The development and performance of plant species in Brazilian extensive green roofs

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ABSTRACT: The intense development of cities and the consequent reduction of its green areas results in environment imbalance. While sustainability attribute the green roof is a viable option, but not yet widespread in Brazil. This experimental research aimed to evaluate the development of plant species and their influence on the performance of extensive green roofs in the city of Curitiba - PR on five prototypes. The chosen species were: *Bulbine frutescens, Trandescantia zebrina, Zoysia tenuifolia, Sedum Angelina* and *Callisia repens.* The methodology consists of observation and photographic monitoring of the species, as well as analysis of storm water retention in the day after rainfalls with measurements of the volume of water retained in containers coupled to the output water drainage of each green roof's module. The analysis of the influence of plant species and their performance for green roofs, found a variation between species as the water holding capacity. Regarding the development of the species, *Trandescantia zebrina* was better adapted to the imposed conditions, followed by *Zoysia tenuifolia*. It also concludes that it's essential in Curitiba's climate the use of species that do not suffer burns, or total loss of leaves during periods of frost, which was the main problem observed.

Keywords *Green roofs, Plant species, Sustainability, Curitiba, Brazil*

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1. INTRODUCTION

The urban areas have grown exponentially. Early in the century the urban population accounted for 15% of world population; currently represents 54%, and in Brazil, the population in urban areas exceeds 85% (UN, 2015). Thus the residual rain water cause many disorders on the routine of the big cities in Brazil and worldwide. The problems are aggravated due to the increasing growth of waterproofed areas in city centers added to the lack of proper maintenance in the system of storm sewer (Berndtsson, 2010).

If it is difficult to solve this problem at the ground level, the solution may be on the rooftops. The use of green roofs in urban coverages can significantly reduce the excess of rainwater over the surface of many cities (Baldessar, 2012). This positive effect is ensured by green roofs and arises from the phenomenon known as evapotranspiration which happens due the combination of plants and substrates that compose the green cover. By virtue of this phenomenon, the water is retained long enough to returning to the atmosphere by evaporation from the substrate and plant's transpiration (Nowak, 2004 cited by Shinzato, 2009)

On this scenario the discussion regarding the application of green roofs in urban centers to mitigate these problems is fundamental. Green roofs can reduce around 70% of the stormwater runoff (Baldessar, 2012) or up to 14mm of precipitation (Cunha and Mediondo, 2014) in cities like Curitiba and São Carlos, depending on the dry period that preceded precipitation. It also can reduce temperatures inside the buildings and through the absorption of rainwater assist in flood control in urban centers. (Andrade and Roriz, 2013). Properties like height, color, soil closing capacity and water retention capacity in roots and leaves assist in the performance of the green roof (Niachou et al., 2001).

Due to its geographical conditions; 25 degrees south latitude, 1000m altitude above sea level, 85 km distance from the sea, the climate of the city of Curitiba has very peculiar and distinctive features when compared to others regions of Brazil. With a very humid summer with good intensity of rainfall the city could be more suitable for tropical plants, although its average temperature in summer does not exceed a lot of 25 degrees. But it is in winter that are given the conditions most critical for the suitability of plants. Low temperatures, averaging 11 degrees (IBGE, 2010) in autumn and spring, generate events of usual frosts in June and July. Associated with long droughts and low rainfall this period creates a complex setting for the plants which would be used in a green roof.

Before possible natures of green roofs as intensive or extensive, will be more difficult to define the plants for extensive green roofs, which necessarily have a lower height of substrate and maintenance limited to the minimum possible. Therefore, it becomes important the study of species suitable for the composition of green roofs while observing the weather and construction conditions of the place where will be built, or rebuilt, the green coverage.

1.1 Goal

This article presents the monitoring of plant species and their conditions of adaptation in order to be used in extensive green roofs in the city of Curitiba, Paraná state capital in southern Brazil.

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2. METHOD

While experimental work the species were planted in prototypes of approximately 100x75cm each. They were under visual monitoring for one year, beyond the collection procedure to the residual rain water measuring in containers individually coupled to each prototype. The results of the runoff rainwater are objects of another article.

