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ARTICLE

Adaptability of different plant species on an extensive green roof

Adaptabilidade de diferentes espécies de plantas em um telhado verde extensivo

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Abstract: Plant species used on green roofs in Brazil are of predominantly exotic origin, which is at variance with the diversity of plants available naturally in the country. This study aims to evaluate the development and adaptation of different species of the flora of the state of Rio Grande do Sul, Brazil, using the extensive green roof system in the presence and absence of irrigation. Eight treatments were carried out using three species native (*Alternanthera hirtula, Angelonia integerrima* and *Dyckia hebdingii*) and one exotic species (*Aptenia cordifolia*), which had their development evaluated in the presence and absence of irrigation. Monthly evaluations were carried out over twelve months to assess height, vegetation cover, maintenance of aerial vegetation, visual aspect of plants, shoot dry matter, and root dry matter. For *Dyckia hebdingii* and *Aptenia cordifolia*, the height showed a linear growth independent from the irrigation regime and a decrease in temperature in colder seasons. *A. hirtula* and *A. integralerrima* presented oscillation in height increase influenced by environmental temperature conditions. The same behavior was observed for vegetation cover. For most of the time, all species maintained an adequate visual aspect, except for the period when *A. hirtula* and *A. integerrima* entered senescence. For shoot and root dry matter, only *A. hirtula* showed higher values when irrigated among the native species tested. It is concluded that the different species of native flora of the state of Rio Grande do Sul tested have a potential for use on extensive green roofs without the need for irrigation under the conditions in which the present work was developed.
Keywords: green cover, irrigation, native species.

Resumo: As espécies de plantas utilizadas em telhados verdes no Brasil são de origem, predominantemente, exóticas, o que é discordante com a diversidade de plantas disponíveis naturalmente no país. Este estudo teve como objetivo avaliar o desenvolvimento e a adaptação de diferentes espécies da flora do estado do Rio Grande do Sul submetidas ao sistema de telhado verde extensivo, na presença e ausência de irrigação. Foram realizados oito tratamentos a partir de três espécies nativas do estado do Rio Grande do Sul (*Alternanthera hirtula, Angelonia integerrima* e *Dyckia hebdingii*) e uma espécie exótica (*Aptenia cordifolia*), as quais tiveram seu desenvolvimento avaliado na presença e ausência de irrigação. Foram realizadas avaliações mensais ao longo de doze meses para altura, cobertura vegetal, manutenção da vegetação aérea, aspecto visual de plantas, matéria seca da parte aérea e raízes. Para *Dyckia hebdingii* e *Aptenia cordifolia* a altura apresentou crescimento linear independente do regime de irrigação, e da diminuição da temperatura nas estações mais frias. Já *A. hirtula* e *A. integerrima* apresentaram oscilação do aumento de altura influenciada pelas condições ambientais de temperatura, o mesmo comportamento foi observado para cobertura vegetal. Durante a maior parte do tempo, todas as espécies mantiveram aspecto visual adequado, com exceção do período em que *A. hirtula* e *A. integerrima* entraram em senescência. Para massa seca da parte aérea e de raízes, apenas *A. hirtula,* entre as espécies nativas testadas, apresentou valores superiores quando irrigada. Conclui-se que as diferentes espécies da flora nativa do estado do Rio Grande do Sul testadas apresentam potencial para uso em telhados verdes extensivos sem necessidade de irrigação nas condições em que foi desenvolvido o presente trabalho.
Palavras-chave: cobertura verde, espécies nativas, irrigação.

Introduction

Green roofs, also called live roofs or ecological cover, are characterized as any roof that has a layer of substrate and another layer of vegetation. They can provide several benefits to urban areas in terms of aesthetic and environmental aspects (Besir and Cuce, 2018), such as rainwater retention, which can be approximately 53% (Arboit, et al., 2021) and thermal stress attenuation decreases the time of exposure of thermal conditions regarding hazardous and extreme danger conditions from 17.3% to 5.4% (Feitosa, 2019).

