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Sedum survival and ramification patterns under different pedoclimatic conditions

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ABSTRACT

This article explores the use of *Sedum* species in landscape design, focusing on their adaptability to different pedoclimatic conditions and their ability to thrive in conditions of neglect. The article discusses the importance of understanding a plant's place of origin and natural habitat when considering its cultivation in a different area and the benefits and drawbacks associated with different types of substrates. Sedums are identified as an excellent choice for those who want to enjoy the aesthetic value of plants without the hassle of regular upkeep. The study investigates the growth and survival patterns of three *Sedum* cultivars in different growth media without additional watering or fertilization. The findings have the potential to provide insights into landscaping solutions and the evolution of these succulent species in arduous conditions. The study also explores Romanian identity and tradition by incorporating traditional motifs and patterns as mosaics into the landscape, creating a new style of landscaping. In addition to our main objective, we were interested in displaying an intricate landscape design to further illustrate the negative visual impact an un-cared-for outdoor environment can have.

Keywords: succulent, stress tolerance, ramification, traditional motifs, substrates

INTRODUCTION

We inhabit a changing society with erratic weather patterns, where global climate shifts complicate rainfall predictions. Urbanization often favours functional designs over green spaces, resulting in a scarcity of green areas in cities. Additionally, this urban expansion may require the removal of structures, including historically significant edifices. Green roofs provide ecological advantages in such contexts without negatively impacting communities.
Contemporary challenges in maintaining aesthetically pleasing landscapes due to busy lifestyles necessitate solutions that demand minimal upkeep. Relocating plants from their native habitats to unfamiliar environments with disparate soil and climate conditions heightens maintenance requirements but by aligning a plant's origin and habitat with its new setting, its horticultural needs and hardiness can be determined and put into practice (Stephenson, 1994).
Assessment of a plant's natural habitat aids in gauging protection requirements in the new environment. Stonecrops from rocky sites necessitate excellent drainage, while forest glade species thrive in moist, partly shaded borders. Coastal annuals demand sandy substrates, and alluvial lowland species favour rich loam. Certain plants exhibit rock preferences, warranting suitable top dressings like volcanic chips or calcareous gravel. An

adequate growth substrate is pivotal for plant support and nourishment, with associated benefits and drawbacks (Ampim *et al.,* 2010).

For our case study, plants were chosen to match various substrates and climatic conditions, requiring drought resistance, minimal nutrient needs, ground coverage, ease of maintenance, and rapid root establishment. Sedums (stonecrops) were identified as suitable due to their adaptability, resilience, and low upkeep. In practice, the optimal plant choice for extensive green roofs has predominantly featured succulent plants, particularly species from the *Sedum* genus (Snodgrass, 2006).

These plants are favoured for extensive green roofs due to shallow roots, efficient water use, Crassulacean Acid Metabolism (CAM), and resilience to harsh conditions (Kluge, 1977; Terri *et al.,* 1986; Durhman *et al.,* 2006; Lu *et al.,* 2014, 2015; Rayner *et al.,* 2015). Their adaptability and efficiency in resource utilization make them ideal for shallow soils (Getter, 2008; Benvenuti *et al.,* 2010; Ondoño *et al.,* 2015; Balaj, 2017).

This study investigates the consequences of neglect on landscape designs and the resilience of sedums, mirroring conditions commonly found on green roofs without ongoing irrigation and fertilization. The primary objective of this study is to gain insights into the influence of the inherent characteristics of these plants on their survival and branching patterns within a south-facing roof garden context. The findings from this research may offer valuable insights for landscape design solutions and contribute to the evolutionary understanding of succulent species in demanding environmental conditions.

MATERIALS AND METHODS

Conducted between 2020 and 2021, this study took place in Cluj-Napoca, Romania, specifically on the southern terrace of the Institute of Advanced Horticultural Research of Transylvania, situated in the University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca. The documented mean yearly temperatures ranged from 10.6°C to 9.8°C. Additionally, the cumulative precipitation during this period was 1,114.47 mm, encompassing both rainfall and snowfall.

