.

3. RESULTS

Species Evaluation. Plant cover performance

To facilitate the assessment, from the image processing, the coverage performance allowed us to classify species according to their cover behavior and separated them into three differentiated categories: Group I over 60%, Group II between 45% to 59%, and Group III, less than 44% (Table 2). The performance of the different species was based firstly on the number of days in which each material achieved a maximum cover and whether or not it was maintained in the period with the coverage higher or equal to 60% until the study finished.

Table 2. Performance of the different species according to the green coverage area (GCA) reached under extensive green roof conditions. Values shown: minimum and maximum, number of days to reach coverage area > 60%, number of days until maximum coverage values were reached, and coverage area superior to 60 constant to the end of the essay (yes/no).

Species Performance	GCA Min (%)	GCA Max (%)	Days to reach ≥ 60%	Days to reach GCA max	GCA>60% Constant Overtime (Yes/ No)
Sedum acre L.	9	100	58	86	Yes
Phyla nodiflora (L.) Greene	10	100	31	86	Yes
Glandularia x *hybrid*	8	100	31	86	No
Bulbostylis sp.	9	100	86	198	Yes
Melica macra (Nees.)	16	100	114	389	Yes
Eustachys retusa (Lag.) Kunth	8	90	142	389	Yes
Grindelia cabrerae Ariza cabreare	12	88	170	414	Yes
Scoparia montevidensis Spreng.	5	100	114	58	No
Justicia squarrosa Griseb.	12	75	114	142	No
Senecio sp.	8	60	170	170	No
Heliotropium curassavicum L.	10	55	114	114	No
Hysterionica jasionoides Willd.	5	40	-	198	No
Nama undulatum Kunth.	5	34	-	114	No
Sisyrinchium sp.	8	34	-	387	No
Adesmia sp.	5	20	-	114	No
Schizachyrium condensatum (Kunth.) Nees.	5	15	-	31	No

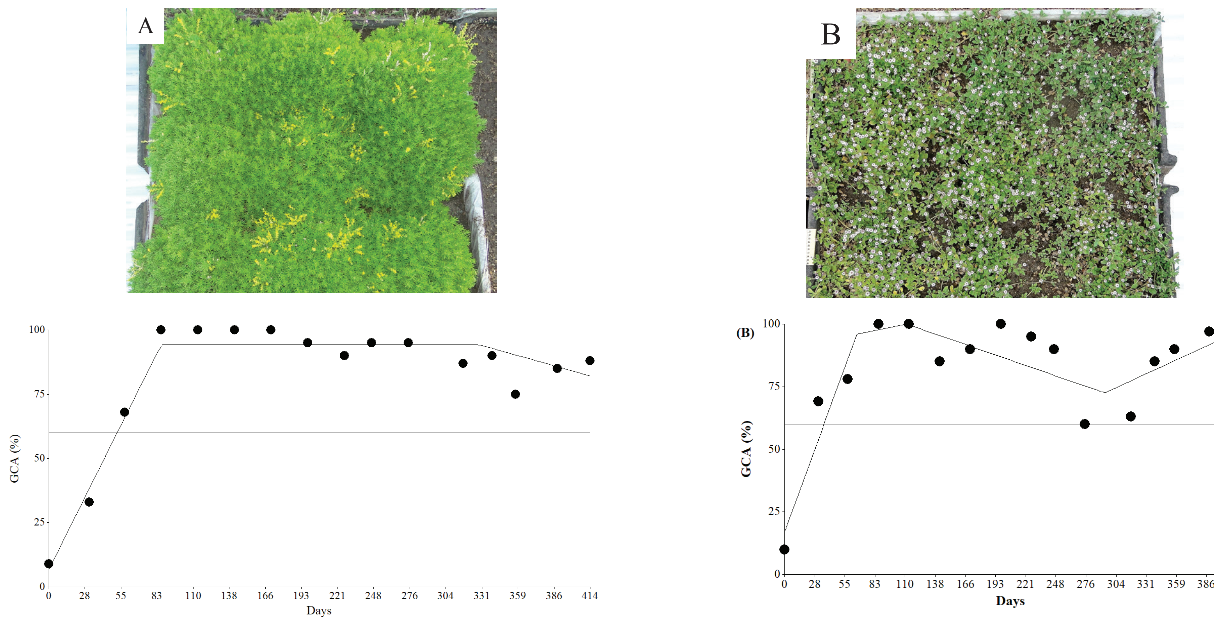
***GCA values**. GCA min and GCA max: minimum and maximum percentage reached over the period of study.

