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LIVING WALLS IN URBAN LANDSCAPE

Marta Weber-Siwirska, PhD
Wroclaw University of Environmental and Life Sciences
(Poland)

Relevant to lack of space for urban greenery, green walls becomes to be more and more popular in the big cities landscape. Against the common opinion, green walls are not the discovery of the last decades. They were inseparable element of the Middle Ages houses in region of Mediterranean See. At that time it was mainly Vitis viniphera climbing on building surfaces or bowers as a decorative plant that sometimes gives shadow and fruit.

Decorative aspect of plants is still very important, but currently need for bring greenery into urban areas is connected with their other properties. First of all plants are producer of oxygen which is essentials for life for every organisms, furthermore they have an impact on improvement on local microclimate by ability of temperature reduce as well as moisture control. Plants have also ability to reduce pollution.

In the cities this days, beside popular climbing plants, deferent ways of greenering vertical surface of buildings can be seen frequently. All green walls can be divided into two main groups: green facades based on the application of climbing plants, and living walls systems (LWS). In spite the fact that almost every company installing LWS has their own system structure technology, there are two basic ways of installation: continuous LWS and modular LWS.

Between modular systems it is possible to make further division. When the living wall is already done and plants completely cover the surface of building, the differences between using systems are not noticeable. Decision which technology of living wall structure is the best, depend on building construction and possibilities of additional its wall load as well as planed shape of living wall. Suitable plants selection to chosen system is very important as well. Correctly made living wall is integral part of the building and fulfill all function described before.

Key words: Green wall, city, plant, structure.

Historical Overview. The first green walls were created by nature itself, with no human intervention, as some species of plants do not need any complicated supporting structure to grow vertically. Examples of such spontaneous vertical gardens are common to all latitudes and all climates. However, the hut sealing by a primitive man can be considered the first green wall established deliberately. For sure, some plants often managed to survive in such an unusual place for a couple of years or even longer. A little later, there appeared climbing plants on the walls of buildings. There are records

stating that as early as 2000 years ago in the Mediterranean region grapevines were placed on people's homes, thus transforming their walls into early vertical gardens.

On the other hand, in Central Europe, 500 years ago, grapevine was also the most common creeper on the walls of castles and cities. But almost equally popular were climbing roses – people's favourite ornamental plants (Köhler 2008). In the 19th century, in many European and North American cities, some climbing plants, lignifying with time, were introduced on simple, plain façades. In Central Europe in the 1980s, interest in environmental protection started to grow, which resulted in a tendency to return urban spaces to nature (Köhler and Schmidt 1997).

Especially in German cities, numerous programmes were created which encouraged building owners to plant and care for vines in courtyards and on the walls. At the same time, a lot of scientific papers and theses on the beneficial role of vine were published (Köhler 2008). Today, all the above aspects of green walls are well known as they refer to the general role of plants in an urban environment. It seems, however, that in the case of plant walls the list of possible benefits may even be somewhat longer.

The benefits of setting up green walls. Green walls are an ideal solution to the problem of not having enough greenery in densely populated urban areas. First of all, they significantly increase the aesthetic value of the space where they have been installed. They usually become large parts of the design, perfectly visible to both passers-by and car drivers. Extremely important is the role of plants as producers of oxygen, component necessary for the life of all organisms.

A plant wall of the surface of 155m^2 is able to satisfy one person's daily demand for oxygen (Kania et al. 2013). Moreover, such installations contribute to the improvement of the local microclimate by retaining rainwater and reducing the temperatures on the façades. The difference in the temperature between the bare wall surface and a wall covered with plants can be as high as 12 ^{0}C to 20 ^{0}C, whereas the temperature of the air near the plant wall is reduced by 1^{0}C… 2^{0}C (Chen 2002). Not without significance is the shadow given by the leaves. The ability of plants to reduce urban pollution is also very important. This is done in two ways: the mechanical one, when chemical compounds settle on leaves, and the physiological one when the plants resistant to urban pollution absorb certain amounts of particulate matter. For example, a properly maintained green wall whose surface equals 10m^2 may absorb as much CO_2 during one year as a tree measuring 4m in height (Kania et al. 2013).

