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# Evaluation of Indoor Ornamental Plants Suitable for Indoor Vertical Garden in Response to Different Nutrient Formulations

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***Abstract***: There is limited scientific information regarding the appropriate fertigation required influencing various growth and physiological parameters of indoor ornamental plant species for an indoor vertical gardening under Indian conditions. The experiment was therefore set up with the objective to determine optimum concentration of nutrient formulations for successful installation of vertical garden by using eight indoor ornamental plant species i.e. *Aglaonema angustifolium*, *Dracaena compacta* (Red), *Dracaena godseffiana, Scindapsis aureus, Schefflera arboricola variegata, Syngonium podophyllum, Philodendron selloum* and *Schefflera arboricola*. These were grown in soilless media consisting of cocopeat, perlite and vermiculite in the ratio 3:1:1 with four concentrations of Hoagland nutrient solution (25 %, 50 %, 75 % and 100 % of Hoagland's solution) and the fifth concentration was self-composed nutrient formulation. Experimental design was factorial completely randomized design (CRD) keeping three replications in each treatment. NF IV (100 % of the Hoagland's solution) proved significantly better over other treatments in terms of plant growth and physiological characters under indoor conditions. Best five species based on performance of various parameters studied were *Schefflera arboricola, Dracaena godseffiana, Philodendron selloum, Syngonium podophyllum* and *Scindapsis aureus*.

***Keywords***: Hoagland solution, Nutrient formulations, Indoor vertical garden, Indoor ornamental plant species

With increasing urbanization, a large population is shifting from rural to urban areas resulting in congested cities and towns leading to a limited horizontal space for greenery and landscaping. Integration of sustainable development into urbanization is anticipated as the solution of this complex situation. Vertical gardening is one such solution to this problem which is an innovative urban greening technique for limited urban spaces alternative to traditional systems of landscaping and presents substantial ecological and aesthetic opportunities. Since, most of the urban population spends most of their time indoors where air pollution can be several times higher than outdoors, hence, the quality of the indoor environment has become a major health concern. Indoor' potted-plants can remove air-borne contaminants such as volatile organic compounds (VOCs), over 300 of which have been identified in indoor air (American Lung Association 2001). Creating an indoor vertical garden can help in mitigating these and many more health related issues besides offering a high aesthetic and impact value thereby, making our cities more sustainable and help addressing environmental concerns of the citizens. As the indoor vertical gardens are grown on the walls, the growing medium other than permitting satisfactory growth of the plants and firmness to the roots, ought to be light in weight as it might influence the load capacity of the building walls hence, the use of soilless media i.e. coco peat, perlite and vermiculite possibly satisfies the essential prerequisites. Also, the nutrient supply to the indoor ornamental plants species which are to be used in the indoor vertical garden influences plant growth in many aspects. The growth of the indoor plants is not only influenced by the macronutrients but also micronutrients. Therefore, the nutrient solution which contains all necessary nutrients required for optimum plant growth would be a key factor on the growth. Hoagland solution was thus selected as it is one of the most adequate sources of macro and micro nutrients used in the soilless cultivation of plants. However, lack of scientific data related to the suitable nutritional requirement for indoor ornamental plant species for an indoor vertical garden especially under Indian conditions makes the current research of paramount significance. The importance of the study becomes more valuable as this is the first work being done on various aspects of indoor vertical gardening involving indoor ornamental plant species under Indian conditions. The experiment was thus initiated to evaluate indoor plants and to standardize their nutrient requirement for a functional indoor vertical garden.

## MATERIAL AND METHODS

The study was conducted at Punjab Agricultural University, Ludhiana, Punjab which is located at 30º 54' North (latitude) and 75 º 48' East (longitude) at the height of 247 m above the sea level. Eight indoor ornamental plant species i.e. *Aglaonema angustifolium*, *Dracaena compacta* (Red), *Dracaena godseffiana, Scindapsis aureus, Schefflera arboricola variegata, Syngonium podophyllum, Philodendron selloum* and *Schefflera arboricola* were selected on the basis of their popularity and suitability among the common household for growing under indoor conditions and planted in 15 cm pots filled with media consisting of cocopeat, perlite, and vermiculite in the ratio 3:1:1. The experiment consisted of five treatments four of which included fertigation using modified Hoagland solution (Hoagland and Arnon 1950) i.e. 25 % of the Hoagland's solution (NF I) (control), 50 % of the Hoagland's solution (NF II), 75 % of the Hoagland's solution (NF III) and 100 % Hoagland solution (NF IV). The fifth treatment (NF V) included self-composed nutrient formulation (Azeezahmed 2014) (Table 1). Plants were fertigated (100 ml/plant) after every 10 days and irrigated with water alone after every 4-5 days during the entire experimental period. Irrigation frequency was doubled during hot summer months i.e. May-June. The fertigation volume was determined by adding the leaching amount to water consumed by plants i.e. 300 ml/pot. Experimental design was factorial completely randomized design (CRD) keeping three replications in each treatment.

