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Effect of substrates on the vertical landscape systems ornamental plant species quality metrics

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Abstract
The experimental study was carried out to understand the effect of interaction between different plant media and different ornamental plant species over plant qualitative growth parameters. From whole experiment it resulted that the S_1 (*Chlorophytum comosum*), S_5 (*Philodendron hederaceum 'Aureum*'), S_9 (*Sansevieria trifasciata 'Hahnii*'), S_{10} (*Peperomia obtusifolia 'Variegata*) were with highest growth rate, plant coverage rate and overall plant quality and the Species like S_4 (*Haworthia glabrata*), S_6 (*Crasulla ovata*) and S_8 (*Philodendron 'Xanadu'*) were recorded lowest growth rate, plant coverage rate. The Plant media like M_1 (Commercial mix) recorder lowest qualitative growth performance. Whereas, M_3 (Arka fermented Cocopeat+ LECA (3:1)) resulted with highest performance for growth rate, plant coverage rate and overall plant quality. The interaction effect showed a significant difference in the growth rate, plant coverage rate and overall plant quality. The obtained data can be utilized for further studies for betterment of vertical gardening.

Keywords: Arka fermented cocopeat (AFC), Lightweight expandable clay aggregates (LECA), growth rate, plant coverage rate, overall plant quality, cation exchange capacity (CEC), air filled porosity (AFP), water holding capacity (WHC) and vertical garden

Introduction
One of the most difficult issues in the twenty-first century will be bringing nature into urban settings and the vertical garden may be the most practical and stunning approach (Shiah and Kim, 2011) [5]. According to Yeang (1997) [7]. "Facade planting emerged as a solution to the challenge of better integrating and relating plants to structures. The concept is that vegetation is a significant indigenous characteristic of a place and in addition to being environmentally important, should be an important regionalist design component. It might also be argued that significantly more greenery should be integrated into the urban environment than is presently the case ".

Vertical gardens provide a wide array of benefits. Experts and non-experts alike agree that the managed introduction or restoration of vegetation into the urban environment may provide a slew of advantages. For millennia, humans have been planting trees and bushes in densely populated areas. When analysing such attempts, there is a unique historical focus on the healing benefits of plants in a built environment. Individual and community well-being was enhanced by exposure to nature. The advantages of vegetation have been demonstrated in recent years and have acquired increasing popularity as a result of scientific research (Ulrich, 1986) [6].

Environmental advantages
1. Lowering the temperature
2. Enhancement of air quality
3. flora and wildlife habitat

Economic advantages
1. More room to work with
2. Insulation against the elements
3. Lowering energy use

Aesthetic advantages
1. Juxtaposing the visual
2. Enhancing the aesthetics of hardscapes
3. Concealing the unpleasant portions

Health Advantages
1. Lowering stress levels
2. De-escalate allergic reactions
3. Inhaling oxygenated air

To begin, an appurtenant framework and modules that are robust, lightweight and visually beautiful should be installed, with an irrigation system integrated, depending on the location and structure of the building and the position where the vertical garden is to be created. Different types of structural components are required for various environmental situations. The height of the building, the height of the green wall, the temperature, humidity, wind speed, rainfall pattern and other elements must all be considered to construct an appropriate and cost-effective structure. Vertical landscapes have been made feasible by the use of current technology that enables a far larger choice of climbing and non-climbing plants to reach previously unthinkable heights. Stronger and lighter trellises, modules and frameworks allow for more design freedom and overall sustainability of the green walls, ensuring that they are trouble-free.

The very next step is to choose a suitable substrate or medium for anchoring the plants. The plants should benefit from it in a symbiotic relationship. Light-weight substrates with adequate aeration, water retention capacity and the ability to retain and feed nutrients to plants are desirable. Some of the media available include rock wool, felt cloth, perlite, vermiculite, cocopeat, LECA (lightweight expandable clay aggregate) balls, biochar and vermicompost. We should investigate the pH of the media, as well as its Cation Exchange Capacity (CEC), Air Filled Porosity (AFP) and Water Holding Capacity (WHC) and employ a medium alone or in combination depending on these parameters to establish the ideal circumstances for plant development. Again, adopting local resources would significantly reduce the cost of setup.

The next task is to choose flora that can flourish in the local climate, has an appropriate growth habit, has aesthetic appeal and the capacity to endure pruning is readily available and is long-lasting. Exotic plant species are often a primary cause of vertical garden failure, demanding plant replacement regularly. Green wall plants should ideally have a slow growth rate, a spreading nature and some unique features of attraction such as smooth, shiny leaves or feathery foliage or leaves of fancy shapes or hirsute and furry leaves or brightly coloured flowers or fronds with tiny leaves arranged in a beautiful pattern and should be visually catchy and soothing overall. The use of plants that are complementary to one another is also important. This is when a person's inventiveness comes into play. It's almost like an artist painting on a large canvas.

