Study of the effect of substrates on the ornamental traits of crops used in vertical gardening

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Abstract. In modern ornamental horticulture, there are many species and varieties of plants, particularly indoor crops, which can be used for vertical gardening. This contributes to the creation of favorable conditions for humans. The paper presents the results of analysis of growth and development, as well as evaluation of ornamental traits of some ornamental indoor crops (*Elettaria cardamomum*, *Tradescantia pallida*, *Senecio macroglossus 'Variegatus'*, *Epipremnum pinnatum*, *Pelargonium zonale*, *Cissus alata*, *Hedera helix 'Glacier'*, *Peperomia clusiifolia*, *Zebrina pendula*, *Syngonium podophyllum*, *Nematanthus gregarius*, *Spathiphyllum floribundum 'Vivaldi'*, *Callisia repens*, *Spathiphyllum wallisii*) when grown in different substrates in a winter glazed greenhouse for further use in vertical gardening. The greatest growth was revealed in *E. pinnatum* (using a mixture of peat and vermiculite - 16.8 cm, peat - 12.3 cm), among annual flowering crops - in *D. repens* (using a mixture of peat, vermiculite and perlite - 18.8 cm, a mixture of peat and perlite - 17.1 cm). *S. floribundum* (90 points), *S. wallisii* (82-90 points), and *T. pallida* (85-90 points) were the most decorative on a 100-point scale in all variants of the experiment; among annual flower crops, *P.* × *hybrida* (38-42 points) and *D. repens* (44 points).

1 Introduction

One of the modern trends in ornamental horticulture is vertical gardening. However, unfortunately, at the moment there are not enough studies that would affect the choice of specific plants in the creation of sustainable vertical phytomodules for indoor landscaping. The main crops for creating phytowalls in interiors are tropical and subtropical plants. The leaders are unpretentious species that can grow even in restricted conditions. Most often research papers related to interior landscaping involve representatives of the following genera: *Saintpaulia* H.Wendl., *Spathiphyllum* Schott in Schott & Endl., *Chlorophytum* Ker Gawl., *Ficus* L., *Tradescantia* Ruppius ex L., *Epipremnum* Schott, *Hedera* L., *Pelargonium* L'Hér. ex Ait., *Begonia* L., *Fuchsia* L., *Syngonium* Schott, *Pilea* Lindl. Recently, *Citrus limon* (L.) Osbeck) and *Schefflera* J.R.Forst. & G.Forst have been mentioned as indoor plants for landscaping [1-15].

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When creating compositions of indoor plants, special attention should be paid to substrates that should be porous, non-compact, air- and water-permeable and have a suitable acidity level (pH). This is because the root system of plants is constantly confined to the limited space of the container, where the substrate is frequently flushed with water, rapidly depleted and prone to compaction and changes in acidity. Many soil mixes use peat, which is the main component of the vast majority of ready-made substrates. This material does not always create favorable conditions for the growth and development of plants, because if the moisture content of peat is less than 60-65%, it is worse wetted when shedding plants. Due to the uneven structure of peat, the upper layer quickly dries out, and the lower layer remains moist. To improve the quality of substrates use inert minerals such as perlite, zeolite, vermiculite, expanded clay, coconut fiber and tree bark. These components allow the substrate to become more friable, increase its absorption capacity, air permeability, and prevent caking and compaction of the soil mixture [16].

Studies on the influence of substrates on plant growth and development usually focus on the aspect of seed germination or rooting of cuttings, and much less often on the influence on the growth of already formed shoots [17-20]. Nevertheless, some experiments with annual crops (eschscholzia, marigold, lion's green, velveteen) show that the dynamics of plant height change depends not only on the selected substrate, but also on the growth regulator used [21].

The results of one of the foreign studies involving the effect of different substrates on morphological parameters of *Epipremnum pinnatum* (L.) Engl. show that there are no significant differences in shoot length between plants grown on different variants of substrates such as sphagnum, a mixture of sphagnum with silica sand, and a mixture of leafy soil with silica sand [22]. However, it was observed that plants planted in sphagnum and coconut fiber substrate at a ratio of 1:3 had significantly larger leaves than those in other soil mixtures. The highest number of seedlings was observed in the substrate made of leafy soil and silica sand at a ratio of 1:1, while the highest number of leaves was observed in the mixture of leafy soil and coconut fiber at a ratio of 3:1.

