PhD THESIS

Research regarding *Sedum* plants in mosaic designs and their adaptation to various pedoclimatic conditions

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INTRODUCTION

In the context of rapid urbanization and climate change, conserving green spaces becomes an urgent challenge. Cities, often driven by economic and utilitarian interests, neglect the ecological benefits of green areas. Green roofs offer an efficient contemporary solution for integrating ecological elements into the urban landscape (FRANCIS and JENSEN, 2017).

Succulent plants of the *Sedum* genus are ideal for green roofs due to their adaptability and resilience in harsh conditions (DURHMAN et al., 2006; WOLF and LUNDHOLM, 2008; ZAHARIA et al., 2016), efficiently utilizing resources (KLUGE, 1977; TERRI et al., 1986), and contributing to the absorption of heavy metals and carbon (GETTER et al., 2009). Implementing green roofs with *Sedum* can enhance urban resilience, especially in warm and arid climates, promoting sustainable landscapes (SNODGRASS and SNODGRASS, 2006).

The doctoral study explores the use of *Sedum* varieties in a floral mosaic inspired by traditional Romanian motifs, emphasizing the importance of local cultural identity in landscape design. The experimental design involved the use and establishment of a *Sedum* culture on various types of substrate and the evaluation of plant behavior under water and nutrient stress conditions (without maintenance interventions, such as irrigation or fertilization of crops) exposed exclusively to existing pedoclimatic conditions.

STRUCTURE OF THE PH.D THESIS

The thesis ***"Research regarding Sedum plants in mosaic designs and their adaptation to various pedoclimatic conditions",*** consists of 150 pages and is conducted in accordance with the current standards of development and drafting at the university and national level.

The doctoral thesis is structured into two parts, comprising eight chapters, and containing 40 tables, 67 figures and graphs, as well as 263 bibliographic references.

The first part of the doctoral thesis, dedicated to the current state of knowledge, is organized into two chapters, totaling 50 pages.

Chapter 1 provides a detailed presentation of the *Sedum* genus, covering various aspects related to this plant group. The chapter begins with the origin and distribution range of the genus (1.1), followed by the systematic classification, including a description of several species (1.2 and 1.2.1). The chapter then proceeds with details about the ecological requirements of the plants, such as temperature, water, light, culture substrate, and biochemical content (1.3, 1.3.1 - 1.3.5). Cultivation technology is then addressed, including methods of propagation and maintenance (1.4, 1.4.1 and 1.4.2). Finally, the chapter deals with the use of *Sedum* plants, highlighting their ecological importance, types of floral compositions and landscaping, the influence of climate change on plant development, and their drought tolerance (1.5, 1.5.1 - 1.5.4).

Chapter 2 explores various traditional motifs and patterns and how they are used across the world. It begins by introducing the concept of traditional motifs on a global scale (2.1), providing insight into the diversity and significance of these motifs in different cultures. It continues with an analysis of Romanian traditional patterns and the design principles that characterize them (2.2), emphasizing the particularities and aesthetic values native to Romania. The chapter concludes with a section dedicated to the use of traditional motifs in gardening (2.3),

highlighting how these patterns can be integrated into modern landscape design and horticulture.

The second part of the thesis, dedicated to original research, is structured into six chapters and spans 97 pages. The results are illustrated through 31 tables and 33 figures.

Chapter 3 outlines the aims and objectives of the research. ***Chapter 4*** details the geographical location of the research site. ***Chapter 5*** describes the materials and research methods, as well as the organization of experiments. ***Chapter 6*** presents the results and discussions of the six research studies, followed by ***Chapter 7*** which lists the conclusions and recommendations formulated based on the obtained results. The elements of originality and personal contributions are highlighted in ***Chapter 8*** of the doctoral thesis.

The thesis concludes with the references and abstracts in both Romanian and English.

RESEARCH AIMS AND OBJECTIVES

The aim of the research conducted within the doctoral thesis ***"Research regarding Sedum plants in mosaic designs and their adaptation to various pedoclimatic conditions",*** was to closely analyze the development of *Sedum* species exposed to various pedoclimatic conditions, without external interventions such as watering or additional fertilization, and to promote the use of traditional motifs and patterns in landscape designs.

