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Effect of nutrient formulations on leaf nutrient accumulation and biomass production of ornamental plants for an indoor vertical garden

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Abstract

There is no possibility of creating a permanent and sustainable society without vertical gardening. It can be installed in any part of the world by using plant species suitable for that particular area. As there is lack of horizontal expansion, the only space left is vertical. Hence, the only solution to live with greenery in cities is creating green vertical walls. Current investigation was conducted to study the effect of different concentrations of nutrient formulations on total plant fresh and dry biomass as well as leaf nutrient accumulation in eight indoor plant species namely *Aglaonema angustifolium, Dracaena compacta* (Red), *Dracaena godseffiana, Scindapsis aureus, Schefflera arboricola variegata, Syngonium podophyllum, Philodendron selloum* and *Schefflera arboricola*. These plants were grown using five nutrient formulations which included four concentrations of Hoagland's nutrient solution (25%, 50%, 75% and 100% of Hoagland's solution) and fifth was self-composed nutrient concentration. Experimental design was factorial completely randomized block keeping three replications in each treatment. The nutrient formulation of 100% of the Hoagland's solution (NF IV) proved to be the best in terms of the growth and nutrient accumulation. Best five species evaluated based on performance of various parameters studied were *Schefflera arboricola, Dracaena godseffiana, Philodendron selloum, Syngonium podophyllum* and *Scindapsis aureus*.

Keywords: Hoagland solution, nutrient formulation, leaf nutrient composition, indoor ornamental plant species, indoor vertical garden

Introduction

Increase in urbanization has led most of the people spend most of their time indoors which has evolved the new concept of indoor vertical garden so as to make people stay close to mother nature. More than 50% of the world's population lives in cities and it has been estimated that by 2030 this figure will exceed 60% (Banco-Mundial 2013) [15]. Replacement of vegetated surfaces with concrete surfaces in urban areas have increased the temperature upto 6 °C higher than in rural areas because the concrete surfaces absorbs, retain and reradiate more solar energy than vegetation. Vertical gardening is expected to reduce the temperature of such concrete structures. The main benefit of 'vertically greening' the buildings is to mitigate the heat island effect in cities (Wong *et al.* 2010) [18]; passive cooling of buildings by means of shading the walls and increasing the thermal insulation of the building envelope (Kontoleon and Eumorfopoulou 2010, Perini *et al*. 2011) [12, 16] thereby providing a cleaner and greener indoor environment. As vertical gardens are installed to the walls, its growing medium should allow satisfactory plant growth, root firmness and should be light in weight as it may affect the load capacity of walls of the building. The necessity of cultivating plants out of their natural environment creates the obligation to use mediums that provide physical support, water, nutrients, oxygen etc. for vegetative development. The proposal of growing soil-less media i.e. coco peat, perlite and vermiculite will possibly fulfill these essential requirements. Nutrition is another important factor influencing plant growth and quality. Hoagland solution is one of the most adequate source of nutrient used in soilless cultivation of plants. As little information is available on the optimum nutritional requirements and growing medium for various indoor ornamental plants to be grown in an indoor vertical garden under Indian conditions, the study is of utmost significance. The study also becomes more valuable as this is the first work being done on various aspects of indoor vertical gardening involving indoor ornamental plants. The experiment was hence initiated to determine the effect of different nutrient concentrations on the growth and leaf nutrient accumulation of different indoor plant species suitable for growing plant species for an indoor vertical garden.