In 2020, an experiment was conducted at the College of Agriculture in Nagpur (India) to find out how different substrates affect the characteristics of *Calendula officinalis* L. plants (in particular, shoot growth). The highest shoot growth was recorded in a potting mix of garden soil, manure, biohumus and coconut fiber in a 2:1:1:1:1 ratio, while the minimum growth was recorded in a 2:1:1:1 mix of garden soil, sand and coconut fiber. The researchers concluded that the active growth was due to the high carbon content promoting photosynthetic activity and division in the plants, leading to enhanced vegetative growth [23]. Another work conducted under the auspices of Malaysian Agricultural Research and Development Institute (MARDI) [24] showed that the growth rate of *Tradescantia* plants was significantly better on a soil mixture of coconut fiber, fertile soil layer, and sand in equal ratio: such soil mixture was much more conducive to the growth of vegetative parts of the plant and the emergence of new stems and leaves compared to other substrates. A similar study conducted by researchers from Pakistan using *Antirrhinum majus* L. showed that the maximum growth of 13.5 cm was observed in a mixture of leafy soil, silt and topsoil (1:1:1) [25]. Experiments with *Petunia grandiflora* and *Nicotiana alata* Link & Otto of the University of Pitesti (Romania) revealed that plants grown in substrates made of Biolan peat (60%), acidic peat (30%) and perlite (10%) had the highest ornamental quality [26].

In addition, positive results on survival, rooting and values of morphological parameters of plants when using mixtures of peat with perlite and vermiculite were observed in experiments on rooting of cuttings and adaptation of microplants to soil conditions of various berry crops, including those differing in ornamental traits [27-42].

To date, many applied materials on the topic of plant selection for interior landscaping and care recommendations are available, but there are not many scientific materials, and often the authors rely on old sources. This confirms the need for new research in the field of

phytodesign. In this paper, plants not quite usual for creating phytowalls are used, in particular annual flower crops. The results of the study will provide additional information about the nature of cultivation and maintenance of these crops.

The aim of the research is to analyze the growth and development indicators, as well as to evaluate the ornamental traits of some ornamental indoor and annual flower crops depending on the substrate used for their use in vertical gardening.

2 Materials and methods

The following crops frequently used in interior landscaping were selected as objects of the study: *Elettaria cardamomum* L., *Tradescantia pallida* Rose, *Senecio macroglossus* DC. *'Variegatus'*, *Epipremnum pinnatum* Schott, *Pelargonium zonale* L., *Cissus alata* Jacq., *Hedera helix* L. *'Glacier'*, *Peperomia clusiifolia* Jacq., *Zebrina pendula* Schnizl., *Syngonium podophyllum* Schott, *Nematanthus gregarius* D.L. Denham, *Spathiphyllum floribundum* Linden & André *'Vivaldi'*, *Callisia repens* Jacq., *Spathiphyllum wallisii* Regel, *Petunia* × *hybrida* Vilm.), *Dichondra repens* J.R.Forst. & G.Forst., *Pelargonium peltatum* (L.) L'Hér., *Antirinum majus* L. *'Tom Thumb'*, *Chaenostoma cordatum* (Thunb.) Benth. *'Snowtopia'*.

The studies were conducted in 2022-2023 on the territory of the S.I. Rostovtsev Botnik Garden (on the base of the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy) in a glazed rack greenhouse consisting of several blocks connected by a corridor. The average air temperatures during the day were +22...+24ºC, relative humidity was 65-70%.

In the course of the study to reveal the influence of substrate composition on the growth and development of ornamental indoor crops, 2 variants of the experiment were considered: 1) peat (control); 2) peat + vermiculite (3:1). For ornamental crops grown as summer plants, the experiment variants were: 1) peat + perlite (3:1) (control); 2) peat + perlite + vermiculite (2:1:1). Measurements of morphometric parameters of each plant, including shoot size, were made every 10-14 days. In addition, the above-ground part of plants was sprayed with Cytovit at a concentration of 1.0 ml per 1 liter of water once every 2 weeks.

The assessment of crop ornamentality was carried out using a 100-point system according to the following attributes: leaf resistance to burnout, color intensity, plant habitus (shape, ornamentality), plant condition (variety uniformity). The method of V.N. Bylov [18] was taken as a basis, which was revised for the crops under study. For indoor crops, the assessment of decorativeness was carried out in the spring period, when there is active growth and development of plants, for annual flower crops - in the summer period. Statistical processing of experimental data was carried out using commonly used methodologies [43, 44].