The primary focus of this inventory was to document the survival rates and morphological adaptations exhibited by each plant cultivar in response to the growth substrates employed. The study employed specific growth substrates, including a semi-intensive green roof substrate (G.R.), a commercial topsoil blend containing minor quantities of dolomite and perlite (C.M.), and river sand (R.S.). These substrates corresponded exactly to those detailed in a prior research publication (Cotoz *et al.,* 2023).

Each of the 12,276 *Sedum* cuttings, representative of three colour-categorized cultivars (Figure 1) – *Sedum spurium* 'Purpur Winter' (SS'PW'), *Sedum spathulifolium* 'Cape Blanco' (SS'CB'), and *Sedum spathulifolium* 'Purpureum' (SS'P'), underwent rigorous examination.

These cuttings were distributed among 2,046 individual containers, each measuring 17x17x13 cm, and suspended across six distinct metal mesh structures of varying elevations (Figure 2).

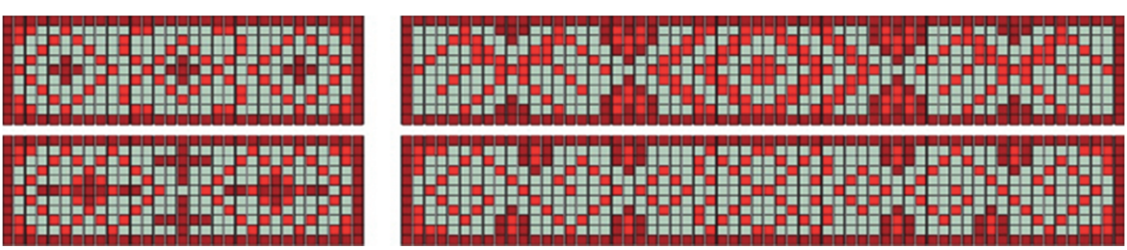

Figure 1. Traditional motif design used in the landscape design
Colour categorization: SS'PW' – red, SS'CB' – light green and SS'P' – dark red

The inventory procedure involved meticulous monitoring and data collection. For each cutting, the following parameters were recorded:

- Survival Rate: The number of specimens from the initial 12,276 cuttings that remained viable throughout the study duration;
- Ramification Count: Each branch, secondary shoot, and offshoot was enumerated to establish the extent and intricacy of growth adaptation in response to the different growth substrates and stress factors.

G.R. (a) C.M. (b) R.S. (c)

Figure 2. (a, b, c) Planting – completion, density and structure

Through this comprehensive methodology, the survival and growth behaviour of the *Sedum* cultivars to the specific growth substrates were systematically assessed.
The collected data may pave the way for a deeper understanding of how these succulents respond to challenging pedoclimatic conditions and provide essential information for both horticultural practices and ecological restoration efforts.

RESULTS AND DISCUSSIONS

In this section, the outcomes of this botanical inventory were presented, shedding light on the survival rates and morphological adaptations of our specimens.
The data presented in Tables 1–3 illustrate the survival and growth patterns of *Sedum spurium* 'Purpur Winter' (S.S.'PW'), *Sedum spathulifolium* 'Cape Blanco' (S.S.'CB'), and *Sedum spathulifolium* 'Purpureum' (S.S.'P') grown in three different substrates (green roof sub-strate, commercial mix, and river sand).

Table 1. Plants inventory for the green roof substrate (G.R.)
X and 1 through 6 mark the number of plants per container, where X is equal to 0

Specification	Plant cultivars	X	1	2	3	4	5	6
number of pots	SS'PW'	3	1	4	4	4	23	109
	SS'CB'	25	32	42	84	76	43	23
	SS'P'	49	37	43	31	26	17	6
initial plant inventory	SS'PW'	888	100%	Total	4,092			
	SS'CB'	1,950						
	SS'P'	1,254						
survived plants inventory	SS'PW'	806	91%	Total	2,272			
	SS'CB'	1,025	53%					
	SS'P'	441	35%					
number of ramifications	SS'PW'	2,292		plants/pot	5.56	stems/plant		15.81
	SS'CB'	4,367			3.42			14.56
	SS'P'	1,984			2.76			12.40