In order of performance, species within Group I (CA > 60%) were *Sedum acre*, *Phyla nodiflora* (L.) Greene), *Glandularia* x *hybrid*, *Melica macra* Nees, *Eustachys retusa* (Lag.) Kunth, *Grindelia cabrerae* Ariza cabrerae, *Bulbostylis* sp. Despite some fluctuation on the coverage, mostly affected by the climate extreme conditions (high or low temperatures), these species conserved a 60% on coverage all the period of study. An interesting comparison among the performance of *S. acre* and two native spreaders, *P. nodiflora* and *G.* x *hybrid* emerged. *S. acre* showed 68% of green cover at day 58, and from day 86 onwards its coverage showed full cover (100%) with minimal fluctuations during the winter period. On the other hand, *G.* x *hybrid* and *P. nodiflora* had a similar outperformed behavior, reaching a superior green coverage of 89% and 75% respectively during the same period (day 58). It is significant to note that at day 72; both materials presented coverage values of 95% and 98%, respectively, exceeding the percentage reached by *S. acre* at this date (87%). However, at low temperatures, *P. nodiflora* had reached and maintained constant its coverage at 79% for almost all the rest of the trial, decreasing its growth from June to August to 62.5%.

E. retusa and *G. cabrerae* grew progressively and kept their coverage constant proximally to 65%. On the last day of measurement, both of them had reached a 90% of green coverage. *Melica macra* performed an optimum cover percentage, but showing a slow growth, reaching 90% of coverage at day 275, and *Bulbostylis* sp. had a completed coverage (100%) on day 142 but it had frequent fluctuations due to extreme weather conditions during the trial.

Heliotropium curassavicum L., *Justicia squarrosa* Griseb, *Scoparia montevidensis* Spreng and S*enecio* sp. formed group II. *S. montevidensis* showed a potential of cover, for the reason that had reached 100% at day 114, as some species from group I. In spite of this, these group II materials had reduced their coverage slightly to 0% at the beginning of lower temperatures. It was the same situation for *J. squarrosa*, which showed a 75% coverage at day 142; however, it species completed disappeared during early autumn. *H. curassavicum* also showed coverage variations. During the period of higher temperatures, a marked water stress was observed in its leaves, almost disappearing; however, due to its rhizome system, *H. curassavicum* was competent to restore quickly. *Senecio* sp. reached 60% coverage after 275 days, but most of the period it was below to 50%. Group III included very slow-growing species (< 45%) (*Hysterionica jasionoides* Willd, *Sisyrinchium* sp., *Adesmia* sp., *Nama undulatum* Kunth and *Schizachyrium condensatum* (Kunth) Nees. *H. jasionoides* and *Sisyrinchium* sp. had reached 20% and 33% coverage respectively at the end of the trial. Finally, *S. condensatum*, *N. undulatum* and *Adesmia* sp. had never scoped a coverage superior to 25%.

The best materials, (the species of group I) were analyzed with growth models (Figs. 2A-E). The adjusted curves of these models showed the velocity on plant cover to points of interest such 60% or GCA maximum and cover variations over time. Each graphic showed a cut line at 60 percent of green coverage area reached by each species. To *S. acre* the greatest adjust model was a three-segment one.