Within the conducted **six studies**, the following **objectives** were derived in accordance with the general aim of the research:

- Establishing the impact of climatic conditions on culture substrates and identifying the ideal substrate for cultivating certain *Sedum* varieties;
- Determining the impact of water and nutrient stress factors – without irrigation or fertilization - on the growth of *Sedum* plants in different substrates;
- Establishing the density of *Sedum* plants in different substrates under the influence of water and nutrient stress factors - without irrigation or fertilization;
- Determining the biochemical composition of the studied plants in different substrates under water and nutrient stress conditions – without irrigation or fertilization;
- Determining the extent and use of the *Sedum* genus locally;
- Identifying methodologies through which the studied plants can be integrated into floral mosaic arrangements.

MATERIALS AND METHODS

BIOLOGICAL MATERIAL

In the doctoral thesis, three varieties of *Sedum* belonging to two species were studied – *S. spurium* 'Purpur Winter', *S. spathulifolium* 'Cape Blanco', and *S. spathulifolium* 'Purpureum'.

A total of 12,276 cuttings, 2,046 pots, and 3 cubic meters of growing substrate were needed to complete the entire arrangement:

- 482 pots, equating to 2,892 cuttings of *Sedum spurium* 'Purpur Winter' (SS'PW');
- 983 pots, equating to 5,898 cuttings of *Sedum spathulifolium* 'Cape Blanco' (SS'CB');
- 581 pots, equating to 3,486 cuttings of *Sedum spathulifolium* 'Purpureum' (SS'P').

CULTURE SUBSTRATE

The experiments were conducted on a grassy terrace at U.S.A.M.V. Cluj-Napoca (ICHAT) to study the influence of different growing media on *Sedum* plants, using four growing substrates:

- **Green roof substrate (A.V.):**
  - Advantages: porous, lightweight, retains water and fertilizers, good drainage, does not decompose, sterile (AMPIM *et al.,* 2010);
  - Disadvantages: coarse, some plant roots may not anchor well (AMPIM *et al.,* 2010);
  - Characteristics: N – 0.038%, P – 69 ppm, K – 810 ppm, pH – 8.01, Water-soluble < 1.5 g/l, sediment < 20%, air > 60%, retained water 50%, organic matter 3-8%, absorption > 140 mmol/l.
- **Commercial mix (A.C.):**
  - Advantages: nutrient-rich, retains water (AMPIM *et al.,* 2010);
  - Disadvantages: variable salinity, may contain residues of herbicides/insecticides, risk of weeds (AMPIM *et al.,* 2010);
  - Characteristics: N - 1.31%, P - 3800 ppm, K - 4740 ppm, pH - 4.92, maximum soluble water 2%, maximum microelements 0.2%.
- **River sand (N.R.):**
  - Advantages: efficient root contact (AMPIM *et al.,* 2010);
  - Disadvantages: heavy when wet, prone to erosion, low in nutrients and water retention (AMPIM *et al.,* 2010);
  - Characteristics: N - 0%, P - 7 ppm, K - 254 ppm, pH - 8.82.
- **Gravel (Control):**
  - Advantages: cool, stable microclimate, good aeration, reusable (AMPIM *et al.,* 2010);
  - Disadvantages: does not absorb water, lacks nutritional value, heats up in summer (AMPIM *et al.,* 2010).

RESEARCH METHOD

To conduct the research, experimental cultures needed to be established. These were introduced into an original design with a Romanian specificity.

Sedum cuttings were planted six per pot in pots with a diameter of 17 cm and a depth of 13 cm. The pots were pre-filled with three different types of growing substrate - A.V., A.C., and N.R., and then distributed on a specially constructed suspended metal structure.

The metal structures were created according to an original concept, made of welded mesh, with dimensions of 110 x 400 cm and metal profiles of 3 cm, cut at different lengths to create the wavy effect of the 'work tables'.

The investigated plants were exposed to water and nutrient stress. Specifically, during the studies, no fertilization or irrigation interventions were carried out, and the plants were exclusively subjected to rainwater and the nutrients already present in the chosen growing substrates.