Extensive roofs are an ecological cover characterized by the lightness of the system, the low maintenance, the use of small species planted in a substrate at a depth of less than 20 cm, and because they do not necessarily require a coupled irrigation system (Green Roof Organization, 2021; Besir and Cuce, 2018, Shafique et al., 2018).

Considering the stress conditions that characterize the extensive green roof system, mainly due to the reduced volume of substrate, the choice of species to be used is of fundamental importance since the good development and the good appearance of a green roof will be determined by the species chosen, guaranteeing the environmental services proposed by this technology (Green Roof Organization, 2021).

In general, the species used under green roofs have a low growth and drought tolerance and are represented mainly by different species of *Sedum* (Cáceres et al., 2018). However, there is a growing interest in increasing the diversity of species, especially native species, due to aesthetic, environmental and ecophysiological characteristics, which could result in a greater adaptability and a less demand for resources and maintenance (Calviño et al., 2023, Chell et al., 2022, Cáceres et al., 2018).

Currently, plant species used on green roofs in Brazil are of predominantly exotic origin, which is at variance with the diversity of plants available naturally in the country. Brazilian plant biodiversity is rich and abundant, which classifies Brazil as the main holder of the planet's megadiversity, with almost 20,000 endemic species (BFG, 2021) and being the most catalogued new species in the world since 2008 (Cheek et al., 2020)

The Rio Grande do Sul State has two biomes, the Pampa and the Mata Atlântica, with distinct floristic and structural characteristics and a great diversity of species. The Pampa has approximately 1,685 species of plants, while the Atlantic Forest has more than 15,000 plant species. In both biomes, there is a predominance of herbaceous species (The Brazilian Flora Group, 2015), whose size and ecophysiological characteristics can be promising for use on green roofs.

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In this sense, many species adapt to reduce the loss of water to the environment and withstand situations of water restriction, such as the presence of trichomes, waxes and waterproofing oils, thick leaves and/or reduced size, presence of rhizomes, xylopodia and tuberous roots, which allow survival and favor a fast regeneration in situations of stress or environmental disturbance (Bencke, 2016).

In general, irrigation is necessary for the initial establishment of green roofs for six to eight weeks. In the case of extensive systems, its use should be avoided. However, this management depends on the water storage capacity of the culture medium, the local rainfall patterns, and the species selected (Green Roof Organization, 2021).

This study aims to evaluate the development and adaptation of different species of the flora of the state of Rio Grande do Sul using the extensive green roof system in the presence and absence of irrigation.

Materials and methods

This study was conducted at the Faculty of Agronomy, Horticulture and Forestry Department at the Federal University of Rio Grande do Sul (-30°04'13,52"S -51°08'23,23"W), located in the city of Porto Alegre, Rio Grande do Sul State, Brazil. The climate is Cfa (humid temperate climate with hot summers), according to the Köppen-Geiger climate classification.

The experiment started on November 20, 2017 and ended on November 22, 2018, totaling 367 days. The experimental design was randomized blocks with subdivided plots and four replications. The plot was composed by the presence or absence of irrigation and the subplot by the selected species.

For the experiment, four species were used, three of which are native species to the flora of Rio Grande do Sul with ornamental potential (*Alternanthera hirtula* (Mart.) R. E. Fr., *Angelonia integerrima* Spreng., *Dyckia hebdingii* L. B. Sm.), and the fourth (*Aptenia cordifolia* (L. f.) Schwantes) is an exotic species usually used in green roofs in Brazil (Fig. 1). The four species were combined with the irrigation factor (with and without irrigation), totaling eight treatments.

Fig. 1. Species studied. Images of plants in the green roof system: (A) *Alternanthera hirtula*, (B) *Angelonia integerrima*, (C) *Dyckia hebdingii* and (D) *Aptenia cordifolia*.

To carry out the experiment, prototypes of green wooden roofs were constructed and covered with a 0.5 cm thick fiber cement tile (Figure 2). The prototypes had dimensions of 1.40 x 2.40 m, 1.20 m above the ground and 6% slope. Above the fiber cement tile, wooden boxes were built to divide the experimental plots into dimensions of 0.70 x 0.60 m and 0.30 m high. Once ready, the waterproofing layers (75-micron transparent plastic canvas), filtering material (geotextile blanket), substrate, and plants were placed in each box simulating the constitution of a green roof system.