2.1 The test tables

For the experiment a test table was built, consisting of 14 modules of 100x75cm, 8 of these modules were objects of study in this work. This table was made in solid wood structure (pillars and beams) supported on a concrete basis. The structure of the modules was done with plywood naval pinus with inclination of 2% (Figure 1). The modules were sealed with liquid rubber in the base and the sides (Figure 2).

Figure 1- Assembly of the table tests structure

Figure 2 - Waterproofing of the modules

The green roof modules are made up of the following layers, as shown in Figure 3: waterproof/root repellant membrane, drainage layer, filter membrane, growing medium and vegetation. For waterproof/root repellant membrane was used high density polyethylene mat with a thickness of 0.5 mm. The drainage was made with expanded clay (particle size 22 to 32mm) with a depth of 4 cm over this layer was placed a geotextile mat for retention of the growing medium. Immediately above the filter membrane was arranged the elements of the growing medium, consisting of: turf, vermiculite, carbonized rice husk and black soil in the proportion of 35% of land, 20% turf, 40% of carbonized rice husk and 5% vermiculite and thickness of 10cm, as Muller (2014) study indication on growing medium for green roofs. This growing medium composition also provided greater retention of rainwater, an important characteristic to aid the survival of plant species in the dry season. Farrell et al. (2012) stated that the higher the rain water retention capacity, higher is the plant survival.

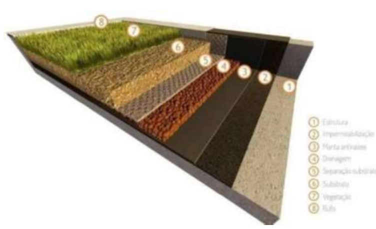

Figure 3 - Green roof system design

Figure 4 - Table test

2.2 Choice of species criteria

For a full analysis of plant species, the first criterion for the choice of plant species were their morphological characteristics, size, growth, water retention capacity etc., which should differentiate between them. The selected plants have characteristics suitable to the climate of Curitiba. The first condition is that being perennial, that is, plant species whose

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life cycle is lasting, allowing it to live for more than two years, more than two seasonal cycles. This feature of the plant is the key to reduce the maintenance of green roofs.

Liu et al. (2012) points out that the plants with green leaves are effective in reducing upper temperatures when compared to plants of red and purple leaves. In this way, we opted for three species of green leaves and two of purple leaf to verify this temperature change between species with different colorings.

The same authors also allege that the plants of CAM (Crassulacean Acid Metabolism) type are the most suitable for green roofs due to its ability to store acids in their leaves or aerial parts, which aids the plant resistance in dry seasons. According to INMET(2014), Curitiba is characterized by a rainy and moderately humid climate, especially in summer, with a rainfall average of 1500 mm per year, from this, it was decided to plant both the CAM type (*Bulbine frutescens and Sedum mexicanum*), or succulents, the C3 type (*Arachis repens, Tradescantia zebrina and Callisia repens*). The plants of CAM type close their stomata and reduce sweating during the day to conserve moisture, and open their stomata at night in order to sequest carbon in form of organic acids for beeing used in photosynthesis during the day. The C3 type perform photosynthesis in common form (JIM, 2014).

2.3 The vegetal species

The species chosen are described below.

The first selected plant species was *Bulbine frutescens*. According to Lorenzi (2013), Bulbine is an herbaceous, perennial and succulent, native to South Africa with a height of 20 to 30 cm. Characterized by long leaves, cylindrical, fleshy and waxy, it is composed of tufts with inflorescences at its center, with small yellowish flowers, which appear throughout the year. Lorenzi (2013) points out that it is a tolerant plant to cold and with little water requirement, ideal feature for green roofs in the region of Curitiba. Its multiplication is by clumps, reason why isn’t very spreading. It is a full sun vegetation and likes soil rich in organic matter and well permeable.

The second selected species is the *Tradescantia zebrina*, variation purpusii. It is characterized also by being a succulent vegetation native to Mexico. It has dark purple color when in the full sun. Its leaves are fleshy and colorful, ranging from green to dark purple. It was chosen due to its color, and for being characterized by Lorenzi (2013) as a rustic plant that requires neither pruned nor contentions. However, it is not resistant to frost and can have their leaves burned. Due to its easy rooting, can sprout without the need of exchange of seedlings when hit by frost. Its multiplication is made by cuttings and rooted creeping branches.