- **Study 1 – The influence of climate on culture substrates**
  This study analyzed the physico-chemical properties of different culture substrates and monitored the impact of climatic conditions over 20 months.
- **Study 2 - Morphological development of *Sedums* under conditions of abiotic stress**
  The morphological development and growth of *Sedum* plants under abiotic stress conditions were evaluated, focusing on root and stem development, as well as morphological changes in response to different substrates and environmental conditions.
- **Study 3 - Survival and ramifications of *Sedums* under conditions of abiotic stress**
  This study assessed survival rates and branching patterns of *Sedum* plants under abiotic stress conditions, examining over 12,000 cuttings to determine the effects of different substrates and altitude levels on plant adaptation.
- **Study 4 - Biochemical content of *Sedums* under conditions of abiotic stress**
  The biochemical content of *Sedum* plants exposed to abiotic stress was analyzed, focusing on the impact of different substrates on the plants' biochemical composition.
- **Study 5 - Local distribution and use of the *Sedum* genus**
  A survey conducted in 2022 explored the prevalence and local use of *Sedum* species, identifying popular varieties and decorative applications based on responses from 411 participants and market data.
- **Study 6 - Plant integration within the Romanian cultural context**
  Three landscape design concepts integrating different plant typologies were developed for various locations to demonstrate how these plants can enhance cultural and historical settings through aesthetic and sustainable arrangements.

RESEARCH RESULTS AND DISCUSSIONS

Results regarding the influence of climate on culture substrates

Soil temperature influences biological, physical, and chemical processes in the soil (WARING, 2007), and consequently, the healthy development of plants. Low temperatures, on the other hand, hinder water absorption due to its viscosity, thereby slowing down the process of photosynthesis (https://eos.com/blog/soil-temperature/). In a short interval, chemical and biological processes can double for every 10°C added. Soil temperature affects the soil water saturation percentage, and as soil moisture content increases, so does the temperature level, resulting in greater heat storage capacity (AL-KAYSSI et al., 1990; HOWE & SMITH, 2021).

From a statistical standpoint, the obtained results indicate that concerning the influences of atmospheric temperature on crop substrates, at a significance level *of* $p < 0.05$, no significant differences were observed between treatments. At the same time, analyzing the values of substrate moisture retention, no significant differences were identified between the substrates A.V. and A.C., while the N.R. substrate exhibited significant differences.

Upon reviewing the data on culture substrates and the presented climatic influences, it could be concluded that the specific substrate for green roofs - A.V. - stood out due to the following characteristics:

- A.V. recorded higher average temperatures than the atmospheric temperature in the studied years, indicating its ability to maintain favorable conditions for plants;
- It still provides a good source of nutrients, essential for plant development;
- It allows for good air circulation at the plant roots;
- It stores enough moisture to ensure the healthy development of plants, which is crucial for the studied crops.

Results regarding the morphological development of *Sedums* under conditions of abiotic stress

Root system development under conditions of abiotic stress – Within this research, the development of the root system of three *Sedum* varieties was investigated. The results highlighted significant variations in root growth among different substrates. Generally, the green roof substrate (A.V.) favored the greatest root growth (SS'PW' - 14.77 ± 0.74 cm; SS'CB' - 16.22 ± 0.81 cm; SS'P' 15.31 ± 0.77 cm), followed by the commercial blend (A.C.) - 8.10% weaker, and river sand (N.R.) - 24.11% weaker. Additionally, it was observed that *Sedum spathulifolium* 'Cape Blanco' exhibited the highest total root growth. The discussion reveals that thermal fluctuations and soil moisture significantly influence root development, and the plant's adaptation to pedoclimatic conditions plays a crucial role in its survival and growth.

Aerial part development under conditions of abiotic stress – The study examines the stem growth rates for *Sedum spurium* 'Purpur Winter' (S.S.'PW'), *Sedum spathulifolium* 'Cape Blanco' (S.S.'CB'), and *Sedum spathulifolium* 'Purpureum' (S.S.'P') under different substrate conditions (green roof substrate, commercial mix, river sand) and varying levels of substrate temperature and humidity, subjected to water and nutrient stress.