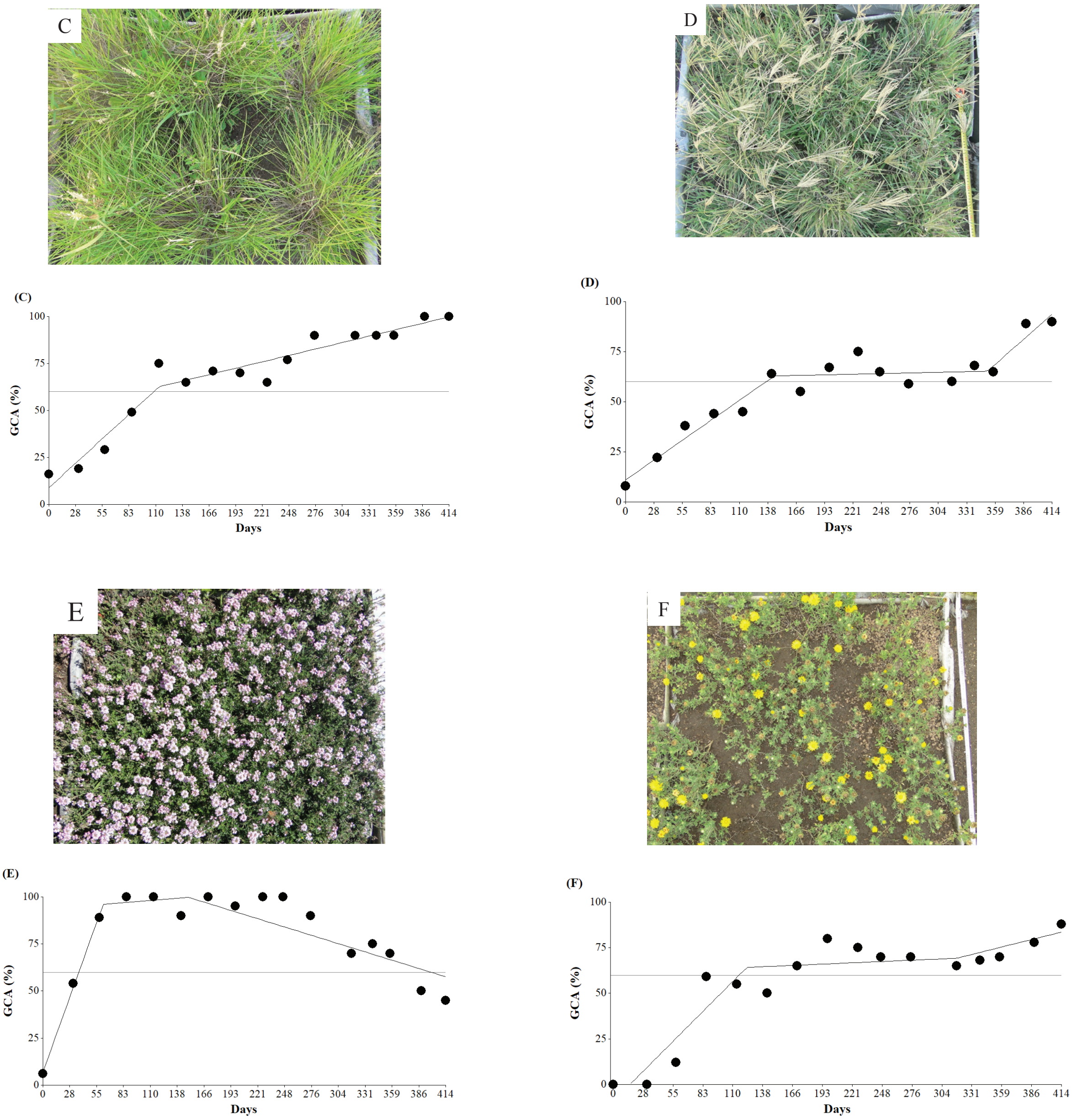


Figure 1. Photographs of the best materials on their full cover stage. Below each photograph, a graphic showing their adjusted growth (not linear models) for each species of Group I over 414 days of assessment. A) *Sedum acre* L.; B) *Phyla nodiflora* (L.) Greene.; C) *Melica macra* Nees.; D) *Eustachys retusa* (Lag.) Kunth. E) *Glandularia* x *hybrid*; F) *Grindelia cabrerae* Ariza*.* Cut lines at 60% of green coverage (GCA) showed the number of days in which this percentage was reached for each species. Photographs: Cáceres, N. (2017)

There was observed minimal disturbances suffered on winter o caused by the herby attack. *P. nodiflora*, *G.* x *hybrid*, *E. retusa*, and *G. cabrerae* likewise showed three-segment models, on which for each species there was observed how the green area grow, stabilized and finally went up or down respectively. The low values on coverage are the result of the moment in which the species was dormant, losing part of its green cover, but in the growing season, either by sprout or by natural reseeding, these values increased again. *Melica macra*, showed a two-segment growth model, showing a rising growth to end of the study.