Table 2. Plants inventory for the commercial mix substrate (C.M.)
X and 1 through 6 mark the number of plants per container, where X is equal to 0

Specification	Plant cultivars	X	1	2	3	4	5	6
number of pots	SS'PW'	4	-	-	5	14	26	118
	SS'CB'	14	41	92	105	49	10	18
	SS'P'	43	47	48	24	13	6	5
initial plant inventory	SS'PW'	1,002	100%	Total		4,092		
	SS'CB'	1,974						
	SS'P'	1,116						
survived plants inventory	SS'PW'	909	91%	Total		2,130		
	SS'CB'	894	45%					
	SS'P'	327	29%					
number of ramifications	SS'PW'	5,805		plants/pot	5.58	stems/plant		35.61
	SS'CB'	6,971			2.84			22.13
	SS'P'	2,635			2.29			18.43

Table 3. Plants inventory for the river sand substrate (R.S.)
X and 1 through 6 mark the number of plants per container, where X is equal to 0

Specification	Plant cultivars	X	1	2	3	4	5	6
number of pots	SS'PW'	4	2	1	6	22	47	85
	SS'CB'	30	21	40	64	66	57	51
	SS'P'	86	33	23	16	14	14	0
initial plant inventory	SS'PW'	1,002	100%	Total		4,092		
	SS'CB'	1,974						
	SS'P'	1,116						
survived plants inventory	SS'PW'	855	85%	Total		2,256		
	SS'CB'	1,148	58%					
	SS'P'	253	23%					
number of ramifications	SS'PW'	1,449		plants/pot	5.25	stems/plant		8.89
	SS'CB'	3,288			3.84			11.00
	SS'P'	927			2.53			9.27

Green roof substrate – G.R.

According to the data collected in the inventory, out of the 4,092 cuttings initially planted, only 2,272 managed to survive. These surviving cuttings were further categorized into three groups based on their species.

The first grouping was comprised of *Sedum spurium* 'Purpur Winter' (SS'PW'), encompassing 806 specimens with a survival rate of 91%. The second grouping involved *Sedum spathulifolium* 'Cape Blanco' (SS'CB'), containing 1,025 specimens and exhibiting a survival rate of 53%. The final group consisted of *Sedum spathulifolium* 'Purpureum' (SS'P'), containing 441 plants and displaying a survival rate of 35%.

Among a total of 682 containers, 77 exhibited complete loss of initially planted cuttings, denoted by the symbol 'X' – 3 containers for SS'PW', 25 for SS'CB' and 49 for SS'P'.

The maximum number of SS'PW' containers was 109, each containing six cuttings. The highest number for SS'CB' containers reached a maximum of 84, each housing three cuttings, whereas SS'P' containers peaked at 43, each with two cuttings.

In terms of branching, SS'PW' demonstrated a total of 2,292 newly formed stems, while SS'CB' exhibited 4,367. In contrast, SS'P' displayed the least vigorous growth with 1,984 newly established stems.

Furthermore, averages for the number of plants and stems per container were calculated. For SS'PW', the average was 5.56 plants and 15.81 stems per container. SS'CB' showed an average of 3.42 plants and 14.56 stems per container, while SS'P' exhibited an average of 2.76 plants –the highest amount of plants/pot for this cultivar among all treatments–and 12.40 stems per container.

Commercial mixture of topsoil with traces of dolomite and perlite – C.M.

The acquired dataset unveiled that among a total of 4,092 cuttings initially established, a mere 2,130 managed to persist. Noteworthy among these enduring specimens was SS'PW' again, exhibiting the highest survival rate at 91%. In contrast, SS'CB' displayed a survival rate of 45%, whereas SS'P' demonstrated the least robust survival rate, standing at a mere 29%.