Materials and Methods

Location

The experiments were conducted at ICAR-Indian Institute of Horticultural Research, Bengaluru. Which is in Hesaraghatta located 25 km away from Bangalore in Karnataka. The institute is spread over a land area of 263 hectares. Which is geographically situated at a Latitude of 13.135° N, Longitude of 77.493° E Altitude: of 890 meters above mean sea level.

Plant Nursery

An existing shade net facility was utilized to serve as the nursery for the plants. The young plants procured and produced by the division were left in the nursery to get acclimatised and uniform-sized plants were chosen for the study.

Substrate or Growing Media

Different substrates were used in the study in different combinations. Their physical and chemical properties were analysed. The substrates used in the study are as follows:

Growing media

Requirements
1. Weightless media
2. High Water holding capacity
3. High Nutrient holding capacity
4. Good Porosity
5. Neutral pH

The soil is not used since it increases the weight of the green walls.

Commercial Mix

Cocopeat, Perlite, Sphagnum moss, vermiculite, vermicompost, shredded bark and leaf moulds are the common media combinations used.

Perlite

Perlite is a naturally occurring, non-renewable, inorganic, salicaceous volcanic rock that is produced by mining ore and grinding it to desired particle size. Once ground, the crude ore is heated at very high temperatures causing expansion of the ore anywhere between four to twenty times its original volume. This results in a sterile, lightweight, white, porous aggregate that has a neutral pH of 6.5 to 7.5 (Hanan, 1998) [2].

LECA (Lightweight Expanded Clay Aggregate)

Lightweight Expanded Clay Aggregate (LECA) commonly referred to as Grow rock is obtained by heating montmorillonite clay minerals to 69º C, when it expands and forms highly porous calcined clays which are physically and chemically stable.

Arka Fermented Cocopeat

It's a novel substrate for the raising of seedlings. Developed by the solid-state fermentation of the raw coir-pith with the tannase-producing fungal consortium. It has reduced tannins and polyphenols content.

Plant coverage

The spread of the plant was assessed by Visual Scoring methods and grades from 1-4 were given to the plants depending upon the percentage of plant coverage of the modules.

Grade Plant coverage (%)
1. 0-25
2. 26-50
3. 51-75
4. 76-100

Growth rate

The growth rate of the plants was observed and classified

based on their speed of growth on a rating scale from 1-4.

Scale Growth
1. Very slow
2. Slow
3. Moderate
4. Vigorous

Overall plant quality
The plant species were rated according to their growth, coverage, survival rate, aesthetic and visual appearance *viz.*, colour, pigmentation, texture, shapes and variations of leaves and size of foliage during their growth period. Quality was evaluated from 1 to 9 for each character mentioned and the mean was expressed in grades (Zollinger *et al.*, 2006) [8].

Scale Quality
1-3 Poor
3-5 Regular
5-7 Good
7-9 Excellent

Results and Discussion
Plant coverage
The different plant species under study showed a significant difference in their mean coverage grades at the end of the period of study at 150 DAP, in the different substrates used. The species S_1 (*Chlorophytum comosum*), S_9 (*Sansevieria trifasciata 'Hahnii'*), S_5 (*Philodendron hederaceum 'Aureum'*), S_2 (*Syngonium 'White'*) and S_{10} (*Peperomia obtusifolia 'Variegata*) recorded the maximum plant coverage with a mean grade of 4.00, 4.00, 4.00, 3.75 and 3.50, respectively. The species S_4 (*Haworthia glabrata*) was found to have the minimum plant coverage with a mean grade of 2.25 (Table 1).
There was a significant difference in the plant coverage when the performance of the plant species in the different substrates used was recorded at 150 DAP. The higher performance was observed in M_3 (Arka Fermented Cocopeat+ LECA (3:1)) with a mean value of 3.70 and the two treatments M_2 (Arka Fermented Cocopeat) and M_4 (Arka Fermented Cocopeat+ Perlite (3:1)) were on par recording mean plant coverage grades of 3.30 and 3.40, respectively. The treatment M_1 (Commercial mix) showed minimum plant coverage with mean grades of 3.20. The interaction effect showed a significant difference in mean coverage grades with values ranging between 2 to 4 (Figure 1).
The plant coverage is another important character in assessing the performance of the substrates. *Haworthia glabrata*, *Crassula ovata* and *Pandanus pygmaeus* recorded poor plant coverage. All the other species showed good coverage rates. *Chlorophytum comosum*, *Sansevieria trifasciata 'Hahnii'* and *Philodendron hederaceum 'Aureum'* showed the highest coverage (4 each respectively) in all substrates. It was interesting to find that the plant coverage was markedly lesser in all the plant species in M_1 (Commercial mix) (3.20 respectively) and best plant coverage (3.70) was observed in M_3 (Arka Fermented Cocopeat+ LECA (3:1)) and good plant coverage was observed in other treatments. This might be due to the interaction effect of cocopeat and LECA. This is in agreement with the findings of Samadi (2011) [4] on cucumbers. The plant coverage is a prime factor in the case of vertical gardens as the splendor of the green wall can be relished only when the plants spread and cover the entire area of the display and this to a greater extent depends on the growth habit of the plant and its growth rate. The plants in the study were graded based on their growth rate and coverage. The succulents had a very slow growth rate which again resulted in very low coverage. Hence, if one is keen on using succulents in green walls, it would be wise to use a scheme populated entirely by succulents as their growth rate and water requirements are contradictory to other plants, else it would not synchronize. Plants with very aggressive growth rate as well as very slow growth rate are inapposite for vertical gardens as the former would lead to wild growth, resulting in smothering of the other plants, while the latter would not cover the base structure, leaving bald pockets in between and thus both affecting the overall homogeneous visual effect. This excellent performance of the outdoor plants would be because most plants chosen are hardy and tolerant to the temperature, light, wind and relative humidity conditions prevalent in the place of study, which is in line with the theory laid out by Patrick Blanc (2011) [1] in his book 'The Vertical Garden'. Jain and Janakiram (2016) [3] have stated that plant selection should be based on local climatic conditions. Plants should have a compact growth habit which is likely to provide thick and dense cover. It would be ideal if plants have short growth habits, shallow fibrous root systems and long life cycles.