Survival and Health Status

At the end of the study plant survival rates were differentiated on: 1) Species with high survival: *S. acre*, *G. cabrerae*, *H. jasionoides*, *M. macra*, *P. nodiflora*; 2) Species with an increase on population: *Bulbostylis* sp., *E. retusa*, *Sisyrinchium* sp., *G.* x *hybrid*, and *Senecio* sp.; 3) Reseeding species but that also showed a high rate of mortality: *S. montevidensis*, *Adesmia* sp., *H. curassavicum*, *N. undulatum*; 4) Species whose population was maintained constant but was substantially reduced until die: *S. condensatum*.

Outstanding health status ranges were the flowering period and the reseeding capacity. A highlighted case was the full blooming showed by *E. retusa*, which enriched its potential for reseeding. This species showed an increment on coverage and high seed production and viability. *G.* x *hybrid* had progressively reduced its coverage to less than 50%, although it reemerged because of its ability for reseeding, and reached a coverage superior to 60% after the end of the period. Reseeding process could guaranty perpetuation of the species over time. It is essential to point out that not in all the cases under study, high or low coverage values did always correspond with an optimal or not optimal survival rates and/or a high health status value. For example, *Sisyrinchium* sp. and *H. jasionoides*, both had shown an increment on its population and a full blooming period but a very slow growth (Table 3).

Table 3. Species survival percentage (S %) and health status (HS) under extensive green roof conditions after 414 days of the experimental trial. In the HS column, the number of months (mode value) is indicated for each species.

Species	S (%)	HS (Mode value and Season)	Reseeding* (O/ NO)
Sedum acre L.	100	5 (Spring-Summer)	NO
Glandularia x *hybrid*	25	5 (Spring-Summer)	O
Phyla nodiflora (L.) Greene.	80	5 (Spring-Summer)	NO
Eustachys retusa (Lag.) Kunth.	100	5 (All seasons)	O
Melica macra Nees.	100	4 (Summer)	NO
Grindelia cabrerae Ariza cabrerae	80	5 (All seasons)	O
Scoparia montevidensis Spreng.	0	4 2 (Spring-Summer-Autumn)	NO
Bulbostylis sp.	100	4 2 (Spring)	NO
Justicia squarrosa Griseb.	0	5 1 (Spring- Summer- Autumn)	O
Senecio sp.	15	4 3 (Autumn-Spring)	O
Heliotropium curassavicum L.	25	4 2 (Spring)	O
Hysterionica. jasionoides Willd.	60	5 3 (All seasons)	NO
Sisyrinchium sp.	40	5 (Spring-Summer)	O
Nama undulatum Kunth.	0	3 (Spring)	O
Adesmia sp.	0	5 (Spring-Summer)	O
Schizachyrium condensatum (Kunth.) Nees.	0	3 (Late summer)	NO

*Reseeding: O=Observed reseeding, NO: Not observed reseeding.

In a specific moment of the assessment, *S. acre* showed changes on leaves color as a consequence of low temperatures or high humidity conditions, and as well had suffered interspecific relationships like herbivory. Another example was the case of *M. macra*, which showed high potential for fire hazards, as a result of dry matter accumulation.