Fig. 2. Illustrations of the prototype built to receive the next layers of the green roof system are shown and after installation. In (A), the base of the structure is depicted; in (B), the base is shown after receiving the fiber cement tile; in (C), the prototype with a box is illustrated; in (D), the prototype is depicted already installed and filled with pine bark substrate; in (E), one of the blocks with developed plants is shown. Subsequently, (E.1) shows the drip irrigation system, and (E.2) shows the block without an irrigation system.

As a substrate, a commercial mixture based on composted pine bark was used. It has a dry density of 448 Kg m^{-3}, substrate water content of 45%, total porosity of 60%, electrical conductivity (1:5) of 0.50 dS m^{-1} and pH 5.5 (water). The substrate layer was 0.12 m high and each plot was 50.4 L.

At the time of implementation of the experiment, 5 g L^{-1} of controlled release fertilizer (15% total N, 8% de P_2O_5, 12% de K_2O, 2% MgO, 12% SO_3, 0,02% B, 0,05% Cu, 0,4% Fe, 0,06% Mn, 0,015% Mo and 0,02% Zn, with granulometry of 2.5 to 3.5 mm and effective duration of 12 months), were manually mixed in the substrate.

The seedlings of *A. hirtula* and *A. integerrima* were obtained by vegetative propagation by cutting roots and stems, respectively, while plants of *D. hebdingii* were obtained by *in vitro* sexual propagation. The seedlings of *A. cordifolia*, on the other hand, were purchased from the local trade specialized in ornamental plants.

For all species, there was a period of acclimatization before installation on the green roof structure. During the acclimatization period, all species received manual irrigation and were fertilized fortnightly with a nutrient solution containing calcium nitrate (1 g L^{-1}) and N-P-K 6-12-36 (4 g L^{-1}) formulation at a dose of 20 mL per plant.

The planting of the seedlings in the prototype of the green roof system was carried out, respecting a final stand of 19 plants per square meter, which resulted in the planting of eight seedlings in each plot (0.70 x 0.60 m). After planting and up to seven days later, manual irrigation with a garden hose was conducted in all plots to favor the survival of the seedlings.

In the treatments with the presence of irrigation a localized drip irrigation system was installed, using drip tape, with a spacing between drippers of 0.10 m in lines and 0.20 m between lines. In the spring and summer, the irrigation system was activated three times a day for 10 min each time; in the autumn and winter, irrigation was reduced to twice a day at the same time interval. The irrigation depth used was 2.1 mm day^{-1} and 1.4 mm day^{-1}, respectively.

The control of spontaneous plants was performed manually monthly by removing the unwanted species. In addition, during the execution of the experiment, there was a need for a cleaning pruning for *A. hirtula* and *A. integerrima*, which grew in the winter period (July). This practice was carried out by removing all dry branches and structures in senescence, leaving only new shoots.

The prototypes were allocated outdoors in an environment with an average of eight hours of daylight facing Northeastern. Table 1 contains climate data obtained from an automatic surface weather station in Porto Alegre city, located at latitude -30 ° 05'35.36"S and longitude -51°17'47.66W", distancing 3.7 km of the experiment.

Table 1. Minimum temperature (Tmin), maximum temperature (TMax), relative humidity (RH) and total accumulated rainfall (TAR) data obtained from INMET's agroclimatic bulletin maps for the months of this study, in addition to the climatological normal for total accumulated rainfalls (CNTAR) in the city of Porto Alegre, RS.