Material and Methods

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. Six month old plants of these species were transplanted during the last week of February 2017 in 6" pots filled with soilless media consisting of cocopeat, perlite and vermiculite in the ratio 3:1:1. The experiment consisted of five treatments of which four included fertigation with modified Hoagland solution (Hoagland & Arnon 1950) [5] i.e. 25% of the Hoagland's solution (NF I) which served as control, 50% of the Hoagland's solution (NF II), 75% of the Hoagland's solution (NF III) and 100% of the Hoagland solution (NF IV). The fifth treatment (NF V) included self-composed nutrient formulation (Table 1) (Azeezahmed 2014) [2]. Plants were fertigated (100 ml/plant) after 10 days and irrigated with water alone at 4-5 days interval (as per requirement) during the entire experimental period. Irrigation frequency was doubled during hot summer months i.e. May-June. The irrigation water volume was determined by adding the leaching amount to water consumed by plants i.e. 300 ml/pot. The experimental design was factorial completely randomized block with three replications in each treatment. All data was analyzed using Statistical Analysis Software (SAS version 9).

Leaf nutrient analysis (%): Leaf Nitrogen was estimated by Microkjeldhal distillation method (A.O.A.C. 1970) [1], Phosphorus by Vando-molybdophosphoric yellow colour method described by Jackson (1973) [8]. Potassium, Calcium and Magnesium was estimated using Flame photometer method, whereas Sulphur by using Atomic absorption spectrophotometer (Jackson 1967) [7]. The data was recorded after 12 months.

Total fresh and dry plant biomass (g): Total fresh and dry plant biomass was recorded by collecting samples (shoot and root samples) during March, 2018 by removing whole plant from the growing media followed by its decontamination from dust and other foreign particles. Fresh shoots were first washed in 0.2 percent detergent solution to remove waxy coating and soil particles from the leaf surface, followed by diluted N/10 HCl solution to clear off metallic contaminants. Lastly, in order to wash off the former two solutions these plants were washed in de-ionized water. After the removal of excessive moisture, the plant were weighed using an electronic balance. Roots were carefully dug out and washed with water to remove adhered soil particles followed by measurement of fresh root weight. The dry weight of plant samples was calculated after drying them at 60 ± 5 °C for a period of 48 hours until a constant weight was attained and was expressed in grams. Both root and shoot weight were added to get total fresh and dry plant weight.

Results and Discussion

Leaf nutrient analysis (%): The mean leaf N, P and K concentration significantly increased with increasing nutrient concentrations and was found maximum in the plants fertigated with NF IV and NF V (Fig. 1). From the observations made amongst the various indoor ornamental plant species studied, maximum Nitrogen accumulation was witnessed in *Syngonium podophyllum* and *Philodendron selloum* (3.12%) which was at par with *Schefflera arboricola* (3.06%) and *Aglaonema angustifolium* (2.97%). Maximum P content was observed in *Scindapsis aureus* (0.4%) whereas maximum K content was observed in *Syngonium podophyllum* (4.20%).

An increasing percentage in the accumulation of leaf Calcium, Magnesium and Potassium was observed with increasing nutrient concentrations from NF I (25% of the Hoagland's solution) to NF IV (25% of the Hoagland's solution) where Maximum mean leaf Ca and S percentage was found in the plants fertigated with NF IV alone, whereas NF IV and NF V in terms of Mg concentration (Fig. 2). Maximum% of leaf Ca was in *Scindapsis aureus* (4.12%), Mg in *Philodendron selloum* (0.65%) which was at par with *Schefflera arboricola* (0.64%) whereas S in *Syngonium podophyllum* (0.30%) and *Philodendron selloum* (0.29%). The data recorded in Fig. 1 & 2 shows the mean values of the nutrient composition of different species calculated individually.

All nutrients play a fundamental role in plant life and tends to exhibit symptoms as a function of its deficiency, excess or imbalance. It is an established fact that application of nitrogenous fertilizers has a definite positive impact on plant vegetative growth over lesser or no N application. Also, it is the most imperative element for overall growth and development of plants which significantly enhances plant quality by playing a vital role in plant biochemical and physiological functions. Nitrogen is a component of protoplasm, proteins, nucleic acid and chlorophyll, thus a basic component for plant life. Among all the mineral nutrients, it is the most mobile element absorbed by the plant. Phosphorus is also a key element required for plant growth and healthy root formation. It enhances plant water use efficiency and its deficiency leads to reduced synthesis of carbohydrates which reduces accumulation of photosynthates in the plants. Potassium is generally required in higher quantity by most of the ornamental crops. This nutrient is directly related to the maintenance of osmotic balance in plant cells, the process of the regulation of gas exchange and transpiration, enzyme activation, protein synthesis, photosynthesis, and stress resistance (Benites *et al*. 2010 and Marschner 2012) [3, 14].

