All Sciences Proceedings

5th International Conference on Applied Engineering and Natural Sciences

July 10-12, 2023: Konya, Turkey

All Sciences Proceedings
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# Use of Cactus and Succulents in Vertical Gardens

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***Abstract –*** A vertical garden is a type of garden created by arranging plants on a vertical surface. It is often used for growing plants on vertical surfaces such as walls, fences, buildings, balconies and terraces in cities with limited garden space. The plants are planted in custom made vertical garden panels or containers and the roots of the plants are placed in a special soil mix in the panel. Special systems can be placed behind the panels for irrigation and fertilization. Vertical gardens provide a suitable environment for many plant species. In such gardens, flowers, herbs, shrubs, vegetables and even trees can be grown. In this paper, cactus and succulents that can be used in vertical gardens will be evaluated.

*Keywords – Cacti, Wall, Vertical Garden, Hydroponic*

## I. INTRODUCTION

The concept of creating a plant surface on the wall dates back to the Hanging Gardens of Babylon (600 BC), one of the seven wonders of the world. In the 17th century, climbing, winding plants, wall ivy, roses, and grapes were wrapped in mansions, castles, and garden fences. In the 1980s, for the first time, such climbing plants were encouraged to reach higher in the vertical plane with a steel cable system (Yıldız, 2014).

The vertical garden was first invented by the French botanist Patrick Blanc. At the age of 13, while searching for a plant to clean aquarium water, he noticed that Philodendron erubescens could grow without soil, feeding only on fish excrement. Continuing his research in the rainforests of Malaysia, Blanc noticed that 2,500 of 8,000 species grow in a soilless and low-light environment on trees and rocks by feeding only on moisture (Tekin, 2012). Based on the nature observations he has made over the years, Blanc (2008) has planned to grow these types of plants in cities.

In the 1990s, the vertical garden system was invented by Patrick Blanc, and for the first time, the plants were started to be kept alive in a vertical plane system in an integrated manner with an automatic irrigation and fertilization system in hydroponic culture. After all these years, the concept of a vertical garden has been both a starting point and a source of inspiration for innovative companies all over the world. Green wall systems in world literature are divided into two categories: green facades and vertical gardens. In short, green facade systems are created by placing potted plants on top of each other or by wrapping climbing plants with steel lines. The vertical garden, on the other hand, is based on a completely different system (Yıldız, 2014).

Vertical gardening is applied to the vertical surfaces of buildings, with or without soil. Vertical gardens can also be used on the exterior wall of the building or as a garden, road, etc. separation wall (İpekçi and Yüksel, 2012). These designs provide the green texture needed, even if there is not enough space to create large green areas (Blanc, 2008). In its simplest definition, it means covering the outer surfaces of buildings with living plants (Lambertini and Leenhardt, 2007).

Patrick first showcased what he calls 'living walls' at the Chaumont Garden Festival in 1994. Upon intense interest, he decided to continue this work and increased the number of walls he greened to over 200. The smallest work is 12 x 30 cm, and the largest is 1500 m2 (Blanc, 2008).

Bringing a new understanding to today's modern architecture, the "vertical garden" is one of the best solutions produced to increase the green effect in the built environment, especially in big cities (İpekçi and Yüksel, 2012). Vertical gardens, which add a new dimension to the usage areas of ornamental plants, have attracted attention in recent years as a new trend in landscape architecture studies in the context of the integration of architecture and nature (Yücel and Doğan, 2012).

### *A. Benefits of a Vertical Garden*

Reducing energy and water consumption
Reducing the urban heat island effect
Increasing indoor and outdoor air quality
Reducing sound pollution
biodiversity
Improving the quality of life of people living in urban areas
Aesthetic contributions
heat insulation
Protecting the building facade
Economic valuation

## II. Application Methods of Vertical Gardens

It is stated that panel system planting is effective in reducing high heat generation, especially on the exterior. It has the feature of being a flexible and modular system, resistant to heavy rains, wind, and earthquake loads, and applicable in all climatic conditions. It can be applied with or without soil. Plant selection, seasonality, and color variations depending on the characteristics of the plant offer different possibilities in terms of visual impact in applications. Waste water or rainwater is also used to meet the water needs of plants (İpekçi and Yüksel, 2012). The panel system is divided into two types: hydroponic and earthed panel systems.