4. DISCUSSION

In the current study, plant selection was looked on species that complied some potential traits to be used under green roofs for semiarid conditions. Following outlines of the habitat template hypothesis proposed by LUNDHOLM (2006), different creeping crassulaceas, creeping herbaceous, upright forbs and grasses form were collected, characterized, evaluated and selected. The analysis of the green coverage showed that the control, had reached 100% after three months of establishment, being consistent this result with those exposed by DURHAMN et al. (2004); but, for MONTERUSSO et al. (2005), *S. acre* showed full coverage a year later from the establishment. SENDO et al. (2010), had also evaluated the coverage performance for ten ornamental species for a period of five months in Kobe (Japan). These results showed that only three species reached a coverage superior to 60% (*Thymus* sp.; *Evolvulus* sp.; *Verbena* sp., with 90%; 65%; 60% respectively) to the end of the period assessed. If we compared these results with the best performers at the end of our essay (Córdoba, Argentina) four different life form species had reached coverage major to 80% (*Melica macra*, *Phyla nodiflora*, *Eustachys retusa*, and *Grindelia cabrerae*).

In terms of survival rates, grasses had shown the best survival at the end of the study. Three of the four kinds of grass we had tested in this research had reached a 100% of survival. Results that are consistent with those materials proved for SCHNEIDER et al. (2014), where six of the eight graminoids evaluated showed not any mortality; instead of having a good behavior on the green roof, these type of plants are still ignored worldwide (BOUSSELOT et al., 2010). At the other end, *Adesmia* sp., *Nama undulatum*, *Scoparia montevidensis*, and *Justicia squarrosa* had shown mortality from earlier autumn and winter period in this study; as the same Monterusso et al. (2005), in Michigan found that half of the species tested suffer high mortality rates at the same growing season. Last, as KAZEMI and MOHORKO (2017) affirmed, *Eustachys retusa*, was the species with more new seedlings found, and although having a slow growth that finally reached a 90% of green cover on the essay, that contributes to guaranty the perpetuation overtime of the roof green layer, factor that is condition by a good plant sanitary status.

Based on the results exposed and betting on the low maintenance of semiarid green roof systems, a series of premises are suggesting when choosing the right plant species to be implemented in EGR. If we are looking to achieve a fast and sustainable coverage over time, species more tentative in order of growth are *Sedum acre*, *Phyla nodiflora*, *Glandularia x hybrid*, *Eustachys retusa*, *Grindelia cabrerae*, *Melica macra*, *and Bulbostylis* sp.; just like if what the aim of the roof is to be self-regulated, where species with reseeding ability will be the more appropriate. Species with this property are *Eustachys retusa*, *Scoparia montevidensis*, *Nama undulatum*, *Senecio* sp., *Sisyrinchium* sp. On the other hand, if the purpose of the roofscaping is particularly aesthetic and species with a long bloom period is look the species with the best performance are these ones. *Grindelia cabrerae*, besides of bringing an optimal cover showed full bloom, even when temperatures got down, *Phyla nodiflora*, *Glandularia* x *hybrid*, *Scoparia montevidensis*, *Heliotropium curassavicum* also had a long a high flowering, mostly at springtime. On the other hand, for species that had not a rapid expansion or have a slow growth, they could be employed in combined groups because of their resistant to drought. *Sisyrinchium* sp. alternatively, even some species could be employed on summer season or winter season, for example, *Hysterionica jasionoides*, and *Senecio* sp. respectively.

Understanding their growing dynamics, based on the adjustment of different growth models, was a key tool for the selection of suitable species for semiarid roofscaping conditions.

5. CONCLUSIONS

Our main results showed that there exist a great potential of native germplasm for green roofs conditions in a semiarid region. Particularly and when combining the response variables, *Phyla nodiflora*, *Grindelia cabrerae*, *Eustachys retusa* and *Glandularia* x *hybrid* can be highlighted because they presented higher coverages, survival rates and optimal health status all year round. Moreover, *Scoparia montevidensis* and *Heliotropium curassavicum* showed excellent results during shorter periods (spring-summer) but with reseeding capability. Finally, some creeping herbaceous materials (*Phyla nodiflora* and *Glandularia* x *hybrid*) reached full cover before the control species (*Sedum acre*). Further investigations can combine species using the best materials over longer periods, registering successional events on green roofs and relating them to ecosystem services for urban landscapes of semiarid regions.