The data on effect of different fertigation levels on plant height, plant spread, fresh and dry weight of plant canopy and roots, leaf chlorophyll content (Hiscox and Israelstam 1979), leaf carotenoid content (Kirk and Allen 1965) and relative leaf water content (RLWC) were recorded. Statistical analysis using SAS software version 9.0 was to find the best nutrient formulation as a medium of growth for these species.

## RESULTS AND DISCUSSION:

Significant variability in the mean plant height and spread was observed under various nutrient solution formulations where plants fertigated with NF IV (100 % of the Hoagland solution) observed highest results among various indoor plant species under study. However, similar response w.r.t. plant height with NF V was observed (Table 2). Among the various plant species, maximum plant height was in *Dracaena godseffiana* (33.57 cm) and minimum in *Schefflera arboricola variegata* (16.58 cm) whereas maximum canopy was in *Aglaonema angustifolium* (17.23 cm) and *Schefflera arboricola* (17.89 cm) which was at par with canopy in *Syngonium podophyllum.* Kaur et al (2016) in tomato also reported maximum plant height with 100 % of the Hoagland's solution in comparison with its lower concentrations. Azeezahmed (2014) in chrysanthemum observed subsequent increase in plant height and spread with

**Table 1.** Hoagland nutrient formulations (NF) (mg/l)

| Element | NF-I (Control) (25 % of Hoagland's solution) | NF-II (50 % of Hoagland's solution) | NF-III (75 % of Hoagland's solution) | NF-IV (100 % of Hoagland's solution) | NF-V |
|---|---|---|---|---|---|
| N | 52.50 | 105.00 | 157.50 | 210.00 | 250.00 |
| P | 7.75 | 15.50 | 23.25 | 31.00 | 40.00 |
| K | 58.50 | 117.00 | 175.50 | 234.00 | 200.00 |
| Ca | 40.00 | 80.00 | 120.00 | 160.00 | 170.00 |
| Mg | 8.40 | 17.00 | 25.50 | 34.00 | 90.00 |
| S | 16.00 | 32.00 | 48.00 | 64.00 | 35.00 |
| Fe | 0.63 | 1.25 | 1.88 | 2.50 | - |
| Cu | 0.005 | 0.01 | 0.02 | 0.02 | - |
| Zn | 0.013 | 0.03 | 0.04 | 0.05 | - |

**Table 2.** Effect of different nutrient formulations on growth parameters of indoor ornamental plant species

| Nutrient formulation | Plant height (cm) | Plant spread (cm) | Fresh canopy weight (g) | Dry canopy weight (g) | Fresh root weight (g) | Dry root weight (g) |
|---|---|---|---|---|---|---|
| NF I | 17.41$^{d}$ | 14.66$^{d}$ | 13.90$^{e}$ | 1.76$^{d}$ | 11.35$^{c}$ | 1.87$^{c}$ |
| NF II | 21.96$^{c}$ | 16.78$^{c}$ | 17.17$^{d}$ | 2.37$^{d}$ | 13.94$^{b}$ | 2.25$^{bc}$ |
| NF III | 25.00$^{b}$ | 20.17$^{b}$ | 23.50$^{c}$ | 3.89$^{c}$ | 14.77$^{b}$ | 2.53$^{b}$ |
| NF IV | 28.82$^{a}$ | 24.17$^{a}$ | 33.92$^{a}$ | 5.50$^{a}$ | 18.95$^{a}$ | 3.58$^{a}$ |
| NF V | 28.21$^{a}$ | 20.28$^{b}$ | 29.71$^{b}$ | 4.76$^{b}$ | 19.65$^{a}$ | 3.44$^{a}$ |

The different letters in each column are significantly different at $P \le 0.05$ by Duncan's Multiple Range Test (DMRT) increasing nutrient concentrations. Shorter plants at lower dose of N, P and K might have been due to their effects on cell division and elongation. Increase in plant height is attributed to an increased supply of nutrients N, Ca and S as these are the major nutrients responsible for an increase in plant height. Nutrient inadequacy often leads to lesser growth of the plants (Siddiqui and Kumar 2017). This indicates that higher nutrient concentration is required by plants to obtain longer heights.