The third species is not a succulent, but is a vegetation widely used in green roofs in Brazil, it was chosen to verify their adaptation to the climate of southern Brazil, since it is native of Brazil. *Arachis repens*, is characterized by being a herbaceous, perennial, with a height 20 to 30 cm, prostrate and thin branches with nodes and internodes highlighted. The leaves are small and in pairs of 2 to 3 cm in length. In the summer and spring sprout small solitary yellow flowers. It is an excellent plant to be used as ground cover in full sun, replacing lawns. It likes moist soil rich in organic matter. It is easily multiplied and tolerates drought, but not frost (Lorenzi, 2013).

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The fourth selected species is the *Sedum mexicanum* it's a specie used very often in green roofs in Europe, due to its high tolerance to cold, is characterized by a yellowish green color and, despite being a succulent, is well suited to areas of mild and humid climate, resistant to sandy soils with low fertility, is indicated for the subtropics (Lorenzi, 2013). The sedum kind, in general, has as main characteristic high resistance to water stress, an important feature to reduce the maintenance of green roofs. It was chosen due to its yellowish green color, its characteristic as a succulent and for provide a dense closing of the soil, even if slowly.

Finally, the last species chosen was *Callisia repens*. It is an herbaceous and trailing plant, small, reaching only 5-25 cm high. It has a dense and ornamental foliage, formed by branched, filamentous and long stem with numerous, serous, delicate, small purplish and green-purple leaves. It is often grown as ground cover in shade. When grown in shadow their leaves are greenish and when grown in the sun have smaller leaves, more dense and purplish (Lorenzi, 2013).

Between these vegetation's there are species with suitable features for being planted in green roofs of the extensive type and at the same time different characteristics such as color, size, soil closing, structure and growth.

The planting was made on February 10th 2014. The same quantities of seedlings were placed, in order to have the same closure of the soil, and to verify the growth of plants and their ability to ground coverings. At the Figure 5 and Figure 6 it's possible to check the modules on the planting day.

Figure 5: The day of seedling planting 10/02/2014

Figure 6: The day of seedling planting 10/02/2014

3. RESULT ANALYSIS

3.1 General analysis

Prototypes were observed during one year. This was the photographic survey of the species with monthly or fortnightly photos, as Figure 7 (period from 02/10/2014 to 07/15/2014) and figure 8 (period from 07/25/2014 to 02/26/2015).

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Bulbine frutescens *Tradescantia zebrina* *Arachis repens* *Sedum mexicanum* *Callisia repens*

Figure 7 - Vegetation development between the months of February and July 2014

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Figure 8 -Vegetation development between the months of July 2014 and February 2015

In the Figure 7 it can be analyzed the development of the plants in the months from February to July 2014. In the first month all the plants showed a certain degree of growth. The species *Tradescantia zebrina* and *Callisia repens* presented the further development and the closing of the soil, which may be associated with its spreading characteristics. In April, all species had almost complete closure of the soil. The species *Sedum mexicanum* showed the slowest growth among the species analyzed, characteristic of the species, with complete closure of the soil only in June 2014. The plants have developed steadily until mid-May, and *Bulbine frutescens* still presented flowering in this period.

Photos taken on 05/26/2014 already show a change in the vegetation, due to the moderate frost that happened in the early hours of 05/20/2014. The *Arachis repens* species suffered the greatest impact, its leaves "burned" due to frost (Figure 7).

Frost is a process of deposition of ice crystals, usually being registered when the soil temperature is below 0 ° C and the air temperature just above that (3°C or 4°C). What happens to the plants is that their organs cannot withstand the low temperatures and die, and this may be noticeable in plants by the black color of its aerial parts, as Figure 7 on the date of 11.06.2014.

While effects of frost on *Bulbine frutescens* was observed that their flowers have died, but their leaves had little change, as well as *Sedum mexicanum* who suffered only a slight change in its color. As for, many of the leaves of *Tradescantia zebrina* and *Callisia repens* died but less intensively than in the species *Arachis repens*, which can be seen through the dark color of most of the leaves and being able to sprout.