### *B. Hydroponic Panel System*

It is a soilless system. Hydroponic material fulfills the soil function. Plants benefit from a nutrient solution containing the minerals they need to replace the nutrients in the soil. Growing media such as sand, peat, vermiculite, perlite, coconut, rock wool, or expanded clay aggregate are used to support plants and their root systems. The possibility of them retaining moisture around the roots is also increased (Tekin and Oğuz, 2011).

As the weight of the garden is reduced by removing the soil in the hydroponic method, the effect of the load created by the elements carrying the system on the structure is also reduced (Seçkin, 2011). In the system where the water is adjusted to come on top of each panel, the irrigation process is carried out quite easily by dripping down with the help of plants. In addition, the water supplied to the system remains in the system and is reused. Therefore, the water cost is low. In the soilless method, the cultivated soil, which forms the basis of the planting unit, forms a light and solid mass when heated. Thanks to its water retention and drainage features, the planting unit is quite light and economical (Tekin and Oğuz, 2011).

### *C. Soil panel system*

It consists of panels on which pots with soil are placed. Modular panels usually consist of corrosion resistant polypropylene containers, geotextile, an irrigation system, growing medium, and plants. The irrigation system is designed to allow moisture to seep through the panel while at the same time keeping the growth medium in balance.

This design allows a small amount of water reserve in each cell to increase the time between water conversions. Cells are made to allow water to pass from panel to panel. Water flows through each panel, and when it reaches the lowest point of the panels, it is discharged through drainage channels. Irrigation systems are designed with automatic meters for ease of use (Tekin and Oğuz, 2011).

Modular system planting offers landscape architects, designers, and individual users a permanent and comprehensive solution to create refreshing, attractive, natural living green walls made of real plants, adopting the permanent garden environment instead of heat-absorbing, boring, monotonous walls. It is a system created by placing pots of various sizes and shapes on the building facades.

Green surfaces are created on the façade by placing the pots on top of each other and/or side by side. The modular arrangement of the system allows easy fertilization and root pruning of potted plants. By opening holes at certain points between the pots placed in the modular system, liquid flow is provided in the vertical direction, and the irrigation system is carried out effectively. In this way, liquid fertilizer and nutrients are transferred to the plants with the drip irrigation system. In the modular system, the drip irrigation system is placed at the top of the facade system. Thus, the irrigation needs of

all plants in the system are met by ensuring the flow of water from the upper pot to the lower row. Pot modules are assembled on facades or vertical carrier elements made of different materials, such as reinforced concrete, brick, wood, aluminum, and sheet metal elements, by using suitable fixing screws and elements (İpekçi and Yüksel, 2012).

Felt serves as a habitat for plants, and the life of the plants is ensured with the minerals supplemented from the outside. The mineral needs of the plants are met by adding mineral supplements to the water used in the irrigation of the plants. For this reason, mechanical irrigation systems are used in vertical gardens where this system is used.

In this system, the dampness of the felts, which are necessary for the survival of the plants, damages the wall surfaces to which they are attached. Therefore, a waterproof insulation material is used for the layer where the felt layer on which the plants are placed is combined with the wall. A panel is obtained by limiting all these layers with a frame. There is a dropper under the frame to drain the excess water that has accumulated in the felts. Excess water accumulates in this dropper. The water accumulated in this container is reused for the irrigation of plants with the help of a pump (Örnek, 2011).

A vine system is used in the application of ivy-type plants. In this system, shapes are obtained by providing surfaces on which plants can hold in a controlled manner. Plant roots are provided by leaving them at ground level as well as by creating pots and similar environments in the spaces on the facade of the building. In this planting type, drip irrigation is done from the ground where the plant takes root. Metal tensioners and wicker elements are used in the creation of surfaces on which plants can hold (Örnek, 2011).

Metal fence system planting is a method used to create a green screen or a semi-permeable green texture. In this application method, moving and different green texture appearances are obtained by using metal fences in various shapes. The fence height is applied at different heights, depending on the shape of the metal fence and whether it is two- or three-dimensional.

In this application, the selected plant type must be an ivy type (climbing plant). The plant is planted directly or previously in pots and brought to the application area with pots, planted in the ground soil, and watered on the ground (Örnek, 2011). The water needs of the plants are met by the drip irrigation system. The water needed by the plant is delivered to the roots by drippers placed close to the roots on the plastic pipe surface visible on the soil. Thus, the ivy-type plant continues to grow along the plane or surface of the metal fence (İpekçi and Yüksel, 2012).