Year	Month	TMin. (°C)	TMax. (°C)	RH (%)	TAR (mm)	CNTAR (mm)
2017	November	16-20	28-32	70-80	150-200	110.9
2017	December	16-20	28-32	80-90	150-200	99.6
2018	January	16-20	28-32	80-90	150-200	110.1
2018	February	16-20	28-32	80-90	120-150	106.5
2018	March	16-20	28-32	80-90	120-150	92.2
2018	April	16-20	28-32	80-90	120-150	107.3
2018	May	13-16	20-24	80-90	90-120	118.8
2018	June	5-7	16-20	90-100	150-200	141.3
2018	July	5-7	16-20	90-100	200-250	141.3
2018	August	5-7	16-20	80-90	120-150	117.4
2018	September	13-16	20-24	80-90	200-250	141.5
2018	October	13-16	20-24	80-90	150-200	138.3
2018	November	13-16	28-32	80-90	150-200	110.9

Source: Adapted from INMET, 2023.

Monthly evaluations of plant height, vegetation cover, maintenance of aerial vegetation, visual aspect of plants was performed. For the exotic species (*A. cordifolia*), the evaluations were performed until 100% coverage area were filled in all replicates. This decision was made because it is a species with a fast development and a perennial cycle, that is, after its establishment, the species remained with a permanent green cover.

The height of plants was verified using a millimeter ruler measuring from the base of the plant to the stem apex. The maintenance of aerial vegetation was visually verified by counting plants with apparent leaf area above the substrate.

For the evaluation of vegetation cover, photos of each replication were taken monthly. At the end of the experiment, plants had their coverage quantified by dividing them into four quadrants. For each quadrant, values between 0 and 25 were assigned (only numbers multiple of five) and, subsequently, the values of the four quadrants were summed, thus determining the final value.

For the evaluation of the visual aspect of plants, a rating system was adopted indicating the occurrence of diseases and pests and whether the species respects its development pattern (Table 2).

Table 2. Description of the scores used in the qualitative analysis of a set of green roofs to evaluate the aspect of plants.

Score	Description
1	Plant intensely attacked by pests and diseases and/or senescent; lousy appearance.
2	Plant attacked by pests and diseases and/or dry branches; bad appearance.
3	Plant with some symptoms of attack by pests and/or diseases; good appearance.
4	Plant without signs of pests and diseases; great appearance.

Twelve months after the installation of the experiment, the shoot and root dry matter were measured. For this, the plants were first separated into shoots (leaves, stems and flowers) and root system, washed under running water, and then placed in an oven with forced air circulation at 65±2 ºC until they reached constant mass.

The data obtained in the evaluations were subjected to analysis of variance by F test and, subsequently, analyzed by polynomial regression and by DMS test at 5% probability of error using the software Costat 6.4 and SigmaPlot 11.0.

Results and discussion

For the final evaluation carried out one year after starting the experiment, interaction between the species and the presence or absence of irrigation was verified only in shoot and root dry matter evaluations. However, when the variables were analyzed over time, differences were found for height, vegetation cover, maintenance of aerial vegetation, and visual aspect of plants.

All species grew in height over time (Figure 2), but there was variation in the behavior of this analysis due to anatomical differences and the phenological cycle between species. At 120 days after the start of the experiment, *A. hirtula* was higher than 50 and 40 cm in treatments with and without irrigation, respectively, 20 to 30 cm above that described in the literature (Reflora, 2020). *A. integerrima*, in the same period, showed an average height of 58 and 51 cm in the presence or absence of irrigation, respectively, also above the average of 40 cm reported by the literature (Winhelmann et al., 2018), demonstrating the good development of plants on extensive green roofs. For *Dyckia hebdingii* and *Aptenia cordifolia*, the height showed a linear growth independent from the irrigation regime and a decrease in temperature in colder seasons.

A. Hirtula and *A. integerrima* showed an increase in height until the beginning of the autumn period (120 days). After this period, with the decrease in temperatures, there was a partial senescence of plant shoots, which again increased in height with the beginning of spring and increased temperatures (300 days after installation), corroborating the behavior observed for vegetation cover for these species.

Considering that a good vegetation cover is above 70% (Noya et al., 2017), it appears that *A. cordifolia* was the most efficient, obtaining 70% of vegetation cover 50 days after the beginning of the experiment, reaching 100% of coverage under both irrigation conditions at 150 days, a value that stabilized until the end of the experiment (Figure 3). *D. hebdingii* showed a linear increase, but with a slower coverage speed, while *A. hirtula* and *A. integerrima* had a greater oscillation of this variable, with growth influenced by the decrease in temperature in the autumn and winter (Figure 3).