With the burning of its leaves, *Arachis repens* failed to sprout enough to cover the ground again, making room for many weeds, as can be seen in the photos of the day 06/23 and 07/15 (Figure 7). As Curitiba has an intense winter and frost is common at this time, it was decided to replace this plant species, pointing out that it is not suitable for green roofs in the city of Curitiba, due to winter conditions.

On 07.25.2014 (Figure 8) was made the exchange of plant species, replacing it with a grassy, considering that this type of vegetation is widely used in green roofs, especially those who have the terrace function, i.e. possess movement of people.

Grasses are easily available and commonly used in landscaping in Brazil. The species chosen was the *Zoysia tenuifolia*, known as Korean or Japanese grass. According to Lorenzi (2013) it's a *rhizomatous herbaceous estolonífera*, native to Japan and Korea, a grass of full sun that has slow growth, thus reducing its maintenance. The choice of this kind before others grasses was given by its slow growth and low maintenance.

3.2 Analysis by species

The *Bulbine frutescens* maintained its size throughout the year, changing its color for more yellow or greenish tones according to the time of year. It is believed that fertilizing, heatstroke and precipitation are the main factors that influence this species.

Tradescantia zebrina due to its spreading characteristic showed a rapid and satisfactory closure of the soil, maintaining throughout the year and undergoing only in the frost period. However, growing again without the need of replacing the species. It presented the best fit to the conditions imposed, with the densest closing ground.

The *Zoysia tenuifolia* is characterized by high consumption of water and it's suggested that it be made its irrigation in the first 3 or 4 months from planting to maintaining and rooting, however the objective of this research was to observe the development of species

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without irrigation, any artificial irrigation was not performed, however after the dry season it returned to present its green color.

The *Sedum mexicanum* was better adapted to the winter weather, with a more complete closure of the soil in this period. In the months with higher temperature (November 2014 to February 2015) had lost much of seedlings which made the closing of soil beeing considered unsatisfactory and made room for the growth of weeds (Figure 18). This feature may be associated with type (succulent) plant (CAM).

Callisia repens showed a closure of the substrate already in the first month and remained constant throughout the year. In periods with higher insolation its leaves were characterized by beeing in smaller number and purplish coloration, during periods of reduced sunlight the leaves were bigger and more greenish. More adapted to the shade condition, decreased leaf area when beeing exposed to intense sunlight, however survived all seasons.

The *Arachis repens* did not show the characteristic of regrowth after a registered frost event, it is not a recommended species for the city of Curitiba or regions where frosts are possible during the winter. Others species showed ability to sprout even after having its leaves burned by the frost, as the case of *Tradescantia zebrina* and *Callisia repens*.

3.3 Excess water and water stress

Succulent plants with CAM type photosynthesis does not require much water and as the summer months have high rainfalls, the excess of water have rotted the roots causing the death of many plants of *Sedum mexicanum*. In Curitiba and other cities which have a high precipitation rate, even if located in only one season, as is the case, the excess water may affect every type CAM plants. In these cases it's recommended using porous substrates with sand, clay or expanded vermiculite in greater quantities in its composition, so that the soil becomes less saturated and contribute to the development of species.

About the resistance to the water stress, the literature recommends the use of species that perform the CAM type photosynthesis, insted of species C3 and C4 type, due to its lower water consumption (up to 100 grams per gram of CO_2) while species of C3 type consume up to 500 grams per gram of CO_2 and C4 type 300 grams of CO_2 per gram. However, it can be seen that due to the high rainfall in Curitiba the species must be able to resist to higher rates of precipitation or so the soil should be porous when used CAM species type.

4. CONCLUSIONS

Regarding the development of species can be concluded that are essential for the Curitiba climate species wich do not suffer burns, or complete loss, of their leaves during periods of frost, or, even if with damage in the plants aerial parts, have the ability to sprout after this frost event. In the specific case of Curitiba plants must have resistance to dry periods and periods of higher rainfall, both conditions, although this research points out more care for this last condition.

It also concludes that green roofs can retain a significant amount of the rain water in their system (together: the growing medium and plant) and due to the morphological characteristics of each species exist variation of retention levels.

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