Of the overall inventory involving 682 pots, a subset of 61 pots incurred the complete loss of their plant constituents marked with 'X'– 4 containers for SS'PW', 14 for SS'CB' and 43 for SS'P'. The highest concentration of container was marked by SS'PW' amounting to 118, each accommodating 6 cuttings. Similarly, SS'CB' occupied a maximum of 105 pots, with 3 cuttings/pot. In comparison, SS'P' was limited to 48 pots, each containing 2 cuttings.

When analyzing the growth of ramifications, the data suggests that SS'PW' exhibited a cumulative count of 5,805 newly formed stems, SS'CB' – 6971, and SS'P' – 2,635.

Further dissection of the data highlighted that SS'PW' exhibited an average of 5.58 plants and 35.61 shoots per individual pot, –the highest numbers for plants/pot and shoots/plant for this cultivar among all treatments –. In the case of SS'CB', these figures were reduced to 2.84 plants and 22.13 shoots per pot –the highest amount of shoots/plant for this cultivar among all treatments –, while SS'P' demonstrated an average of 2.29 plants and remarkably, 18.43 shoots per pot –the highest amount of shoots/plant for this plant among all treatments.

River sand – R.S.

Out of 4,092 cuttings that were planted, 2,256 managed to survive. Specifically, SS'PW had a survival rate of 85% with 855 plants, SS'CB had a survival rate of 58% with 1,148 individuals, and SS'P had a survival rate of 23% with 253 individuals.

Out of a total of 682 pots, 120 pots lost the total number of cuttings, 'X' – 4 containers for SS'PW', 30 for SS'CB' and 86 for SS'P', while the maximum number of SS'PW' was 85 pots with 6 cuttings each, the maximum number of SS'CB'/pot was 66 with 4 cuttings each, and the maximum number of SS'P was 33 pots with 1 cutting each.

Regarding stem development, SS'PW' had a total of 1,449 stems, SS'CB' had a total of 3,288 stems, and SS'P' had a total of 927.

In terms of average number of plants and stems per pot, SS'PW' had 5.25 plants and 8.89 ramifications per pot, SS'CB' had an average of 3.84 plants – the highest amount of plants/pot for this plant among all treatments – and 11.00 ramifications per pot, and SS'P' had 2.53 plants and 9.27 newly formed shoots.

The consensus among numerous studies is that the viability and development of plants are intricately tied to the composition of the growing medium. These play a pivotal role in influencing critical aspects like the presence of water and nutrients, the expansion of roots, and soil temperature (VanWoert *et al.,* 2005b; Durhman *et al.,* 2007; Getter, 2009).

For example, insufficient water availability resulting from subpar growing media can induce a state of water stress. This stress impairs plant growth and can lead to wilting and plant death (Arora *et al.,* 2002; Taiz, 2002; Seghatoleslami *et al.,* 2008). The availability of nutrients also holds a pivotal importance in facilitating plant growth (Ampim *et al.,* 2010). Furthermore, the temperature of the soil profoundly influences root expansion, nutrient absorption, and various other physiological processes within plants (Bevington, 1985).

In a study carried out in 2015 (Nektarios *et al.,* 2015) an experiment using a soil-less growing medium placed at deeper levels of 15 cm, combined with higher irrigation, resulted in increased plant height. Significant differences were found in the type of growing medium, suggesting *Sedum* plants may prefer porous substrates. During the initial water-stress period, *Sedum* plants in shallower substrates grew taller than those in deeper ones. This was likely due to the shallow and fibrous root system benefitting more from the shallower substrate.

On the other hand, researchers (Lassalle, 1998; Durhman *et al.,* 2007), have demonstrated that a deeper substrate can retain more water. This characteristic proves beneficial in situations