Apart from the familiar systems, there is a new system called active wall that provides fresh air circulation in the buildings. This is an air circulation green wall system. Plants filter the air with their biofilters and purify the environment from toxic gases and polluted air. In this system, the air moves through a perforated suction channel. Specially developed mini-jets are used to direct the air towards the roots of the plants and accelerate the flow. Thus, the roots allow the plant to digest the toxic gases formed in the air without causing the plant itself to become toxic, and then the cleaned air is given to the environment (Tekin and Oğuz, 2011).

## III. Plant Selection in Vertical Garden Design

Plant selection should be carried out according to the purpose and goal of the design. The type of plant varies according to the light requirements and seasonal characteristics of the surfaces to be applied. Only plant species that can grow in the ecological conditions of the environment in which the buildings are located should be used in planting studies of building surfaces (Üçok, 2014). Many suitable plant species can be used for vertical gardens. For example, approximately 1500 plants and 150 different species were used in the Caica Forum Museum, designed by Patrick Blanc. The integration of the exterior of the building, which covers a large surface, with the greenery is important for the natural life of the city (Yüksel, 2013).

### *A. Use of Succulents and Cacti in Vertical Gardens*

Succulents, which can be easily grown in vertical gardens, rock gardens, and terrace gardens with different arrangements, are plants from the cactus family (Anonymous, 2016a). There are many types of succulents that can live without water for a long time thanks to their high water-holding ability. Creative compositions can be created by using succulent plants together with pebbles, stones, and grass (Anonymous, 2016a).

Succulent and cactus plants are generally known as plants with spiny leaves and fleshy stems. However, the most important feature of succulents and cacti, which have many different species, is the accumulation of water cells in their stems and leaves. For this reason, they have a lot of usage areas as plants that can grow without needing much water. Succulents and cacti, which also perform the assimilation process with their stems, are widely grown in gardens and homes today (Anonymous, 2016b).

Succulents, which can be grown in vases or pots at home with their radiation collector features and easy maintenance, create a different atmosphere in terms of appearance. Cactus and succulents, which can be used in different arrangements in terrace gardens, rock gardens, and vertical gardens, are effective in creating a colorful appearance.

Succulents, which are common in desert and tropical areas, contain many varieties that can be preferred according to their usage areas. Succulent plants that do not need much water can be kept in semi-light or bright environments. In terms of garden landscaping and home decoration, succulents are plants that will provide a very ideal appearance.

Succulent plants that are resistant to high temperatures can grow in dry climates. Since their roots are not very deep in the soil, they can easily survive by absorbing the water accumulated in the soil. Overwatering of succulent plants, which can remain green even if they are not watered for a long time, can cause their roots to rot. For this reason, it is sufficient to wet the leaves. Winter conditions need to be watered every 20–30 days. It does not need direct sunlight. It likes bright and semi-lit environments. Succulent plants that turn yellow when exposed to direct sunlight appear green in low-light conditions (Anonymous, 2016a).

Since succulents hold water in their leaves, petioles, stems, and roots, they do not need a lot of water. In this way, they can live for a very long time without water. Being plants that live in dry climates, they can withstand high temperatures. But they can be damaged if they are exposed to direct sunlight. In the dark, their vitality is lost. They grow healthier in a bright environment that does not receive direct sunlight. Some varieties are not easily damaged unless they are frozen. There are also varieties that are not resistant to the cold. These should be taken to a closed environment in the winter (Anonymous, 2015).

Dozens of different landscaping experiments can be done in vertical gardens with burgundy, purple, blue, green, and yellow flowering succulents. Succulents, which offer rich landscaping opportunities, are often preferred in vertical gardens because they can take many shapes and extend in many ways (Anonymous, 2016a).

The most important point in succulent care is to grow similar species together and to separate the different ones.

Some succulents used in vertical gardens are Echeveria, Senecio, Sempervivum, Haworthia, Sedum, etc (Table 1).

Table 1. Some succulents and cactus used in vertical gardens

| | |
|---|---|
| Graptopetalum paraguayense | Sempervivum ' Black‘ |
| Echeveria 'Afterglow‘ | Sempervivum arachnoideum ‘Robin’ |
| Kalanchoe thyrsiflora | Sempervivum 'Oddity‘ |
| Cyanotis somaliensis | Sempervivum ‘Jungle Shadows’ |
| Faucaria felina | Sempervivum ‘Lysimachia Congestiflora’ |
| Echeveria setosa | Mammillaria bombycina |
| Sedum pachyphyllum | Mammillaria hahniana |
| Euphorbia enopla | Parodia magnifica |
| Aeonium haworthii 'Variegatum‘ | Echeveria agavoides |
| Sedum palmeri | Euphorbia milii |

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