Azzezahmed (2014) [2] in a study conducted on chrysanthemum reported an increase in plant N, P, K, Ca, Mg and S content with increase in the nutrient concentrations. Studies conducted by Kang and Iersel (2002) [9] in ornamental bedding plants also showed a gradual increase in shoot N, P, K, Ca, Mg and S content with increasing Hoagland solution concentrations and are in agreement with our studies. Also, leaf nutrient concentrations varied with species under study which justifies that amount of nutrient uptake by the plants is species dependent. This difference might be due to difference in genetic makeup of the species and their ability to consume and utilize various nutrients during metabolic functions for the plant growth. Our results further prove that nitrogen being present in many compounds of plant cells, including amino acids and nucleic acids, can hamper growth if its concentrations are lower than desirable (Taiz *et al*. 2015) [17]. This might be the reason that plants with lower nutrient concentrations showed weaker growth as compared to higher concentrations. In most crops, N is absorbed in greater quantity and accumulated in dry mass of the plants in larger amounts. Its deficiency causes widespread chlorosis due to a reduced synthesis of chlorophyll (Malavolta 2006) [13] and stunted habit with retarded and slow growth (Epstein and Bloom 2006) [4]. In a study conducted by Karimi *et al*. (2012) [11] found higher N and Ca level in nutrient solution resulted in taller plants, whereas shortest lily plants were obtained in treatment without fertilization. Our studies also report higher accumulation of leaf Ca content with increase in Hoagland solution concentration and taller plants (data not shown) which establishes that Ca and N work synergistically in enhancing plant growth and height. Our results are in close conformity with Karimi *et al*. (2012) [11] who concluded that optimum dose of calcium nitrate varies with cultivars.

Magnesium being powerhouse behind photosynthesis in plants is essential for chlorophyll to capture sun energy needed for photosynthesis and is used by the plants for metabolism of carbohydrates. Our findings shows a gradual increase in the leaf Mg content with increasing fertigation concentrations with maximum accumulation with NF IV. Similar results were obtained in terms of total plant biomass. These results shows that increase in leaf Mg content might have resulted in increase in leaf chlorophyll content which enhanced the plant photosynthetic rate resulting in higher accumulation of photosynthates causing higher fresh and dry plant biomass. Also, the results of our study showed an increase in N, P and K accumulation with increasing nutrient formulations which was proportionate with increasing plant fresh and dry biomass. This shows that optimum nutrient application to the plants results in a higher nutrient uptake causing higher photosynthetic activity and results in healthy growth of the plants.

It is to be noted that sufficiency ranges for nutrients for the species under study are not available. However comparing these concentration to other ornamental plants suggests, there were no major deficiencies. On the basis of the evaluation of the nutrient formulations, NF IV emerged as the best, hence, this concentration was used further for the growth of the plant species tested for the vertical garden.