Maximum fresh canopy weight was observed in the plants fertigated with NF IV (36.04 g) which was at par with NF V (35.10 g) whereas dry canopy weight was maximum in the plants fertigated with NF IV (5.50 g). Kang and Iersel (2002) also concluded that maximum shoot dry biomass was achieved in Alyssum, Zinnia, Celosia and Dianthus fertigated with 100 % Hoagland solution. Kang and Iersel (2004) reported that its shoot weight increased with increasing Hoagland's solution concentration and reached maximum with 100 % Hoagland solution. There was statistically non-significant difference in the mean fresh and dry root weight between species w.r.t. different fertigation treatments given except *Philodendron selloum* which showed maximum fresh (62.73 g) and dry root weight (9.38 g). However, an increase in the fresh and dry root weight with increasing nutrient concentrations was observed in the plants (Table 2). Azeezahmed (2014) also reported a significant increase in the root and shoot biomass with increasing nutrient concentrations (N, P, K, Ca, Mg and S). The increase in fresh and dry canopy biomass with increased nutrient concentration may possibly be due to increased plant photosynthetic activity leading to higher accumulation of photosynthates which led to an increase in reserved plant food material causing higher fresh and dry canopy biomass. Sublett et al (2018) proposed that nutrients are key factors influencing plant growth and biomass production in soilless culture. The study specify that optimum nutrient concentration is required by plants for their proper metabolic functioning which is responsible for positive influence on their growth and development.

A significant increase in the mean leaf chlorophyll, carotenoid and relative leaf water content was observed with increasing Hoagland solution concentration with maximum accumulation in plants fertigated with NF IV. The maximum chlorophyll and carotenoid content was observed in *Dracaena godseffiana* (3.77 and 0.32 mg/g fresh wt. respectively). Kang and Iersel (2002) attained maximum chlorophyll accumulation with 100 % Hoagland solution concentration in Alyssum, Zinnia, Celosia and Dianthus. The low fertilizer concentrations generally decreased growth and chlorophyll content, presumably because of mild nutrient

**Table 4.** Effect of different nutrient formulations on the mean physiological characteristics of plant species to be grown in an indoor vertical garden

| Nutrient formulation | Leaf chlorophyll content (mg/g fresh wt.) | Carotenoid content (mg/g fresh wt.) | Relative leaf water content (RLWC) (%) |
|---|---|---|---|
| NF I | $1.56^{c}$ | $0.10^{e}$ | $71.66^{d}$ |
| NF II | $1.9^{d}$ | $0.11^{d}$ | $75.83^{c}$ |
| NF III | $2.48^{b}$ | $0.16^{b}$ | $81.78^{ab}$ |
| NF IV | $3.35^{a}$ | $0.23^{a}$ | $85.64^{a}$ |
| NF V | $2.19^{c}$ | $0.13^{c}$ | 81.28 |

The different letters in each column are significantly different at P≤0.05 by Duncan's Multiple Range Test (DMRT)

**Table 5.** Response of plant species under study in terms on physiological characteristics to be grown in an indoor vertical garden

| Treatments/ Indoor plant species | Leaf chlorophyll content (mg/g fresh wt.) | Leaf carotenoid content (mg/g fresh wt.) | Relative leaf water content (%) |
|---|---|---|---|
| *Aglaonema angustifolium* | 3.47b | 0.08d | 86.98a |
| *Dracaena compacta*(red) | 0.97f | 0.22b | 75.35bc |
| *Dracaena godseffiana* | 3.77a | 0.32a | 72.51c |
| *Scindapsis aureus* | 1.89e | 0.14c | 89.00a |
| *Schefflera arboricola variegata* | 0.77g | 0.05e | 63.23d |
| *Syngonium podophyllum* | 1.93e | 0.09d | 77.68b |
| *Philodendron selloum* | 2.30d | 0.12c | 84.66a |
| *Schefflera arboricola* | 3.27c | 0.14c | 84.19a |