For SS'PW', the highest stem development value was recorded in A.C. with a monthly average of 0.87 cm, while in A.V. and N.R., the values were 55.17% and 43.68% lower, respectively.

For SS'CB', the highest value was recorded in A.C., 0.40 cm, while in A.V. and N.R., the monthly average growth was lower by 52.50% and 50%. SS'P' presented similar values to SS'CB', where A.C. had the highest value among the three treatments - 0.35 cm monthly average.

Comparisons with previous studies suggest that environmental factors significantly influence growth rates in *Sedum*, highlighting the importance of substrate composition and management practices in green roof cultivation.

Morphological analysis under conditions of abiotic stress – This research describes how different substrates and environmental conditions influence the development of *Sedum* plants including leaf and stem number, stem weight and length, stem diameter, and leaf surface area, compared to control plants.

The lowest development values of the studied plants were recorded in the river sand (N.R.) batch, with a growth rate 56% lower than that of the control plants. The green roof substrate (A.V.) ranked second, with 50% of the control plant growth, while the commercial soil mix with dolomite and perlite (A.C.) ranked first, with 48%. The results indicate that the development of *Sedum* plants was strongly influenced by abiotic factors such as temperature,

humidity, and soil depth. Different substrates and environmental conditions can lead to significant variations in plant morphological characteristics, and managing these factors is crucial for achieving optimal plant growth.

External stress factors induce a wide range of physiological changes where cellular membranes are their primary targets (ARORA et al., 2002). Under stress conditions, plants adapt, with leaves, branches, and stems being the most affected (BAERENFALLER et al., 2012).

Results regarding the survival and ramifications of *Sedums* under conditions of abiotic stress

The study investigated the adaptations of *Sedum* plants to various pedoclimatic environments, highlighting survival rates and morphological adaptations under water and nutrient stress. For the specific green roof substrate (A.V.), *Sedum spurium* 'Purpur Winter' exhibited the highest survival rate (91%), with 5.56 plants and 15.81 stems per pot. In the commercial blend (A.C.), the same variety showed a similar survival rate, with 5.58 plants but with 35.61 stems per pot. In river sand (N.R.), this decreased to 5.25 plants and 8.89 stems per pot. *Sedum spathulifolium* 'Cape Blanco' variety showed variable survival rates between 45% and 58%, while *Sedum spathulifolium* 'Purpureum' had lower survival rates (between 23% and 35%). Overall, the green roof substrate A.C. favored plant development, while N.R. showed the lowest survival and development rates.

The elevation and exposure level of plants to severe climatic conditions can also have a significant impact on the survival and optimal development of *Sedum* plants. Therefore, it was essential to establish the influence of different "working table" heights on the studied plants, with heights h1 (0-25 cm), h2 (25-50 cm), and h3 (50-75 cm).

In the green roof substrate, SS'PW' had the highest survival at elevation h3, with approximately 5.93 plants/pot, and in the commercial blend, SS'P' showed significant growth at elevation h2, with approximately 2.77 plants/pot. In river sand, SS'PW' exhibited better survival at elevation h1, with approximately 5.42 plants/pot, and SS'P' showed significant growth at elevation h3, with approximately 2.54 plants/pot. Regarding branching, SS'PW' preferred higher elevation (h3) in the green roof substrate, while SS'P' had the highest branching at elevation h3 in the commercial substrate. Overall, both substrate and elevation influenced both survival and branching trends of *Sedum* plants.

A crucial aspect in choosing plants for various projects is their natural habitat and how the local climate influences their development and survival. For example, in a study by GUREVITCH et al. (1986), three groups of *Sedum wrightii* from different elevations in the southwestern USA were compared in greenhouse conditions. The different groups preferred conditions similar to their natural habitat.