There are also examples of combining the vegetation on the walls with the ventilation units supplying the air into the building. Plants alongside with the substrate are used in them as a special type of filter, and the rooms get the air already cleaned. Recently, a lot of attention has been given to increasing the biodiversity in cities. Vegetal walls perfectly fulfil this function by increasing not only the number of plant species, but also of birds, spiders and insects. To some animal species, the plant walls offer residing space, to some others –

feeding. In addition to the environmental benefits, economical ones are also worth noticing. They refer mainly to making some savings on heating and air conditioning, since plant walls are natural insulators that prevent overheating the interior of the building in summer while retaining heat inside in the wintertime.

During hot summers, the temperature gets lowered by an average of 5 ^{0}C inside public buildings with external green walls, which in turn helps to reduce energy consumption while cooling the air by means of using air conditioners (Chen, 2002). In the case of having both a green roof and living walls, the cost associated with air conditioning decreases by an average of 17–79% per annum and the total cost of energy used in the whole building – by 0.6–19.5% (Kuhn 1996, Wong et al. 2009).

Types of green walls. All plant walls can be divided into two basic groups: green facades and living walls (LWS) (Fig. 1). The first group includes the climbers which stick to the walls by themselves (direct green facades) or the indirect ones that require support to be able climb. This support can either be anchored in the ground and reach as high as the facade's tallest point (continuous guides) or be a multi-storey mounting system repeated every one or more floors (modular trellis).

The green facades are undoubtedly cheaper to install than the living walls. This statement applies in particular to direct green façades where virtually the only cost is the purchase of the plants, since planting them can be done on your own. A very important advantage of this solution is that it is exclusively beneficial to the environment because it introduces no mounting hardware. The disadvantages include a limited selection of plants, boiling down to just a few species of native and acclimatized climbers. Another disadvantage is the uncontrolled manner of covering the wall and a long time to wait for the vegetation to cover the entire surface.