Total fresh and dry plant weight (g)

Among the different fertigation treatments, the total mean fresh plant weight was found to be maximum in the plants fertigated with NF IV which was at par with NF V. Among different plant species under experimentation, maximum mean fresh plant weight was observed in *Philodendron selloum* (90.41 g) whereas minimum in *Dracaena compacta* (red) (17.75 g). Similar results in terms of total dry weight were also observed w.r.t fertigation treatments as well as species under study. The increase plant biomass with increase in nutrient concentration owes to greater photosynthetic ability of the plant which leads to accumulation of higher amount of photosynthates resulting in increased quantity of reserved food material causing higher plant fresh and dry biomass. The results also indicate that plants require an optimum nutrient concentration for its proper metabolic functioning leading to a positive effect on their growth and development. Similar results were reported by Hossain *et al.* (2010) [6] who revealed that a certain range of N, P and K concentration resulted in increased photosynthetic rate. Our results are also in agreement with the studies conducted by Kang and Iersel (2002) [9] who witnessed maximum shoot dry biomass in the plants (Alyssum, Zinnia, Celosia and Dianthus) fertigated with 100% Hoagland solution. Another study conducted by them in 2004 on Salvia depicted that the plant shoot and total dry weight increased with increasing Hoagland's solution concentration and reached maximum with 100% Hoagland solution. Azeezahmed (2014) [2] also reported a significant increase in the root and shoot biomass with increase in the nutrient concentration (N, P, K, Ca, Mg and S) in the fertigation formulations.

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: Response of indoor plant species under study in terms of the mean nutrient composition of the leaves

Varieties	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)
Aglaonema angustifolium	2.97a	0.35b	3.4b	0.75f	0.51b	0.20c
Dracaena compacta (red)	1.67d	0.25d	2.79c	0.32h	0.12f	0.26b
Dracaena godseffiana	2.51b	0.19e	2.84c	1.35c	0.13f	0.22c
Scindapsis aureus	2.11c	0.41a	2.95c	4.12a	0.36d	0.15d
Schefflera arboricola variegata	1.75d	0.20de	2.11d	0.70g	0.31e	0.13de
Syngonium podophyllum	3.12a	0.36d	4.20a	1.26d	0.46c	0.30a
Philodendron selloum	3.12a	0.32c	2.87c	1.13e	0.65a	0.29a
Schefflera arboricola	3.06a	0.18e	2.98c	1.50b	0.64a	0.12e

The different letters in each column are significantly different at $p \leq 0.05$ by Duncan's Multiple Range Test (DMRT)

Table 3: Effect of different concentrations of nutrient formulations on total fresh and dry plant biomass of indoor ornamental plant species

Treatments	Total fresh plant biomass (g)	Total dry plant biomass (g)
NF I	25.25e	3.63c
NF II	31.11d	4.63c
NF III	37.60b	6.42b
NF IV	49.83a	8.35a
NF V	47.07a	8.95a

The different letters in each column are significantly different at $p \leq 0.05$ by Duncan's Multiple Range Test (DMRT)

Table 4: Response of plant species in terms of total fresh and dry plant biomass to be grown in an indoor vertical garden

Indoor plant species	Total fresh plant biomass (g)	Total dry plant biomass (g)
Aglaonema angustifolium	41.33b	9.23b
Dracaena compacta (red)	17.75e	2.52d
Dracaena godseffiana	23.40de	6.01c
Scindapsis aureus	28.48cd	2.64d
Schefflera arboricola variegata	25.85de	5.05c
Syngonium podophyllum	40.04b	5.53c
Philodendron selloum	90.41a	11.29a
Schefflera arboricola	38.13cd	8.90b

The different letters in each column are significantly different at $p \leq 0.05$ by Duncan's Multiple Range Test (DMRT)