3 Results and discussion

In the process of research it was found that the dynamics of shoot growth in all the studied cultures had differences depending on the variant of experiments. The greatest growth was observed in *E. pinnatum*: in the experiment variant vermiculite + peat this index amounted to 16.8 cm (this crop grows well on substrates with loosening components), in the experiment variant with peat - 12.3 cm. Significant growth was observed from the first measurements, which was maintained until the end of the research. We also noted a significant growth dynamics in *Z. pendula* on different substrates, which had similar indicators: 9.4 cm in the variant with a mixture of peat and vermiculite and 7.0 cm in the variant with peat. The growth dynamics of *T. pallida* and *S. podophyllum* was most noticeable in the experiment variant with peat - 11.6 and 7.4 cm, respectively (Table 1).

Table 1. Dynamics of growth dynamics of above-ground parts of indoor ornamental crops on peat substrates, cm.

Crop	Shoot length, cm				Total growth, cm
	10.02.2023	24.02.2023	09.03.2023	23.03.2023	
Peat + vermiculite (3:1)					
Callisia repens	5.3	5.3	5.3	5.5	0.2
Cissus alata	1.7	3.2	4.8	5.7	4.0
Elettaria cardamomum	3.0	7.3	7.3	7.3	4.3
Epipremnum pinnatum	13.5	22.5	24.5	30.3	16.8
Hedera helix	4.8	4.8	7.6	8.4	3.6
Nematanthus gregarius	1.1	1.2	1.2	1.4	0.3
Pelargonium zonale	1.7	2.0	2.0	3.3	1.6
Peperomia clusiifolia	1.2	1.7	1.7	1.8	1.6
Senecio macroglossus	1.9	1.9	1.9	3.2	1.3
Spathiphyllum floribundum	2.8	2.8	3.6	4.0	1.2
Spathiphyllum wallisii	2.6	5.0	5.0	5.0	2.4
Syngonium podophyllum	4.8	4.8	6.0	11.0	6.2
Tradescantia pallida	11.1	14.8	20.1	20.1	9.0
Zebrina pendula	3.7	6.0	9.0	13.1	9.4
Peat (control)					
Callisia repens	2.2	4.1	4.1	4.5	2.3
Cissus alata	2.9	4.8	5.7	10.2	7.3
Elettaria cardamomum	4.2	4.2	4.3	4.3	0.1
Epipremnum pinnatum	1.9	2.2	8.5	14.2	12.3
Hedera helix	15.3	15.3	15.3	15.3	0.0
Nematanthus gregarius	1.0	2.4	2.4	2.4	1.4
Pelargonium zonale	3.0	3.0	3.5	5.0	2.0
Peperomia clusiifolia	1.0	1.3	1.3	1.8	0.8
Senecio macroglossus	0.8	1.5	1.5	1.5	0.7
Spathiphyllum floribundum	2.3	2.8	2.9	2.9	0.6
Spathiphyllum wallisii	2.3	3.4	3.4	4.1	1.8

Syngonium podophyllum	0.5	0.5	7.9	7.9	7.4
Tradescantia pallida	15.8	19.0	27.4	27.4	11.6
Zebrina pendula	5.1	9.0	12.1	12.1	7.0
				$LSD_{05\ total}$*	4.6

*LSD stands for the least significant difference.

In other studied crops, even if growth was observed, these indicators were insignificant. For example, there was no growth in *H. helix* in the experiment variant with peat. *N. gregarius* showed weak growth in both variants of the experiment. We observed a jump in growth in *E. cardamomum* present at the beginning of the experiment in the variant of using a mixture of peat and vermiculite, but then the growth stopped. The obtained data are confirmed by the results of analysis of variance: the share of substrate influence in this experiment was the greatest and amounted to 74.5%.

The diagram (Figure 1) most clearly shows the results of observations on the growth of the studied ornamental indoor crops depending on the variant of experiments.