Results regarding the biochemical content of *Sedums* under conditions of abiotic stress

The biochemical analysis of the studied plants at the Research and Development Station for Viticulture and Vinification - Bujoru, Galați, reveals adequate supply of essential macro and micronutrients, with values generally favorable for plant development. However, an

assimilation of heavy metals and other elements that can negatively affect plant growth and resistance has been observed, especially at higher concentrations. Among the chemical elements with significant impact are Li, Cr, Ga, Sr, Ba, Pb, Cd, which can induce various toxic effects, including growth inhibition and deterioration of plant physiological and biochemical processes. Exposure to these heavy metals can lead to serious consequences, such as biomass reduction and photosynthesis decline, ultimately affecting plant health and even survival.

Exposure of plants to heavy metals can cause toxic effects such as biomass reduction, chlorosis, growth and photosynthesis inhibition, alteration of water balance, and nutrient assimilation. These consequences can ultimately lead to plant death. (RIESEN & FELLER, 2005; CHAVES et al., 2011; SINGH et al., 2016; SHARMA et al., 2020).

Results regarding the local distribution and use of the *Sedum* genus

The results of the endeavor highlight the level of knowledge and usage of the *Sedum* genus in the local context. According to data obtained from 411 participants, 81% recognized the plants presented in the pictures, while 19% failed to identify them correctly. Regarding the naming of the plants, 67% identified them using either their scientific names or their main characteristics. Over 87% of participants highlighted the specific traits of the *Sedum* genus, and 29% were aware of the specific characteristic of the *Crassulaceae* family. The most common colors of flowers and leaves were identified, highlighting the preferred species in the local market. The majority of respondents last encountered *Sedum* plants in their own gardens or specialty stores, with 88% having used or intending to use these plants in their landscaping. The main reasons for usage included their beauty (80%), resistance to adverse conditions (12%), and ease of maintenance (6%). In contrast, among those who would not use these plants, the main reason indicated was a lack of appreciation for them. From the perspective of respondents' professional status, employees of the private sector (22.7%) and those who did not specify (24.8%) predominate, indicating a diversified interest in the *Sedum* genus among adults.

Results regarding plant integration within the Romanian cultural context

The study presents three distinct design proposals for integrating plants into the Romanian cultural context. *Design 1* emphasizes spring and summer decor by using a symmetrical floral mosaic inspired by traditional Transylvanian motifs and strategically placed to create visual coherence and contrast. *Design 2* highlights the results of the doctoral study, offering practical recommendations regarding cultivation substrates and plant care, while d*esign 3* proposes integrating a floral mosaic into a fictional historical setting, accentuating the symmetry of floral patterns and thematically integrating them into an environment with native vegetation. Each proposal explores different ways to create attractive and functional green spaces adapted to the Romanian cultural context.

CONCLUSIONS

- **Conclusions regarding the influence of climate on culture substrates**

Temperature and precipitation have a significant impact on cultivation substrates. Substrate A.V., used in green roofs, maintains moderate temperatures throughout the year, favoring the growth of *Sedum* plants. In contrast, substrates such as N.R., composed of river sand, have shown greater temperature fluctuations, negatively affecting plant development. Additionally, substrates like A.C. have demonstrated better moisture retention, ensuring a constant availability of water for plants.

- **Conclusions regarding the morphological development of *Sedums* under conditions of abiotic stress**

In conclusion, the research on the development of the root system and aerial parts of three *Sedum* varieties under different substrate conditions and abiotic stress has highlighted significant variations in plant growth and morphology. Plant adaptation to pedoclimatic conditions has proven to be essential for their survival and growth. The results underscore the importance of managing abiotic factors in the cultivation of *Sedum* plants, with significant implications for the design and maintenance of green roofs.

- **Conclusions regarding the survival and ramifications of *Sedums* under conditions of abiotic stress**

In conclusion, the adaptations of *Sedum* plants to diverse pedoclimatic environments have been highlighted through variable survival rates and morphological adaptations under water and nutrient stress. *Sedum spurium* 'Purpur Winter' exhibited the highest resistance in the specific substrate of green roofs and in the commercial mix, with a notable increase in the number of stems in the latter. In contrast, survival was reduced in river sand. Additionally, variability in survival and development rates was observed among various species and subspecies of *Sedum*, significantly influenced by elevation and substrate type. These findings underscore the importance of choosing suitable species in landscaping projects, considering their natural habitat and adaptations to local conditions.