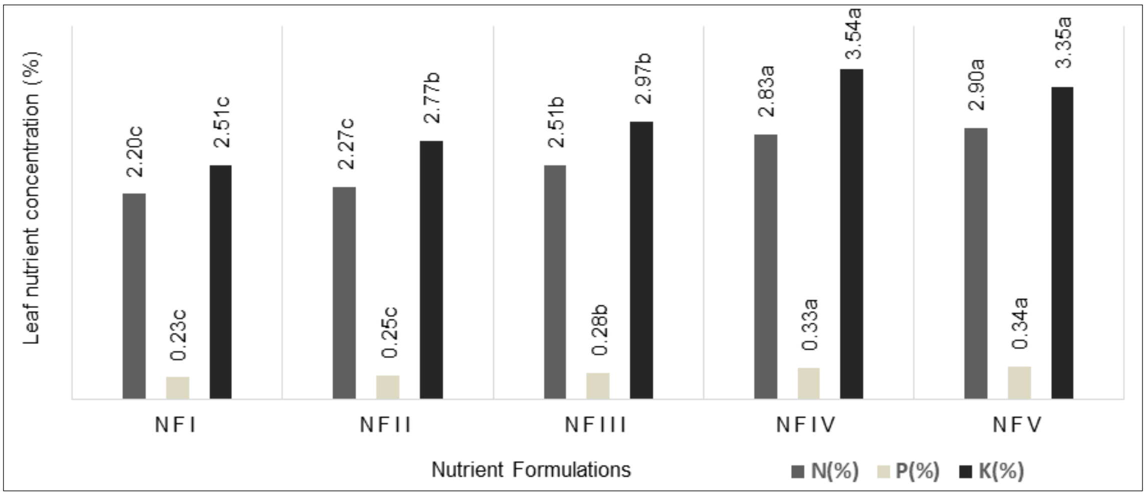

Fig 1: Effect of different nutrient formulations on the mean leaf N, P and K concentration (%) of indoor ornamental plant species

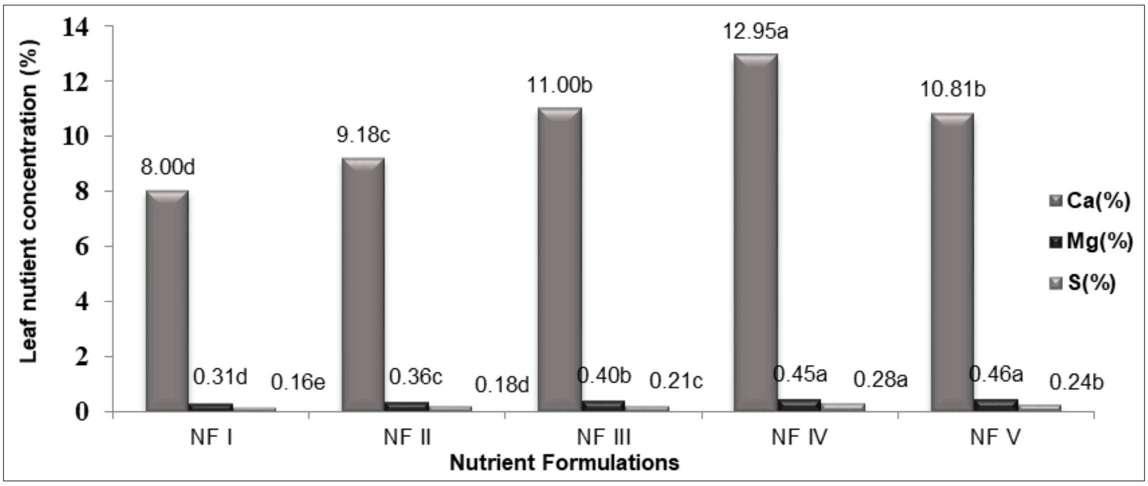

Fig 2: Effect of different nutrient formulations on the mean leaf Ca, Mg and P concentration (%) of indoor ornamental plant species

Conclusion

Plant fresh and dry biomass as well as leaf nutrient accumulation are important parameters in determining the quality attributes of the plant species suitable for indoor vertical garden. It is evident that higher concentration i.e. NF IV (100% of the Hoagland's solution) gave significantly better results as compared to other nutrient formulations due to adequate availability of micronutrients in its formulation which is important for maintaining growth and development of the plants under indoor conditions. Hence, NF IV appears to have a positive and significant effect on the growth and nutrient accumulation of plants under indoor conditions.

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