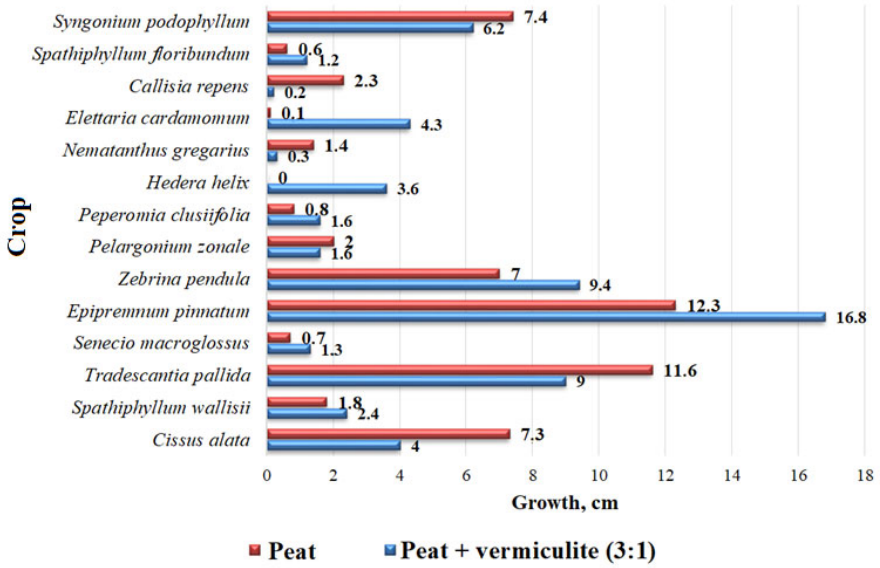

Fig. 1. Above-ground growth of ornamental indoor crops, cm.

The results obtained make it possible to estimate the growth rate of ornamental crops, which should be taken into account when selecting plants for vertical gardening. One of the essential points is to use plants that have a similar growth rate and curl well, completely covering the structures.

The growth rate of annual flower crops was much more active compared to indoor flower crops (Table 2).

Table 2. Dynamics of growth of the above-ground part of annual flower crops on peat substrates, cm.

Crop	Shoot length, cm				Total growth, cm
	04.07.2023	18.07.2023	29.07.2023	06.09.2023	
Peat + perlite + vermiculite (2:1:1)					
Antirinum majus	13.9	20.5	22.2	25.6	11.7

Chaenostoma cordatum	6.9	8.6	16.7	17.1	10.2
Dichondra repens	8.9	13.4	16.3	27.7	18.8
Pelargonium peltatum	9.5	14.2	17.0	22.0	12.5
Petunia × hybrida	8.9	8.9	12.9	20.1	11.2
Peat + perlite (3:1)					
Antirinum majus	6.2	8.7	14.4	14.4	8.2
Chaenostoma cordatum	5.5	6.6	8.9	8.9	3.4
Dichondra repens	7.1	10.4	15.7	24.2	17.1
Pelargonium peltatum	3.5	5.8	8.3	16.2	12.7
Petunia × hybrida	12.9	12.9	12.9	20.1	7.2
				$LSD_{05\ total}$	4.1

The greatest growth was observed in *D. repens* in both experiment variants: in the variant using a mixture of peat with vermiculite and perlite, the growth amounted to 18.8 cm, peat with perlite - 17.1 cm. In *P. × hybrida*, despite the same length of shoots on the last date of measurement, the greatest growth of 11.2 cm was observed when growing in the variant of using a mixture of peat with vermiculite and perlite.

The growth of *P. peltatum* was almost the same in both variants of the experiment. In *Ch. cordatum*, significant growth was observed in the experiment variant vermiculite + peat + perlite and amounted to 10.2 cm. The share of substrate influence amounted to 61%. This is probably due to the fact that the growth and development of annual flower crops under cultivation in protected soil conditions depends on the growing conditions, which include the substrate used, illumination, air temperature and humidity, frequency and quality of watering, and the size of the containers used.

The results of observations on the growth of annual flower crops depending on the variants of experiments are most clearly shown in the diagram (Figure 2).

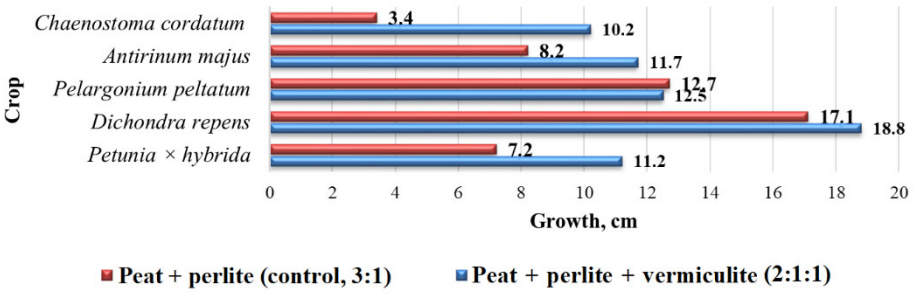

Fig. 2. Growth of the above-ground part of annual flower crops, cm.

The plants used in vertical landscaping should have a certain complex of decorative features to create harmonious compositions. Having analyzed the decorativeness of the studied crops for the purpose of their prospective use in vertical gardening, it can be noted that not all of them have fully manifested their decorative features. The highest score of decorativeness in all variants of the experiment was obtained by the following cultures: *S. wallisii* (82-90 points) - due to the intense and bright color of leaves; *T. pallida* (85-90 points) - due to the active growth and color of leaves; *S. floribundum* (90 points) - due to the rich green color and glossy texture of leaves, well filling the space (Figure 3).