- **Conclusions regarding the biochemical content of *Sedums* under conditions of abiotic stress**

Biochemical analysis revealed that essential elements for the growth of *Sedum* plants were present in adequate quantities. The poor development of plants could also be attributed to the presence of heavy metals such as lead (Pb), zinc (Zn), and cadmium (Cd), which in excess can cause severe toxic effects, such as biomass decrease, growth and photosynthesis inhibition, as well as alteration of water balance and nutrient assimilation. This underscores the need for monitoring heavy metal levels to ensure plant health and environmental protection.

- **Conclusions regarding the local distribution and use of the *Sedum* Genus**

The study showed that the majority of respondents recognize and appreciate *Sedum* plants for their drought resistance and adaptability to different environments. These plants are preferred for landscaping due to their beauty and ease of maintenance. However, some individuals avoid using them due to lack of adequate space or personal preferences. Interest in

these plants is diversified, coming from multiple domains, suggesting widespread appreciation in both urban and rural landscaping.

- **Conclusions regarding plant integration within the Romanian cultural context**

The integration of the *Sedum* genus into the Romanian cultural landscape has demonstrated the potential to create harmonious and captivating green spaces. The use of floral mosaics inspired by traditional motifs has contributed to a pleasant aesthetic and a deep connection with local history and traditions. Low-growing plants have emphasized the delicacy of the design, while taller ones have added depth and drama, thus optimizing the urban landscape and promoting biodiversity.

RECOMMENDATIONS

- **Substrate Selection:** It is recommended to use substrates such as those specific to green roofs or commercial ones to establish an optimal environment for plants, moderating temperature and humidity.
- **Root Development:** Choosing substrates with adequate drainage and moisture retention capacity is recommended for healthy root system growth.
- **Stem Development:** Opt for substrates that provide support and stability to promote stem growth and stability.
- **Adaptation to Abiotic Stress:** Select *Sedum* varieties that exhibit proper adaptation to local conditions to maximize resistance to abiotic stresses.
- **Biochemical Content:** It's important to monitor heavy metal levels and avoid their accumulation in plants and soil to minimize negative environmental impact.
- **Utilization of the *Sedum* Genus:** Integrating *Sedum* plants into landscaping projects is recommended for their adaptability and ease of maintenance.
- **Cultural Integration:** To ensure project relevance and authenticity, it's recommended to integrate plants into the context of local traditions and cultural values.

ORIGINALITY AND INNOVATIVE CONTRIBUTIONS OF THE THESIS

The thesis presents several original and innovative contributions. It identifies environmental factors and their influences on substrates used for *Sedum* cultivation. Additionally, it develops a current study on the implementation of succulent cultivation, exploring three substrate options for short-term and long-term use. An updated morphological analysis is provided, tailored to the pedoclimatic conditions described in the doctoral research. Furthermore, the thesis evaluates the tolerance of different *Sedum* varieties to water and nutrient stress. A questionnaire is created to assess local knowledge and usage of *Sedum* plants. The research also offers landscape solutions for integrating *Sedum* into traditional Romanian floral mosaics and constructs a framework for implementing designs with traditional Romanian motifs. Finally, it examines the determination of biochemical compounds in *Sedum* under water and nutrient stress conditions.