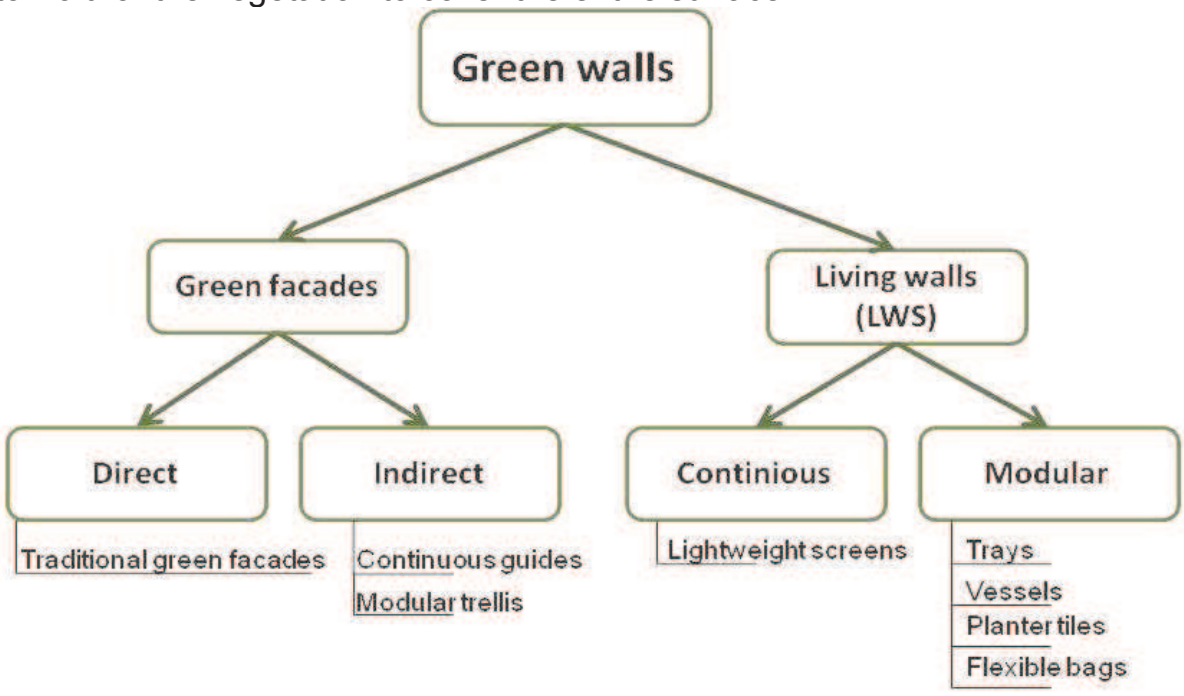

Fig. 1. Diagram of Green walls (Perini et al. 2011)

In the case of indirect greening, the choice is among a slightly larger number of vines which, using modular trellis, will cover the façade much faster. However, they require major financial outlays on the purchase and installation of supports for the plants and an irrigation system running on each floor.

The main advantage of the living walls over green facades is an instant effect of covering the wall with plants. However, they require considerable funding. The cost of green facades does not often exceed €75 / m^2, while the average cost of LWS is approximately €1200 / m^2 (Perini et al. 2011). Such a large difference in cost is related to, among other things, the need to install complex living wall systems. In turn, an advantage of LWS are almost limitless possibilities of selecting the species, while the green facades use climbers only. LWS include continuous living wall systems and modular systems: trays, vessels, planter tiles and flexible bags.

Among the LWS, the continuous living wall system is the one where you do not need any substrate for growing the plants. It involves the use of some textile material of dimensions equal to the wall's surface. The plants are placed in pockets made of the same fabric, and the whole system is stretched on a frame attached to the wall. Water enriched with micro- and macro-elements essential for the plants is supplied through the dripping lines which maintain the material evenly wet over the whole surface.

At the base of the installation there is a tank for unused water. In the tank, a pump is mounted for transporting the water upwards for reuse. The main advantage of these installations, besides the above mentioned immediate vegetation cover, is their relatively low weight and a flexible design which allows giving them any shape and even introducing plants in the corners of the buildings (Fig. 2).

Fig. 2. Continuous living wall system

Due to the low weight, the system is called lightweight screens. The characteristics of its construction do not allow any divisions of its implementation (and thus the cost) into time stages. Associated with this is also the need for frequent maintenance. For example, in case of a viral disease of plants or infection of the substrate, not reacting in due time can lead to ruining the whole system. The need to keep the material in moisture all of the time involves a high consumption of water and nutrients. Constant high humidity of the fabric in which the plants are growing makes it no good place for succulents. Moreover, in their tight pockets, the plants have significantly less space for the roots, which in the case of several species, may adversely affect their shape.

The tray technology has the largest number of variations. Virtually every company applying this system has developed its own installation details. However, the one invariably regular element is the container structure of each panel, with the front part exposed (Fig. 3). Inside the containers there is some substrate in which the plants have to be planted. The substrate is covered with nonwoven fabric or with plastic plates, protecting it against spilling from the container. The last part at the front are the strengthening elements, keeping the whole in a vertical position.

All this is equipped with an automatic irrigation system, passing through each panel. The most important advantages of this system are an easy removal and a possible replacement of single components. Furthermore, the selection of the plants in this case is virtually unrestricted, provided a proper depth of the panels has been planned. Unlike in the previous system, here you can control the degree of hydration and drainage in separate sections. One limitation when choosing this technology may be a heavy weight of the structure, because not every wall can maintain such a high additional load. Another disadvantage is related to the shape of the surface we expect to be covered with greenery, and that factor is connected with the dimensions of the panels (Fig. 4).

Fig. 3. Construction of panels (trays)

Fig. 4. A living wall made by trays

Some form of a merger of the two previously described systems are the wall tiles known as planter tiles, characterised by the beauty of the tiles themselves (Fig. 5). Just like the lightweight screen, it is a system of pockets,

but, similarly to the trays, the tiles have their fixed dimensions. This system is currently used only in the interiors, but one cannot exclude the possibility of applying it also on the external walls.