where water supply is limited, enabling plants to maintain healthier physiological states. Consequently, a deeper substrate tends to enhance the growth rate, survival, and overall development of *Sedum* species (Durhman *et al.,* 2007; Getter, 2009; Thuring *et al.,* 2010).
Nonetheless, researchers (Dunnett, 2004) have found that some sedums didn't experience advantages from extra water present in deeper substrate profiles of 200 mm, unlike some other plant species.
Our results in G.R. and R.S. showed promise, though they may not be visually perfect. However, it's important to note that some irrigation and fertilization would be necessary for healthy plant development. Therefore, choosing the right growing medium is crucial for achieving optimal plant growth and yield.
Besides substrate composition and depth, climate conditions significantly affect plant survival. In a 2021 study by Lee *et al.*, it was found that under 50% shade, plant survival reached 97.1%. This highlights that although *Sedum* plants prefer sunlight for growth, some shade and a cooler micro-climate can be beneficial for their survival.
Another aspect to consider when selecting plants for different designs is their place of origin. For example, in a study (Gurevitch *et al.,* 1986), three distinct groups of *Sedum wrightii* were collected along an elevation gradient – 360 meters, 1,500 meters and 2,400 meters. Their study compared plants under two treatments: "wet" with frequent watering and "dry" with reduced watering. The results were closely linked to the plants' native habitats. Those from 360 m altitude performed best under limited water availability, while plants from 2,400 m altitude struggled.
Planting density matters for *Sedum* plants. Research in Kosovo found that planting them closer together, at 25 plants per square meter, resulted in better coverage. They tested different planting densities (25, 20, and 16 plants/m^2) on green roofs and found that 25 plants/m^2 provided the best horizontal coverage (Balaj, 2017). This information can guide the optimal spacing for *Sedum* mosaics, ensuring efficient area coverage.
In our investigation, even though 54% of the observed plants managed to survive, the complete loss of plants/pots can be seen in Figure 3 – 258 containers of 6 plants.
It's important to highlight that the greatest mortality rate was observed at the outer boundaries of the “work tables”, precisely in the areas most susceptible to severe weather conditions.

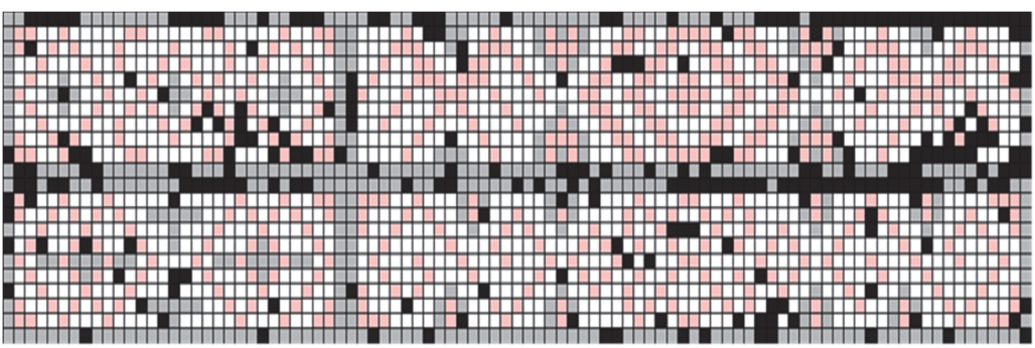

Figure 3. Pot distribution with maximum plant losses
Black cells mark the containers with total plant loss

The findings indicate that *Sedum spurium* ‘Purpur Winter’ (SS’PW’) demonstrated higher rates of survival and newly formed stems across all types of growing media. This plant exhibited a survival rate of 91% in both the green roof (G.R.) and commercial mix (C.M.) substrates, with 85% in the river sand substrate (R.S.). *Sedum spathulifolium* ‘Purpureum’ (SS’P’) displayed the lowest survival rate and the least robust branching across all substrates. This suggests that SS’P’ may not be a suitable choice for this type of design.
Overall, the results show that in comparison to G.R., with a total survival rate of 59.50%, C.M. and R.S. had similar values with 55.10% and 55.39% respectively.