ACKNOWLEDGMENTS

We thank two anonymous reviewers for useful suggestions and comments on early versions of the manuscript; IRNASUS (UCC-CONICET), Mincyt Córdoba, SECyT (UNC), CONICET and FONCyT for financial support. NC is a fellowship holder by CONICET; LI and LG are researchers at CONICET.

AUTHOR CONTRIBUTION

N.C. 0000-0001-8687-5104: was responsible of collecting the plant materials, the design and construction of the essay, the data collection, the analysis and interpretation of data, writing and discussion of the report and for the paper submission. **L.I.** 0000-0002-6850-5502: was responsible of found the economic resources, the design of the essay, on the interpretation of data, writing and discussion of the report. **M.S.** 0000-0002-5519-2359 and **E.H.** 0000-0002-2093-3540: were responsible of design of the essay, the construction of the trial and interpretation of data. **L.G.** 0000-0003-3828-657X: was responsible of found the economic resources the design of the essay, the interpretation of data, writing and discussion of the report.

REFERENCES

ARABI, R.; SHAHIDAN, M.F.; MUSFATA KAMAL, M.S.; JA´AFER, M.F.Z.B.; RAKHSHANDEHROO, M. Consideration for plant selection in green roofs. **Universiti Putra Malaysia. Alam Cipta**, v.8, n.3, p.10-17, 2015.

BEICHLER, S.; BASTIAN, O.; HAASE, D.; HEILAND, S.; KABISCH, N.; MÜLLER, F. Does the ecosystem service concept reach its limits in urban environments? **Landscape Online**, v.57, p.1-21, 2017. DOI: http://dx.doi.org/10.3097/LO.201751

BOIVIN, M.A.; LAMY, M.P.; GOSSELIN, A.; DANSEREAU, B. Effect of artificial substrate depth on freezing injury of six herbaceous perennials grown in a green roof system. **Hort Technology**, v.11, n.3, p.409-412, 2001.

BUTLER, C.; BUTLER, E.; ORIANS, C.M. Native plant enthusiasm reaches new heights: Perceptions, evidence, and the future of green roofs. **Urban Forestry and Urban Planning**, v.11, p.1-10, 2012. DOI: http://dx.doi.org/10.1016/j.ufug.2011.11.002

CABIDO, M. Las comunidades vegetales de la Pampa de Achala. Sierras de Córdoba, Argentina. **Documents Phytosociologiques**, v.9, p.431-443, 1985.

CANTOR, S.L.; PECK, S. **Green roofs in sustainable landscape design**. New York: W.W. Norton and Company, 2008. 320p.

DI RENZO, J.; CASANOVES, F.; BALZARINI, M.; GONZÁLEZ, L.; TABLADA, M.; ROBLEDO, Y.C. **Infostat versión 2011**. Córdoba: Grupo Infostat, FCA, Universidad Nacional de Córdoba, 2001. v.8, p.195-199.

DURHMAN, A.K.; VAN WOERT, N.D.; ROWE, D.B.; RUGH, C.L.; EBERT-MAY, D. Evaluation of Crassulaceae species on extensive green roofs, In Proc. 2nd North American Green Roof Conference: Greening Rooftops for Sustainable Communities, Portland, OR. The Cardinal Group, Toronto. p.504-517, 2004.

DUSZA, Y.; BAROT, S.; KRAEPIEL, Y.; LATA, J.C.; ABBADIE, L.; RAYNAUD, X. Multifunctionality is affected by interactions between green. **Ecology and Evolution**, v.7, p.2357-2369, 2016. DOI: http://dx.doi.org/10.1002/ece3.2691

DVORAK, B.D.; VOLDER, A. Plant establishment on unirrigated green roof modules in a subtropical climate. **AoB Plants**, v.5, n.1, psl049, 2010. DOI: http://dx.doi.org/10.1093/aobpla/pls049

EMILSSON, T.; ROLF, K. Comparison of establishment methods for extensive green roofs in southern Sweden. **Urban Forestry and Urban Greening**, v.3, p.103-111, 2005. DOI: https://doi.org/10.1016/j.ufug.2004.07.001

FRANCIS, R.A.; LORIMER, J. Urban reconciliation ecology: The potential of living roofs and walls. **Journal of environment management**, v.92, p.1429-1437, 2011. DOI: https://doi.org/10.1016/j.jenvman.2011.01.012

GETTER, K.L.; ROWE, D.B. The role of extensive green roofs in sustainable development. **HortScience**, v.41, n.5, p.1276-1285, 2006.