Growth rate
The species S_1 (*Chlorophytum comosum*), S_2 (*Syngonium 'White'*) and S_5 (*Philodendron hederaceum 'Aureum'*) recorded the fastest growth rate with a mean grade of 3.75 each. The species S_6 (*Crassula ovata*) was found to have the slowest growth rate with a mean grade of 2 (Table 1).
The impact of the different substrates on the growth rate of the species was less significant as all the species of species showed almost similar kind of overall growth and performance in the treatments M_2 (Arka Fermented Cocopeat), M_3 (Arka Fermented Cocopeat+ LECA (3:1)) and M_4 (Arka Fermented Cocopeat+ Perlite (3:1)) with the mean grade of 3.20 and the lowest was observed in M_1 (Commercial mix) with the mean of 2.60 at 150 DAP in the experiment. The interaction effect showed a significant difference with mean growth rate values ranging between 2 and 4 (Figure 1).
The growth rate of the plants is another important factor of significance for the plant growth in vertical gardens should neither be too slow for that would leave the base exposed nor be too fast as it would smother the other plants in the green wall. So, it should have a medium-fast growth rate to cover the structure. *Crassula ovata* had a very slow growth rate while all the other plants had the desirable rate of plant growth. The substrate used did not have any effect on the growth rate of the plants as a similar pattern of growth was observed in all the plants in all the media. The plants are grown in M_1 (commercial mix) alone showed a slight decrease in their growth rate.

Overall plant quality
There was a significant difference in the mean overall performance of the ten species of species studied. The species S_2 (*Syngonium 'White'*), S_9 (*Sansevieria trifasciata 'Hahnii'*), S_{10} (*Peperomia obtusifolia 'Variegata*) and S_1 (*Chlorophytum comosum*) had a very good overall performance with mean values of 8.38, 7.63, 7.56 and 7.25, respectively. The species P_8 (*Philodendron 'Xanadu'*) recorded the lowest mean overall performance value of 5.69 (Table 1).

The effect of the substrates on the overall plant growth and performance was highly significant with the treatment M_3 (Arka Fermented Cocopeat + LECA (3:1)) found to have the best overall plant quality with a mean value of 7.39 and the treatment M_1 (Commercial mix) recorded the poorest overall plant quality with a mean plant quality grade of 5.92. The interaction effect showed a highly significant difference in the plant quality grades with the mean grades ranging between 5 and 9 (Figure 1).