The overall poor survival percentages in R.S. may be due to the lack of proper water and nutrient availability, indicating the importance of selecting appropriate long-term substrates for roof gardens.
SS'PW' exhibited a superior performance across the board. A substantial number of SS'PW' plants survived in all substrates: 5.56 plants/pot in G.R., 5.58 in C.M., and 5.25 in R.S.
Among all the treatments, *Sedum spathulifolium* 'Purpureum' (SS'P') exhibited its highest survival percentage in the green roof substrate (G.R.), with 2.76 plants per pot. On the other hand, the commercial mix substrate (C.M.) had the highest number of stems formed, with an average of 18.43 per pot. Notably, the plants in G.R. showed approximately 8.78% better results in terms of plants per pot compared to those in the C.M., and 1% better results than in the river sand substrate (R.S).
Comparing the experimental treatments, it's apparent that *Sedum spathulifolium* 'Cape Blanco' (SS'CB') and 'Purpureum' (SS'P') have similar values. In contrast, SS'P' displayed the least favorable survival rates, with only 2.76 in G.R., 2.29 in C.M., and 2.53 in R.S.
Furthermore, the data related to plant development favoured the C.M., with SS'PW' boasting the highest number of newly formed stems per pot at 35.61. This was followed by SS'CB' with 22.13, and SS'P' plants with 18.43. On the other hand, in G.R., for SS'PW', SS'CB' and SS'P' the results were less desirable with 15.81, 14.56 and 12.40 newly formed stems per pot. Overall, in R.S., for SS'PW', SS'CB' and SS'P' the results were the worst, with 8.89, 11.00 and 9.27 newly formed stems per pot.

CONCLUSIONS

Creating a floral mosaic demands careful consideration of the substrate used, as it plays a pivotal role in plant growth and survival in roof gardens. Commercial substrates, designed to cater to a wide range of plant types, offer advantages such as a balanced nutrient composition and moisture-retention properties, reducing the need for frequent fertilization and watering. However, it's essential to acknowledge that not all commercial substrates are equally effective, and some may retain too much water, which can be detrimental to certain plants.
In our study, we observed that SS'CB' and SS'P' struggled to thrive in C.M. This indicates that these cultivars may have unique requirements not fully met by this particular substrate. Nonetheless, despite concerns about survival rates, the surviving plants in this substrate managed to produce a significant number of stems per pot, partially offsetting the issue.
SS'PW' demonstrated the best growth and survival in C.M., underscoring the importance of substrate selection for successful roof garden plantings. On the other hand, SS'CB' exhibited the highest survival rate in G.R. and the most newly formed stems in C.M. In contrast, SS'P' performed poorly across all substrates, making it unsuitable for this type of design, especially in environments with long periods of neglect.
These findings emphasize the substantial impact of maintenance, substrate type and climate on plant growth and survival. When incorporating plants like stonecrops into mosaic designs, thorough consideration of their origin and appropriate usage is crucial. While sedums are known for their hardiness and ability to endure challenging conditions, they cannot be simply planted and left unattended, especially in mosaic designs where maintenance is key.
In mosaics, while plant survival remains a key consideration, the benefits of branching and spreading growth should not be overlooked, particularly when designing high-density mosaics with intricate patterns in mind. Ultimately, careful substrate selection and ongoing maintenance are both pivotal factors in achieving vegetation coverage and overall success on green roofs while preserving the desired aesthetic.