GIORGIS, M.; CINGOLANI, A.; CHIARINI, F.; CHIAPELLA, J.; BARBOZA, G.; ARIZA ESPINAR, L.; MORERO, R.; GURVICH, D.; TECCO, P.; SUBILIS, R.; CABIDO, M. Composición florística del Bosque Chaqueño Serrano de la provincia de Córdoba, Argentina. **Kurtziana**, v.36, p.9-43, 2011.

JANSSON, A. Reaching for a sustainable, resilient urban future using the lens of ecosystem services. **Ecological Economics**, v.86, p.285-291, 2013. DOI: https://doi.org/10.1016/j.ecolecon.2012.06.013

KAZEMI, F.; MOHORKO, R. Review on the roles and effects of growing media on plant performance in green roofs in world climates. **Urban Forestry and Urban Greening**, v.23, p.13-26, 2017. DOI: https://doi.org/10.1016/j.ufug.2017.02.006

Landschaftsbau,ForschungsellschaftLandschaftsentwicklung. 2008. **Introduction to the FLL: guidlines for the planning, construction and maintenance of green roofing**. Available in: http://www.greenrooftechnology.com/_literature_98993/Introduction_to_the_German_FLL-Guideline_for_the_Planning,_Execution,_and_Maintenance_of_Green-Roof_. Acessed on 7th November 2018.

LI, W.C.; YEUNG, K.K.A. A comprehensive study of green roof performance from environmental perspective. **International Journal of Sustainable Built Environment**, v.3, p.127-134, 2014. DOI: https://doi.org/10.1016/j.ijsbe.2014.05.001

LUEDERITZ, C.; BRINK, E.; GRALLA, F.; HERMELINGMEIER, V.; MEYER, M.; NIVEN, L.; PANZER, L.; PARTELOW, S.; RAU, A.L.; SASAKI, R.; ABSON, D.J.; LANG, D.J.; WAMSLER, C.; VON WEHRDEN, H. A review of urban ecosystem services: six key challenges for future research. **Ecosystem Services**, v.4, p.98-112, 2015. DOI: http://dx.doi.org/10.1016/j.ecoser.2015.05.001

LUNDHOLM, J. The ecology and evolution of constructed ecosystems as green infrastructure. **Frontiers in Ecology and Evolution**, v.3, n.106, p.1-7, 2015a. DOI: http://dx.doi.org/10.3389/fevo.2015.00106

LUNDHOLM, J.; MACIVOR, S.; MAC DOUGALL, Z.; RANALLI, M. Plant species and functional group combinations affect green roof ecosystem functions. **PlosOne**, v.5, n.3, p.1-11, 2010. DOI: http://dx.doi.org/10.1371/journal.pone.0009677

LUNDHOLM, J.; TRAN, S.; GEBER, L. Plant functional traits predict green roof ecosystem services. **Environmental Science and Technology**, v.49, n.4, p.2366-2374, 2015b. DOI: http://dx.doi.org/10.1021/es505426z

LUNDHOLM, J.T. Green roofs and facades: a habitat template approach. **Urban Habitat**, v.4, n.1, p.87-101, 2006.

MARTIN, M.A**. Native Plant Performance on a Seattle Green Roof**. Master of Science. Seattle: University of Washington, v.1, n.4, 2007.

MONTERUSSO, M.; ROWE, D.B., CLAYTON, R. Establishment and persistence of Sedum spp. and native taxa for green roof applications. **HortScience**, v.40, n.2, p.391-396, 2005.