This fluctuation behavior of the vegetation cover was also observed for the species *Sedum acre* and *Arachis repens* in the city of Curitiba, Brazil. However, A. *repens*, a native species, proved to be more efficient for covering the substrate in subtropical conditions, while *S. acre* was less effective especially in rainy and low-temperature months (Noya et al., 2017).

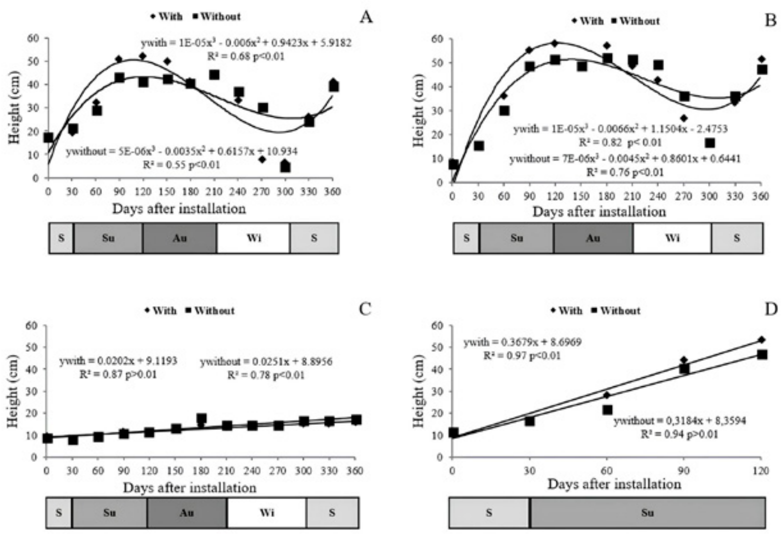

Fig. 3. Height (cm) of the species studied on an extensive green roof with and without irrigation: (A) *Alternanthera hirtula,* (B) *Angelonia integerrima,* (C) *Dyckia hebdingii* (D) e *Aptenia cordifolia.* S: Spring; Su: Summer; Au: Autumn; Wi: Winter.

Species native to arid and semiarid regions of Italy, *Acinos alpinus*, *Sanguisorba minor* and *Thymus serpyllum,* grown on an extensive green roof, had a decrease in vegetation cover in response to increased temperature and decreased water availability. *Festuca ovina* was less influenced by seasonality, with a progressive increase in coverage (D'Arco et al., 2018), as well as that observed for *D. hebdingii* in the present study (Fig. 4).

Also, in the semiarid climate of Argentina species of local flora showed different behaviors when used on extensive green roofs. The species *Phyla nodiflora*, *Glandularia x híbrid*, *Melica macra*, *Eustachys retusa*, *Grindelia cabrerae* and *Bulbostylis* sp. retained 60% coverage throughout the study period regardless of climatic conditions. Other species such as *Scoparia montevidensis* and *Justicia squarrosa*, despite having a good coverage in favorable periods, practically disappeared at the beginning of the cold season. For *Heliotropium curassavicum*, on the contrary, periods of high temperatures were responsible for the partial disappearance of the vegetation cover. However, in this case, the vegetation was quickly restored due to the presence of rhizomes (Cáceres et al., 2018).