REFERENCES

1. Ampim P.A., Sloan J.J., Cabrera R.I., Harp D.A. and Jaber F.H. (2010). Green roof growing substrates: types, ingredients, composition and properties, Journal of Environmental Horticulture, 28(4), 244-252.
2. Arora A., Sairam R.K. and Srivastava G.C. (2002). Oxidative stress and antioxidative system in plants, Current Science, 82(10), 1227–1238.
3. Balaj N. and Balaj S. (2017). *Sedum* vegetation characteristics on extensive green roofs in Kosovo urban areas: Influence of different plant in distances and growing substrate, In 17th International Multidisciplinary Scientific Geo Conference SGEM, pp. 729-73.
4. Benvenuti S. and Bacci D. (2010). Initial agronomic performances of Mediterranean xerophytes in simulated dry green roofs, Urban ecosystems, 13, 349-363.
5. Bevington K.B. and Castle W.S. (1985). Annual root growth pattern of young citrus trees in relation to shoot growth, soil temperature, and soil water content. Journal of the American Society for Horticultural Science, 110(6), 840-845.
6. Cotoz A.P., Dan V.S., Gocan T.M., Andreica I., Rózsa S. and Cantor M. (2023). *Sedum* growth patterns under different pedoclimatic conditions, Plants, 12(14), 2739.
7. Dunnett N. and Nolan A. (2004). The effect of substrate depth and supplementary watering on the growth of nine herbaceous perennials in a semi-extensive green roof. Int. Conf. Urban Hortic., 643. 305-309. 10.17660/ActaHortic.2004.643.40.
8. Durhman A.K., Rowe D.B. and Rugh C.L. (2006). Effect of watering regimen on chlorophyll fluorescence and growth of selected green roof plant taxa. HortScience, 41(7), 1623-1628.
9. Durhman A.K., Rowe D.B. and 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.
10. Getter K.L. and Rowe D.B. (2008). Selecting plants for extensive green roofs in the United States, Michigan State University Extension, East Lansing, MI, USA.
11. Getter K.L. and Rowe D.B. (2009). Substrate depth influences Sedum plant community on a green roof. HortScience, 44(2), 401-407.
12. Gurevitch J., Teeri J.A. and 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, 70:98-204.
13. Kluge M., (1977). Is *Sedum acre* L. a CAM plant? Oecologia, 29:77-83.
14. Lassalle F. (1998). Wirkung von trockenstreßauf xerophile pflanzen. Stadtund Grün, 6(1998), 437-443.
15. Lee J.H., Lim Y.S. and Nam S.Y. (2021). Optimization of shading levels, potting media, and fertilization rates on the vegetative growth of *Sedum zokuriens*e Nakai, 29(4), 239-246.
16. Lu J., Yuan J.G., Yang J.Z., Chen A.K. and Yang Z.Y. (2014). Effect of substrate depth on initial growth and drought tolerance of *Sedum lineare* in extensive green roof system. Ecological Engineering, 74:408-414.
17. Lu J., Yuan J.G., Yang J.Z. and Yang Z.Y. (2014). Responses of morphology and drought tolerance of *Sedum lineare* to watering regime in green roof system: A root perspective, Urban forestry & urban greening, 13(4), 682-688.
18. Nektarios P.A., Ntoulas N., Nydrioti E., Kokkinou I., Bali E.M. and Amountzias I. (2015). Drought stress response of *Sedum sediforme* grown in extensive green roof systems with different substrate types and depths. Scientia Horticulturae, 181:52-61.
19. Ondoño S., Martínez-Sánchez J.J. and Moreno J.L. (2015). Evaluating the growth of several Mediterranean endemic species in artificial substrates: Are these species suitable for their future use in green roofs? Ecological engineering, 81, 405-417.
20. Rayner J.P., Farrell C., Raynor K.J., Murphy S.M. and Williams N.S. (2015). Plant establishment on a green roof under extreme hot and dry conditions: The importance of leaf succulence in plant selection, Urban forestry& urban greening, 15, 6-14.
21. Seghatoleslami M.J., Kafi M. and Majidi E. (2008). Effect of drought stress at different growth stages on yield and water use efficiency of five prosomillet (*Panicum m.* L.) genotypes, Pak. J. Bot, 40(4), 1427-1432.
22. Snodgrass E.C. and Snodgrass L.L. (2006). Green roof plants: a resource and planting guide, (Portland, OR, USA TimberPressInc.)
23. Stephenson, R. (1994). *Sedum*: Cultivated Stonecrops, (Portland, OR, USA TimberPressInc.), pp.27–210.
24. Taiz L. and Zeiger E. (2002). Plant Physiology. Third Ed, Sinauer Associates Inc. Sunderland, MA, USA.
25. Terri J.A., Turner M. and 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.
26. Thuring C.E., Berghage R.D. and Beattie D.J. (2010). Green roof plant responses to different substrate types and depth sunder various drought conditions, HortTechnology, 20(2), 395-401.
27. Van Woert N.D., Rowe D.B., Andresen J.A., Rugh C.L. and Xiao L. (2005b). Watering regime and green roof substrate design affect *Sedum* plant growth. HortScience, 40(3), 659-664.