As for the vessels, they are an integral part of the building, so they should have been planned at the stage of the building being designed by an architect. However, in some cases, an alteration to an already existing building is possible, too.

Fig. 5. Planter panels

Another form of combining a lightweight screen with the trays are flexible bags. It is an in-line arrangement of pockets filled with the substrate in which there are plants (Fig. 6). The main advantage is the possibility of being applied on untypical surfaces, e.g. the curved or inclined ones (Manso et Castro-Gomes, 2015) (Fig. 7). Although it is a system of pockets, just like the lightweight screen, the presence of the substrate and the undefined volume of space for the roots allow an unlimited selection of plants. On the other hand, the heavy weight must be considered its most serious disadvantage.

Fig. 6. Flexible bags

Fig. 7. A living wall made by flexible bags

Summary

A review of the available technologies shows that none of them is definitely the best. Before choosing the type to be used, we must first anticipate the cost of the project. The cheapest solution is climbing plants which will stick to the walls by themselves (direct green facades) and will be planted in the ground. However, if the priority is an immediate effect, we should choose one of the LWS technologies. For buildings with a delicate structure, the best choice is a lightweight screen. In turn, the panel system allows the use of many more plant species. In the case of irregular wall shapes, it is wise to apply flexible bags.

If the most important objective is the aesthetic effect of combining ceramics with the plants, planter tiles will be recommended. Vessels may be an option for those who want a building with plants introduced individually, e.g. by the inhabitants of individual apartments. It is important to remember the heavy weight of most of the systems and adapt this weight to the load-bearing capacity of the wall.

Reference

1. Chen Y., 2002, An investigation of the effect of shading with vertical landscaping In Singapoore. Use of Vegetation in Civil Engineering, London.
2. Kania A., Mioduszewska M., Płonka P., Rabiński J.A., Skarżyński D., Walter E., Weber-Siwirska M., 2013, Principles of design and construction of green roofs and living walls (in Polish: Zasady projektowania i wykonywania zielonych dachów i żyjących ścian). Stowarzyszenie Gmin Polska Sieć „Energie Citiés", Krakow.
3. Köhler M., 2008, Green facades - a view back and some visions, Urban Ecosyst (2008) 11:423-436.
4. Köhler M., Schmidt M., 1997, Verbundene Hof-, Fassaden- Und Dachbegrünung. Landschaftsenteicklung- und Umweltforschung 105: 1-156.
5. Kuhn M., 1996, Rooftop greenering, Eco Architecture.
6. Manso M., Castro-Gomes J., 2015, Green wall system: A review of their characteristics, Renevable and Sustainable Energy Reviews 41(2015) 863-871.
7. Perini K., Otellé M., Fraaij A., Haas E., Raiteri R., Greening the building envelope, facade greening and living wall systems. Open J Ecol 2011; 1:1-8.
8. Wong N. H., Chen Y., 2009, Tropical Urban Heat islands. Climate, building and greenery, New York.

У великих містах дедалі більшої популярності набуває вертикальне озеленення, адже нині урбанізовані середовища характеризуються наявністю дуже обмежених площ під озеленення. Незважаючи на загальноприйняту думку, зелені стіни не є здобутком останніх десятиліть, оскільки вони були невід'ємним елементом ще середньовічних будинків у межах Середземноморського регіону. У цей період найчастіше використовували Vitis vinifera L., який обплітав

фасади будівель та стіни альтанок, одночасно забезпечуючи тінь і приносячи плоди.

Декоративні характеристики рослин і досі є достатньо важливими, проте на сучасному етапі потреба в озелененні урбанізованих середовищ пов'язана з іншими їх властивостями. Насамперед, рослини виробляють кисень, що є першою необхідністю для існування будь-якого живого організму. Крім того, вони впливають на поліпшення мікроклімату за рахунок зменшення температури й підвищення вологості повітря. Також рослини мають властивість зменшувати забруднення навколишнього середовища.