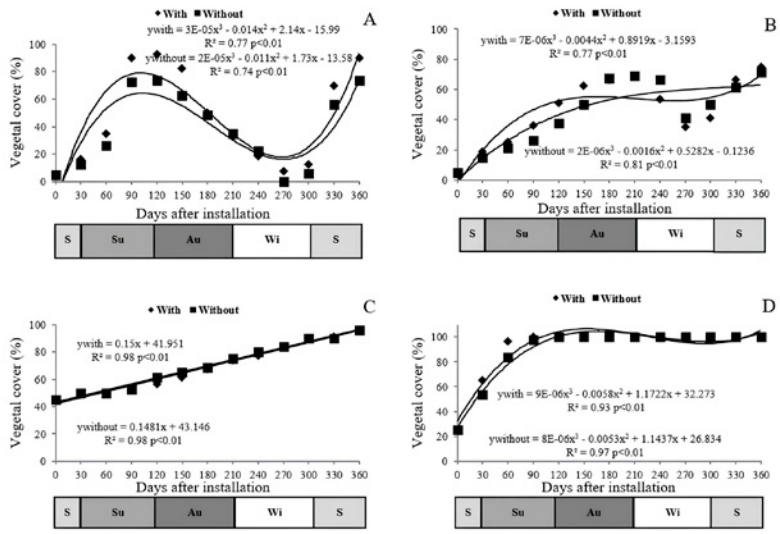

Fig. 4. Vegetal cover (%) of the species studied on an extensive green roof with and without irrigation: (A) *Alternanthera hirtula,* (B) *Angelonia integerrima,* (C) *Dyckia hebdingi* e (D) *Aptenia cordifolia.* S: Spring; Su: Summer; Au: Autumn; Wi: Winter;

This fact may also have occurred in the present work for *A. hirtula* and *A. integerrima*, which showed a tendency to decrease or stabilize, respectively, in cold temperature conditions, increasing the vegetation cover when the conditions were favorable again. Species belonging to the family Amaranthaceae, such as *hirtula*, present a morphology adapted to the seasonality of the climate, with vegetative parts containing a large amount of trichomes, partial or total loss of shoots, and the presence of xylopodium, which allows a fast recovery in case of environmental stress (Marchioretto et al., 2013). *A. integerrima* also have thickened roots that possibly help in the recovery of plants after environmental stresses.

Low mortality, as well as fast establishment and green cover, are desirable characteristics in plants for use on extensive green roofs (Monterusso et al., 2005). In this study, the survival responses were observed by the maintenance of vegetation in shoots, in which the values found were above 80% for all species evaluated regardless of the presence of irrigation (Fig. 5).

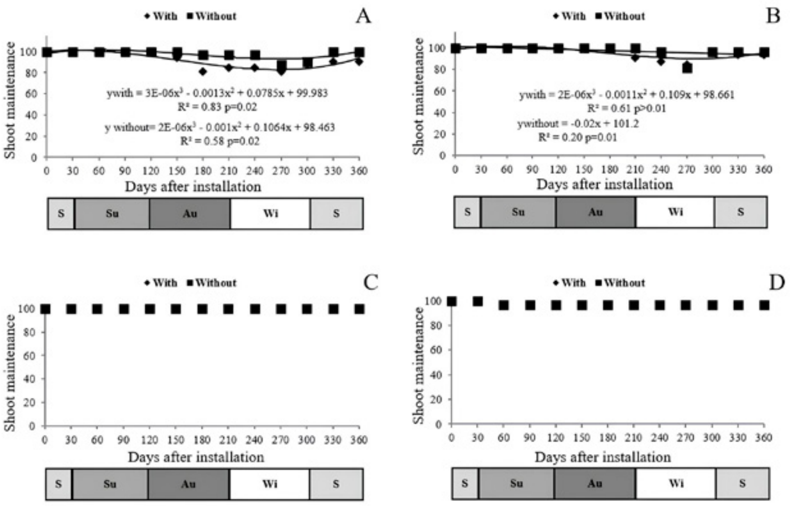

Fig. 5. Shoot maintenance (%) of the species studied on an extensive green roof with and without irrigation: (A) *Alternanthera hirtula,* (B) *Angelonia integerrima,* (C) *Dyckia hebdingii* and (D) *Aptenia cordifolia.* S: Spring; Su: Summer; Au: Autumn; Wi: Winter.

In addition, in case of *A. hirtula*, despite the lower rates of maintenance of shoot vegetation observed among the species evaluated, after 300 days (spring) the species showed the ability to regrowing, as also observed for *A. integrerrima*. *A. cordifolia* showed values greater than 95% during the entire evaluation period and *D. hebdingii* was the species with the greatest prominence for this characteristic, as it maintained 100% of persistence of shoots, that is, 100% of survival.