NAGASE, A.; TASHIRO-ISHII, Y. Habitat template approach for green roofs using a native rocky seacoast plant community in Japan. **Journal of Environmental Management**, v.206, p.255-265, 2018. DOI: https://doi.org/10.1016/j.jenvman.2017.10.001

NOYA, M.G.; CUQUEL, F.L.; SCHAFER, G.; ARMINDO, R.A. Substrates for cultivating herbaceous perennial plants in extensive green roofs. **Ecological Engineering**, v.102, p.662-669, 2017. DOI: http://dx.doi.org/10.1016/j.ecoleng.2017.02.042

PALLA, A.; GNECCO, I.; LANZA, L.G. Hydrologic restoration in the urban environment using green roofs. **Water**, v.2, p.140-154, 2010. DOI: https://doi.org/10.3390/w2020140

PROVENZANO, M.E.; CARDARELLI, M.; SACCARDO, F.; COLLA, G.; BATTISTELLI, A.; PROIETTI, S. Evaluation of perennial herbaceous Species for their potential use in a green roof under Mediterranean climate conditions. **Acta Horticulturae**, v.881, p.611-668, 2010. DOI: https://doi.org/10.17660/ActaHortic.2010.881.109

RAZZAGHMANESH, M.; BEECHAM, S.; KAZEMI, F. The growth and survival of plants in urban green roofs in a dry climate. **Science of the Total Environment**, v.476, p.288-297, 2014b. DOI: https://doi.org/10.1016/j.scitotenv.2014.01.014

RAZZAGHMANESH, M.; BEECHMAN, S.; BRIEN, C.J. Developing resilient green roofs in a dry climate. **Science of the Total Environment**, 490, 579-589, 2014a. DOI: https://doi.org/10.1016/j.scitotenv.2014.05.040

SENDO, T.; KANECHI, M.; UNO, Y.; INAGAKI, N. Evaluation of growth and green coverage of ten ornamental species for planting as urban rooftop greening. **Journal of the Japanese Society for Horticultural Science**, v.79, n.1 p.69-76, 2010. DOI: https://doi.org/10.2503/jjshs1.79.69

SCHNEIDER, A.; FUSCO, M.; BOUSSELOT, J. Observations on the survival of 112 plant taxa on a green roof in a semi-arid climate. Journal of Living Architecture, v.1, n.5, p. 10-30, 2014.

SÉRCIC, A.; COCCUCI, A.; DÍAZ, L.; GLINOS, N.; LAZARTE, C.; MEDINA, M.; MORÉ, M.; BARANZELLI, M.; CÓRDOBA, S.; COSACOV, A.; FERREIRO, G.; IBAÑEZ, A.C.; MARINO, S.; MAUBECIN, C.C.; PAIARO, V.; RENNY, M.; SASARTONIL, F.; SOSA PIVATO, M.; SOTERAS, F.; STRELIN, M.; TRUJILLO, C.; WIEMER, A.P. **Flores del centro de Argentina II: Nueva Guía Ilustrada para conocer 229 especies**. Córdoba: Instituto Multidisciplinario de Biología Vegetal, 2015. 28p.

SUTTON, R.K. **Introduction to Green Roof Ecosystems**. Ecological Studies 223. Cham: Springer International Publishing, 2015. 447p.

THURING, C.E.; DUNNETT, N. Vegetation composition of old extensive green roofs (from 1980s Germany). **Ecological Processes**, v.3, n.4, p.1-11, 2014. DOI: https://doi.org/10.1186/2192-1709-3-4

VAN-MECHELEN, C.; DUTOIT, T.; HERMY, M. Mediterranean open habitat vegetation offers great potential for extensive green roof design. **Landscape and Urban Planning**, v.121, p.81-91, 2014a. DOI: http://dx.doi.org/10.1016/j.landurbplan.2013.09.010

VAN-MECHELEN, C.; DUTOIT, T.; KATTGE, J.; HERMY, M. Plant trait analysis delivers an extensive list of potential green roof species for Mediterranean France. **Ecological Engineering**, v.67, p.48-59, 2014b. DOI: http://dx.doi.org/10.1016/j.ecoleng.2014.03.043

VAN MECHELEN, C.; DUTOIT, T.; HERMY, M. Adapting green roof irrigation practices for a sustainable future: a review. Sustainable Cities and Society, v.19, p.74-90, 2015. DOI: http://dx.doi.org/10.1016/j.scs.2015.07.007