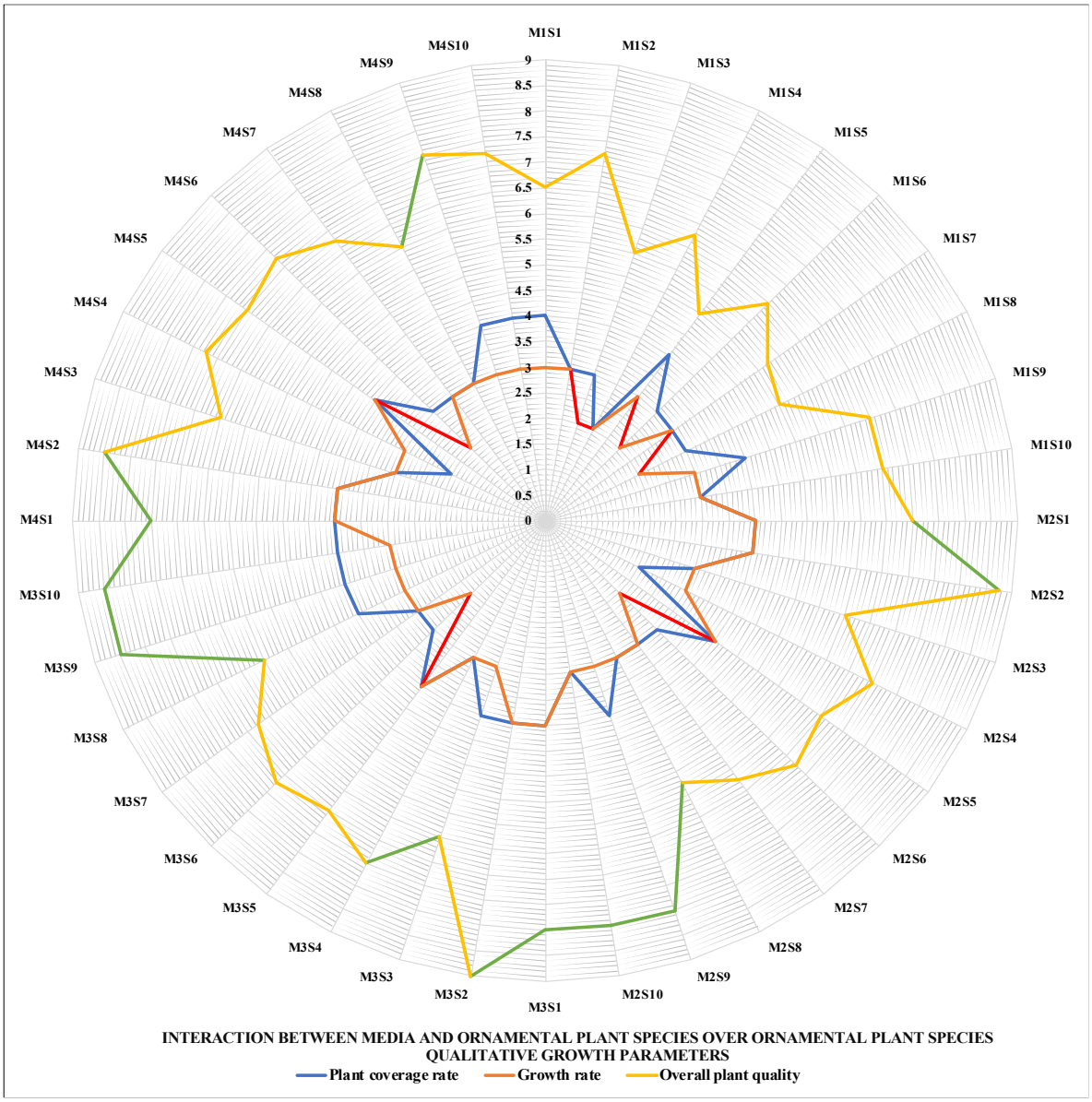

Fig 1: Comparison between different plant qualitative growth parameters over media and ornamental plant species interaction

Table 1: Effect of substrates on ornamental plant species qualitative growth parameters

Factors	Plant coverage rate	Growth rate	Overall plant quality
Differential media concentration			
M_1	3.20	2.60	5.92
M_2	3.30	3.20	6.89
M_3	3.70	3.20	7.39
M_4	3.40	3.20	7.14
Different Ornamental plant species			
S_1	4.00	3.75	7.25
S_2	3.75	3.75	8.38
S_3	3.25	2.75	6.13
S_4	2.25	2.75	7.00
S_5	4.00	3.75	6.38
S_6	3.00	2.00	6.81
S_7	3.00	3.00	6.25
S_8	3.25	2.75	5.69
S_9	4.00	3.00	7.63
S_{10}	3.50	3.00	7.56

Where,
M_1 -Commercial mix
M_2 -Arka fermented Cocopeat
M_3 -Arka fermented Cocopeat+ LECA (3:1)
M_4 -Arka fermented Cocopeat+ Perlite (3.1)
S_1- *Chlorophytum comosum*
S_6- *Crasulla ovata*
S_2- *Syngonium 'White'*
S_7- *Pandanus pygmaeus*
S_3- *Spathiphyllum walliissii*
S_8- *Philodendron 'Xanadu'*
S_4- *Haworthia glabrata*
S_9- *Sansevieria trifasciata 'Hahnii'*
S_5- *Philodendron hederaceum 'Aureum'*
S_{10}- *Peperomia obtusifolia 'Variegata*

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