In this sense, in a research carried out in Nova Scotia, Canada, in a maritime climate with 15 native species of the families Poaceae, Ericaceae, Cyperaceae, Rosaceae, Juncaceae, Asteraceae and Empetraceae, 12 plants showed 100% survival, and ten plants presented more than 90% coverage at the end of the growing season (MacIvor and Lundholm, 2011). These results differ from those observed for some of the native species tested in Argentina, such as *Scoparia montevidensis* and *Schizachyrium condensatum*, which had total mortality and no natural reseeding (Cáceres et al., 2018), thus not showing a regeneration capacity.

In Sheffield, England, in a temperate maritime climate, different irrigation regimes had a significant effect on the survival of herbaceous and grassy species but did not show differences from species of *Sedum*, with a survival greater than 88% even without irrigation for three weeks on extensive green roofs. In addition, the species mix was more advantageous for survival and visual appearance of green roofs compared to the use of a single species (Nagase and Dunnet, 2010).

The proper establishment of vegetation, the maintenance of vegetation cover, the high survival rates and the self-regeneration are important characteristics to achieve the viability of plants over time and boost the functional benefits associated with green roofs. In addition, the selection of a suitable vegetation improves its aesthetic appearance and public acceptance (Cáceres et al., 2018). In this sense, water supplementation may be necessary to keep the vegetation cover alive and healthy, especially when plants other than succulents (Nagase and Dunnett, 2010), more adapted to water deficiency conditions, are used.

The responses of aspect of plants during this study show that all the studied species have potential to be used in extensive green roofs, independent from water supplementation, under the conditions that the present study was developed. In general, the scores were close to the maximum (≥ 3.5) after the vegetation established, configuring an adequate vegetation aspect (Fig. 6). This situation is not recognized only for the period during which the species *A. hirtula* and *A. integerrima* enter senescence (between 180 and 270 days after installation).

Similar results were obtained for *Sedum acre, Glandularia x hybrid*, *Phyla nodiflora, Sisyrinchium* sp. and *Adesmia* sp., which had maximum scores only in spring-summer. The same study reported that *Eustachys retusa* and *Grindelia cabrerae* obtained maximum scores for all seasons in semiarid climate (Cáceres et al., 2018).

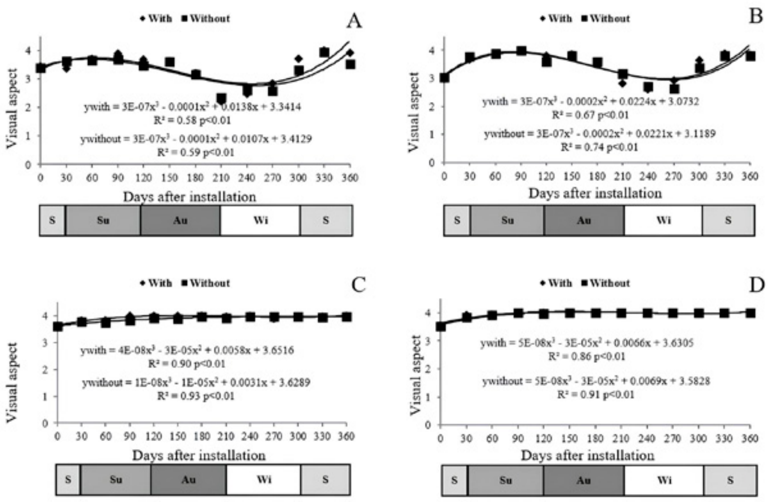

Fig. 6. Visual aspect of the species studied on an extensive green roof with and without irrigation: (A) *Alternanthera hirtula,* (B) *Angelonia integerrima,* (C) *Dyckia hebdingii* and (D) *Aptenia cordifolia.* S: Spring; Su: Summer; Au: Autumn; Wi: Winter.

For shoot and root dry matter, interaction between the species and the presence or absence of irrigation was verified. For shoot and root dry matter, only *A. hirtula* showed higher values when irrigated among the native species tested (Table 3).