SELECTIVE REFERENCES

1. AL-KAYSSI, A. W., AL-KARAGHOULI, A. A., HASSON, A. M., & BEKER, S. A. (1990). Influence of soil moisture content on soil temperature and heat storage under greenhouse conditions. Journal of Agricultural Engineering Research, 45, 241-252.
2. AMPIM, P. A., SLOAN, J. J., CABRERA, R. I., HARP, D. A., & JABER, F. H. (2010). Green roof growing substrates: types, ingredients, composition and properties. Journal of Env. Hort., 28(4), 244-252.
3. ARORA, A., SAIRAM, R. K., & SRIVASTAVA, G. C. (2002). Oxidative stress and antioxidative system in plants. Current science, 1227-1238.
4. BAERENFALLER, K., MASSONNET, C., WALSH, S., BAGINSKY, S., BÜHLMANN, P., HENNIG, L., ... & GRUISSEM, W. (2012). Systems-based analysis of Arabidopsis leaf growth reveals adaptation to water deficit. Molecular systems biology, 8(1), 606.
5. **COTOZ, A. P., DAN, V. S., GOCAN, T. M., ANDREICA, I., RÓZSA, S., & CANTOR, M. (2023a). *Sedum* growth patterns under different pedoclimatic conditions. Plants, 12(14), 2739, DOI 10.3390/plants12142739**
6. **COTOZ, A. P., DAN, V. S., GOCAN, T. M., ANDREICA, I., RÓZSA, S., & CANTOR, M. (2023b). *Sedum* Survival and Ramification Patterns Under Differentpedoclimatic Conditions, Romanian Journal of Horticulture, Volume IV, 2023: 185-192, On line ISSN 2734 – 8083, PRINT ISSN 2734 – 7656, DOI 10.51258/RJH.2023.21**
7. CHAVES, L. H. G., ESTRELA, M. A., & DE SOUZA, R. S. (2011). Effect on plant growth and heavy metal accumulation by sunflower. Journal of Phytology, 3(12).
8. DURHMAN, A. K., ROWE, D. B., & RUGH, C. L. (2007). Effect of substrate depth on initial growth, coverage, and survival of 25 succulent green roof plant taxa. HortScience, 42(3), 588-595.
9. FRANCIS, L. F. M., & JENSEN, M. B. (2017). Benefits of green roofs: A systematic review of the evidence for three ecosystem services. Urban forestry & urban greening, 28, 167-176.
10. GETTER, K. L., ROWE, D. B., ROBERTSON, G. P., CREGG, B. M., & ANDRESEN, J. A. (2009). Carbon sequestration potential of extensive green roofs. Env. science & technology, 43(19), 7564-7570.
11. GUREVITCH, J., TEERI, J. A., & WOOD, A. M. (1986). Differentiation among populations of *Sedum wrightii (Crassulaceae)* in response to limited water availability: water relations, CO 2 assimilation, growth and survivorship. Oecologia, 70, 198-204.
12. HOWE, J. A., & SMITH, A. P. (2021). The soil habitat. In Principles and applications of soil microbiology (pp. 23-55). Elsevier.
13. KLUGE, M. (1977). Is *Sedum acre* L. a CAM plant?. Oecologia, 29, 77-83. https://doi.org/10.1007/BF00345364.
14. RIESEN, O., & FELLER, U. (2005). Redistribution of nickel, cobalt, manganese, zinc, and cadmium via the phloem in young and maturing wheat. Journal of Plant Nutrition, 28(3), 421-430.
15. SHARMA, A., SIDHU, G. P. S., ARANITI, F., BALI, A. S., SHAHZAD, B., TRIPATHI, D. K., ... & LANDI, M. (2020). The role of salicylic acid in plants exposed to heavy metals. Molecules, 25(3), 540.
16. SINGH, S., PARIHAR, P., SINGH, R., SINGH, V. P., & PRASAD, S. M. (2016). Heavy metal tolerance in plants: role of transcriptomics, proteomics, metabolomics, and ionomics. Frontiers in plant science, 6, 1143.
17. SNODGRASS, E.C., & SNODGRASS, L.L. (2006). Green Roof Plants. Portland, OR: Timber Press
18. TERRI, J. A., TURNER, M., & GUREVITCH, J. (1986). The response of leaf water potential and crassulacean acid metabolism to prolonged drought in *Sedum rubrotinctum*. Plant physiology, 81(2), 678-680.
19. WARING, R. H., & RUNNING, S. W. (2007). Spatial scaling methods for landscape and regional ecosystem analysis. Forest Ecosystems (Third edition), Analysis at Multiple Scales, 225-259.
20. WOLF, D., & LUNDHOLM, J. T. (2008). Water uptake in green roof microcosms: Effects of plant species and water availability. Ecological Engineering, 33(2), 179-186.
21. ZAHARIA, A., JUCAN, D., & BUTA, E. (2016). Reaction of *Sedum spurium* " Purpurteppich" exposed to thermal and hydric stress.
22. https://eos.com/blog/soil-temperature/