Нині у містах нерідко зустрічаються різні способи озеленення вертикальних поверхонь. Принципи вертикального озеленення можуть бути умовно поділені на дві основні групи: зелені фасади, створені виткими рослинами, та живі настінні системи. Незважаючи на те, що майже кожна компанія, яка встановлює живі настінні системи, має свої власні технологічні прийоми, існує два основних способи їх встановлення: суцільний та модульний.

Варто зазначити, що коли живу стіну вже створено й рослини повністю вкривають фасад будівлі, відмінності між використанням систем не є помітними. Тому вибір технології створення живої стіни залежить від конструкції будівлі та можливостей додаткового навантаження стін. Важливим є й етап підбору рослин для кожної із систем. Отже, тільки за дотримання всіх вимог при створенні живої стіни, вона стає невід'ємною частиною будівлі та повноцінно виконує всі вищезазначені функції.

Ключові слова: зелені стіни, місто, рослини, структура.

В больших городах огромную популярность приобретает вертикальное озеленение, поскольку сейчас урбанизированные среды характеризуются наличием весьма ограниченных площадей под озеленение. Несмотря на общепринятое мнение, зеленые стены не являются достижением последних десятилетий, так как они были неотъемлемым элементом еще средневековых домов в пределах Средиземноморского региона. В этот период чаще всего использовался Vitis vinifera L., который оплетал фасады зданий и стены беседок, одновременно обеспечивая тень и принося плоды.

Декоративные характеристики растений до сих пор очень важны, однако на современном этапе потребность в озеленении урбанизированных сред связана с другими их свойствами. Прежде всего, растения производят кислород, который является первой необходимостью для существования любого живого организма. Кроме того, они улучшают микроклимат за счет уменьшения температуры и повышения влажности воздуха. Также растения обладают свойством снижать загрязнение окружающей среды.

Сейчас в городах нередко встречаются различные способы озеленения вертикальных поверхностей. Принципы вертикального

озеленения могут быть условно разделены на две основные группы: зеленые фасады, созданные вьющимися растениями, и живые настенные системы. Несмотря на то, что почти каждая компания, которая устанавливает живые настенные системы, имеет свои собственные технологические приемы, существует два основных способа их установки: сплошной и модульный.

Следует отметить, что когда живая стена уже создана и растения полностью покрывают фасад здания, различия между использованием систем незаметны. Поэтому, выбор технологии создания живой стены зависит от конструкции здания и возможностей дополнительной нагрузки стен. Важен и этап подбора растений для каждой из систем. Поэтому, только придерживаясь всех требований при создании живой стены, она становится неотъемлемой частью здания и полноценно выполняет все вышеуказанные функции.

Ключевые слова: Зеленые стены, город, растения, структура.

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БІОТЕХНОЛОГІЧНІ АСПЕКТИ АДАПТАЦІЇ РОСЛИН-РЕГЕНЕРАНТІВ *POPULUS TREMULA* L. ДО УМОВ ЗАКРИТОГО ТА ВІДКРИТОГО ҐРУНТУ

С. Ю. Білоус, кандидат біологічних наук

Розроблено методику адаптації рослин-регенерантів Populus tremula L. зеленокорої форми до умов ex vitro та in vivo. Встановлено оптимальні складові та вологість субстрату для адаптації. Досліджено найбільш сприятливий період, спосіб адаптації рослин та час перебування в умовах підвищеної вологості.

Ключові слова: Populus tremula L., рослина-регенерант, адаптація, ex vitro, in vivo.

Заключним, найтрудомісткішим етапом технології мікроклонального розмноження є адаптація рослин-регенерантів [2, 3]. Вибір способу та умов адаптації має першочергове значення.

Передові біотехнології отримання саджанців осики, що відрізняється швидким ростом та стійкістю до серцевинної гнилі, передбачають їх оздоровлення, розмноження мікроклонами у стерильних умовах – методом культури ізольованих тканин і органів рослин. Кінцевий продукт – оздоровлений садивний матеріал найвищої категорії.

На жаль, нині не існує універсальної методики адаптації рослин-регенерантів до умов *in vivo*, яка була б придатна для всіх рослин *in vitro*.