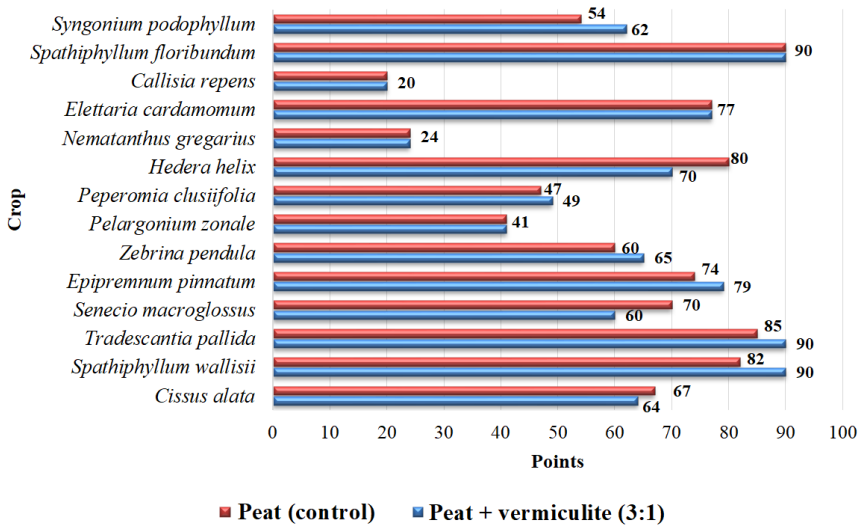

Fig. 3. Diagram of the assessment of ornamentality of indoor crops.

The lowest number of points in both variants were scored by *N. gregarius* (24 points), which poorly filled the space, leaving voids, and *C. repens* (20 points) due to the unsatisfactory condition of the plant and weak growth.

According to the results of the assessment of ornamental value of annual flowering crops, it was noted that all the studied crops in all variants of experiments scored low points (16-32 points). However, *P. × hybrida* and *D. repens* scored slightly higher (38-44 points). Plants experienced reduced turgor in shoots and leaves associated with high temperatures in greenhouse conditions, low quality of flowering due to fewer formed flowers (Figure 4).

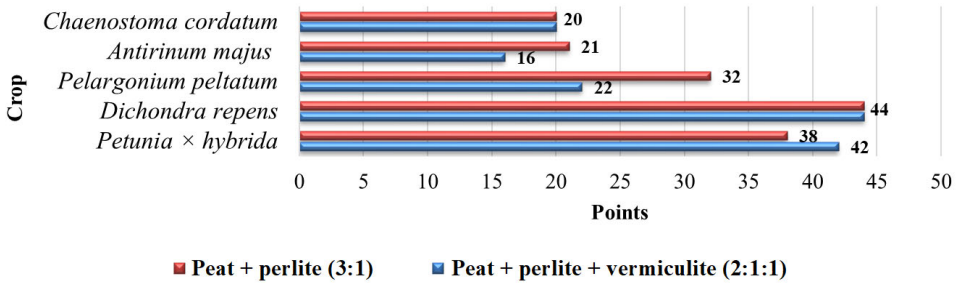

Fig. 4. Diagram of annual flower crops decorativeness assessment.

A. majus in both experiments scored the lowest ornamental value due to partial wilting of plants, low quality of formed flowers and their coloring.

Perhaps, it is necessary to consider more resistant varieties of these plants, or to develop a system of measures for the care and maintenance of these plants, which will allow them to show their decorative features in full.

4 Conclusion

Thus, as a result of the conducted research it was found that the highest growth values of the studied ornamental indoor plants were observed in *E pinnatum* and *Z. pendula* in the

experiment variant with a mixture of peat and vermiculite, as well as *T. pallida* and *S. podophyllum* in the experiment variant with peat. Among annual flower crops, the greatest growth was observed in *D. repens* in the experiment variants with a mixture of peat, vermiculite and perlite and with a mixture of peat and perlite. According to the results of the assessment of decorativeness of the studied indoor crops, *S. floribundum*, *S. wallisii* and *T. pallida* scored the highest score in all variants of the experiment (up to 90 points). Most of the studied annual flower crops in all variants of experiments scored low (up to 32 points), with *P.* × *hybrida* and *D. repens* scored slightly higher (up to 42-44 points). In general, the studied crops have the potential for ornamental value, provided that additional care and maintenance activities are carried out. When developing care technologies, it is recommended to pay attention to the use of other components in the substrate, which can influence the growth and development of plants and increase their decorative attributes.

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