The different letters in each column are significantly different at P≤0.05 by Duncan's Multiple Range Test (DMRT)

**Table 3.** Effect of different concentrations of nutrient formulations on mean plant height, plant spread, fresh and dry canopy and root weight of indoor ornamental plant species

| Treatments/Indoor plant species | Plant height (cm) | Plant spread (cm) | Fresh canopy weight (g) | Dry canopy weight (g) | Fresh root weight (g) | Dry root weight (g) |
|---|---|---|---|---|---|---|
| *Aglaonema angustifolium* | 27.97[b] | 17.23[a] | 29.26[a] | 8.05[a] | 12.06[b] | 1.18[d] |
| *Dracaena compacta* (red) | 19.19[e] | 9.83[bc] | 11.04[c] | 1.39[d] | 6.70[c] | 1.12[d] |
| *Dracaena godseffiana* | 33.57[a] | 11.04[bc] | 11.60[c] | 2.74[d] | 11.80[b] | 3.26[b] |
| *Scindapsis aureus* | 21.20[d] | 11.48[bc] | 22.20[a] | 1.85[d] | 6.28[c] | 0.79[d] |
| *Schefflera arboricola variegata* | 16.58[f] | 11.61[bc] | 18.91[b] | 3.10[d] | 6.94[c] | 1.94[c] |
| *Syngonium podophyllum* | 22.11[d] | 13.97[ab] | 33.63[a] | 4.21[c] | 6.41[c] | 1.33[cd] |
| *Philodendron selloum* | 24.15[c] | 11.32[bc] | 27.68[a] | 1.91[d] | 62.73[a] | 9.38[a] |
| *Schefflera arboricola* | 29.04[b] | 17.89[a] | 34.80[a]s | 6.01[b] | 12.94[b] | 2.88[b] |

The different letters in each column are significantly different at P≤0.05 by Duncan's Multiple Range Test (DMRT)

deficiencies. Any further increase in the nutrient concentration led to decrease in the chlorophyll content. This may be possibly due to lack of micro nutrients in NF V which might have inhibited further chlorophyll production. The linear relationship between nitrogen in the nutrient solution and leaf chlorophyll content was observed. Moreover, an improved growth as well as higher fresh and dry canopy and root biomass was observed in the plants fertigated with NF IV which also had highest chlorophyll content w.r.t. lower concentrations. The increase in the chlorophyll content with increasing nutrient concentration might possibly be due to high N, P, K, Mg and Fe content which leads to its increased synthesis. Hossain et al (2010) reported an increase in chlorophyll content in *Hibiscus cannabis* L. with increasing N, P and K content. Hoagland solution (T2) recorded the maximum chlorophyll content (27.84, 29.32 and 31.51) in *Zebrina Pendula* and *Tradescantia spathacea* plants followed by T3 (Cooper solution) with 24.68, 26.12 and 27.91 at 30, 60 and 90 days (Dhanasekaran 2020). The increased chlorophyll content in *Zebrina pendula* and *Tradescantia spathacea* plants grown under Hoagland solution may be due to the increased dose of nutrition combination which contains N, K, Mg which has the beneficial effect on phloem loading and probably also on mobilization of photosynthates deposited in leaves. The findings of Li and Cheng, (2014) in cucumber, Mohidin et al (2015) in oil palm seedlings agreed with the present results. Studies conducted by Alberici et al (2008) showed an increase in the leaf chlorophyll and carotenoid content of leafy vegetables with increase in Hoagland solution concentration. Indoor ornamental plant species under our study reported maximum RLWC when fertigated with 100 % of the Hoagland's solution. This indicates that high RLWC is important in carrying out various physiological processes required for the healthy growth of the plants. This might be the reason that the plants fertigated with NF IV had better growth characteristics over other fertigation treatments as they showed maximum RLWC. RLWC is a significant indicator of water status in plants as it reflects the equilibrium between water supply to the leaf tissue and transpiration rate.

## CONCLUSION

The highest concentration i.e. NF IV (100 % of the Hoagland's solution) was significantly better over other fertigation treatments in terms of growth and physiological characters of plants under indoor conditions. Among the various species evaluated on the basis of parameters under observation, the best five which were used for the indoor vertical garden were *Schefflera arboricola, Dracaena godseffiana, Philodendron selloum, Syngonium podophyllum* and *Scindapsis aureus*.

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