According to what is considered by Green Roof Organization (2021), these results can be considered positive since for extensive green roofs, irrigation systems must be avoided whenever vegetation supports this stress, especially when there is a need for application in large areas (Nagase and Dunnett, 2010). This effect can also be due to the high rainfall levels and the homogeneous distribution of rainfalls throughout the year of the experiment evaluation. It is even higher than the climatological normal (Table 1), allowing the development of different species regardless of water supplementation by irrigation.

Table 3. Shoot and root dry matter for the four species studied under an extensive green roof system in the presence and absence of irrigation 365 days after planting.

	Shoot dry matter (g m^{-2})		Root dry matter (g m^{-2})	
	with irrigation	**without irrigation**	**with irrigation**	**without irrigation**
A. hirtula	45.55 C a*	14.33 C b	45.57 A a	24.55 B b
A. integerrima	39.52 C a	31.16 B a	17.17 B a	25.05 B a
D. hebdingii	273.19 A a	271.78 A a	26.76 B a	30.42 B a
A. cordifolia	150.52 B a	161.14 A a	26.93 B b	50.45 A a
CV (%)	86.38	101.01	42.06	37.35

CV = coefficient of variation; * Means followed by different capital letters in the column and different lowercase letters in the line differ, by the DMS test at the level of 5% probability of error.

For *A. hirtula*, in the presence of irrigation there was a balance in shoot and root dry matter (45 g m^{-2}), while in the absence of water supplementation there was a greater investment in root dry matter (24 g m^{-2}) in relation to shoot dry matter (14 g m^{-2}). The greatest development of roots at the expense of leaves and stems was also observed in *Amaranthus* sp., a species of the same family as *A. hirtula*, when subjected to water stress conditions, indicating that in this situation, there may be differences in the partition of photosynthesis and a greater development of the root system in order to optimize water intake by exploiting a larger volume of soil (Omami and Hammes, 2006).

By comparing species as for shoot dry matter, a difference was observed between *D. hebdingii* and *A. cordifolia* in the presence of irrigation, with a greater accumulation of the native species in relation to the exotic species. Furthermore, this difference was not observed in the absence of irrigation, demonstrating the adaptability of *D. hebdingii* to the condition of extensive green roofs without water supplementation, with results equivalent to the species commonly used. *A. hirtula* and *A. integerrima* presented lower accumulations of shoot dry matter among the species tested due to the anatomical characteristics of the species, since no differences were observed in different irrigation conditions.

For the roots of *A. hirtula* with the presence of irrigation, there were the largest accumulations of dry matter, differing from the other species tested, while in the absence of irrigation, *A. cordifolia* was superior to the other species.

In a temperate maritime climate, the development of vegetation by module was not affected by the presence of irrigation. For shoot dry matter, differences were only verified due to the diversity of species, while for root dry matter, no differences were observed. However, when considering the species individually, a higher shoot biomass production was observed when irrigation was more frequent, although for *Origanum vulgare, Prunella vulgaris, Anthoxanthum odoratum* and *Sedum* species, no differences were found. The root development of *Armeria maritima*, *Orignum vulgare* and Sedum were also not affected by the difference in irrigation regimes (Nagase and Dunnett, 2010).

Thus, the results presented in this work show that the species of the flora of the state of RS have a potential for use on extensive green roofs as they present results similar as the exotic species analyzed, commonly used for this purpose. In addition, the use of a consortium among the native species studied could be an alternative to improve the coverage and aspect of vegetation throughout the year, since *A. hirtula* and *A. integerrima* show promising results but for a more restricted period (spring-summer).

Conclusions

The different species of the native flora of the state of Rio Grande do Sul tested here have a potential for use on extensive green roofs without the need for irrigation under the conditions in which the present work was developed.

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Author Contribution

BAM: Responsible for the implementation, evaluation and writing of the article; **GS:** assisted in the preparation of the study and the correction of the article; **AAE**: assisted in the implementation and evaluation of the experiment; **PAS:** assisted in the implementation and evaluation of the experiment; **EDA:** assisted in the implementation and evaluation of the experiment; **MT:** assisted in the implementation and evaluation of the experiment.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Data Availability Statement

Data will be made available on request.

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