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Short communication

Growing media and biofertilizer for *Nephrolepis cordifolia* (L.) K. Presl. in vertical garden system

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Abstract

Vertical gardens expand green spaces in urban environments and fulfill various functional roles such as reducing sound and heat, enhancing energy efficiency, improving air quality, mitigating heat islands, optimizing location utilization, creating agricultural spaces, fostering aesthetic appeal, and positively influencing human psychology. *Nephrolepis cordifolia* (L.) K. Presl., commonly known as fishbone fern/ tuberous sword fern/ ladder fern is predominantly used in vertical gardens. Responses of this fern to five different growing media were analysed by the corresponding growth parameters recorded during the study. The results indicated that the plants grown in medium having coirpith: vermiculite: perlite: vermicompost in the ratio of 1:0.5:0.5:1, recorded better growth performance. Different growth parameters such as plant spread, plant height, number of leaves per plant, number of fronds, total biomass production and total chlorophyll content recorded significantly higher values than those compared to the respective controls. Furthermore, the application of biofertilizer VAM @ 3 g/ pot of size 15 x15x 12 cm^3, provided an effective organic source of nutrients for enhanced plant growth under vertical system.

Key words: Fish born fern, *Nephrolepis cordifolia*, Vertical Garden

Vertical gardens, commonly referred to as living walls, green walls, or green façades, play a significant role in enhancing urban landscapes. In urban culture, most people spend between 80% and 90% of their time indoors. Such situations ideally need better indoor environmental quality which can largely improve the occupants' health, productivity, and ability to perform at work (Ling and Ghaffarian, 2012). Vertical gardens have the capability to provide an alternative sustainable solution to the serious problems in populous urban cities such as indoor air pollution and urban heat island effect. These gardens have also proved to be a stress reliever for the tense filled lifestyle of urban folks (Gawroñska and Bakera, 2015). In fact, creating a successful vertical garden depends on the design of the system, containers used, plants selected, growing media, water and nutrient management and pest as well as disease management (Ashok, 2019).

The most decisive factor of a vertical garden system is the growing medium, which supports the plant to the substratum, retain and release water and nutrients and facilitate aeration to roots (Ingram et al., 2003). Commonly used components of growing media include river sand, red soil, sawdust, peat, perlite and vermiculite. Increasing cost and scarcity of the mineral media like peat, perlite and vermiculite compel the usage of suitable alternative components in vertical garden system. In addition, the media components selected should be light weight and easily available. Hence, the selection of appropriate combinations of media components is essential for the establishment as well as the extended duration of vertical garden system.

Considering the above factors, the present study was undertaken to evaluate the effect of different media components such as soil, sand, rock sand, vermicompost, vermiculite, perlite, coirpith, newspaper bits, hydrogel and charcoal bits in different proportions along with biofertilizers such as VAM and PGPR–1, on the growth of a popular ornamental foliage fern, *Nephrolepis cordifolia* in vertical garden system. Native to tropics, this fern belonging to the family Nephrolepidaceae, is an ideal plant for vertical gardens under shaded condition or interiors, as it has compact growth habit ensuring dense and thick cover**.**

The experiment was carried out in the Department of Floriculture and Landscaping, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, India. The objective of the study was to standardize the growing media composition and biofertilizers for improving growth of *Nephrolepis cordifolia* under vertical garden system. A vertical garden system was established by frames or

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supporting panels with detachable containers (15x15x12 cm^3) of recycled polypropylene material. The different growth media were uniformly supplied as per the prescribed ratio. The study was designed in two factorial CRD, with three replications and ten plants per replication. The foliage plant used was *Nephrolepis cordifolia* (Fish born fern). The total treatment combinations were fifteen, involving five factors for growing media and three factors for biofertilizers as shown below:

Growing media
M_1 - control (soil + sand + FYM in 1:1:1)
M_2 - soil + rock sand+ coirpith + vermicompost (1:0.5:0.5:1)
M_3 - soil + rock sand + vermicompost (1:1) + Hydrogel (25 g/pot)
M_4 - coirpith+ vermiculite + perlite + vermicompost (1:0.5:0.5:1)
M_5 - coir pith+ newspaper bits +charcoal bits + vermicompost (1:0.5:0.5:1)

Biofertilizers
B_1 - Control (without biofertilizer)
B_2 - VAM (3 g /pot)
B_3 - PGPR-I (2 g /pot)

All the treatments were given uniform management practices. Irrigation water per pot was given manually using rose can (10-liter capacity 2 times) on alternate mornings. Foliar fertilization using 19:19:19 (1 %) was also given at fortnightly intervals.

The vegetative parameters of the plants such as plant spread, plant height, number of leaves per plant, total biomass production and total chlorophyll content were analyzed. The leaf chlorophyll content was estimated by DMSO (Dimethyl sulfoxide) method. The chlorophyll content was measured using a spectrophotometer and absorbance was measured at 645 nm and 663 nm using distilled water as blank (Khalaj et

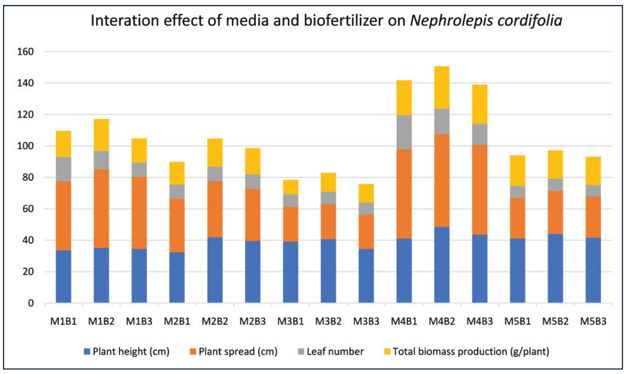

Figure 1. Interaction effect of media and biofertilizer on growth parameters of *Nephrolepis cordifolia* at 5MAP

al., 2011). The various physical and chemical properties of growing media before planting such as pH, EC, water holding capacity, porosity and available N, P, K were also analyzed using the standard methods.

Observations on growth characters such as plant spread, plant height, number of leaves per plant, total biomass production and total chlorophyll content recorded at 5 months after planting (MAP) under various potting media are presented in Table 1 and 2. The interaction effect of media components and biofertilizers on growth parameters of *Nephrolepis cordifolia* at 5MAP are shown in Fig. 1. Plant spread (57.80 cm) was recorded to be significantly higher in plants grown in M_4 (coirpith+ vermiculite + perlite+ vermicompost (1:0.5:0.5:1). The notable variations in plant spread could be attributed to the abundant nutrient content in such enriched medium, as noted by Ikram et al., (2012) in tuberose. Media having soil + rock sand + vermicompost (1:1) +Hydrogel (25 g) recorded lowest plant spread (22.05 cm). High nitrogen content available from the vermicompost and coirpith could be the reason for maximum plant spread. In the present study, the media which performed well in terms of plant spread had vermiculite which stands out as a prevalent physical growth substrate with high water retention capacity, inert chemical characteristics, moderate aeration levels, microbial growth resistance, and effective cation exchange capacity. A similar observation was reported by Dhanasekaran et al., (2020) in spider plant. Additionally, the elevated nutrient content supplied by vermicompost, along with the good physical attributes *viz.*,water retention and aeration) and

Table 1. Effect of potting media on growth of ornamental foliage *Nephrolepis cordifolia* at 5MAP

Treatment	Plant height (cm)	Plant spread (cm)	Number of leaves	Total biomass production (g/plant)	Total chlorophyll content (mg/g)
M1	34.38	46.58	12.13	18.70	1.35
M2	37.93	34.29	9.14	16.33	1.31
M3	38.13	22.05	7.85	11.00	1.28
M4	44.33[a]	57.80[a]	16.98[a]	24.71[a]	1.38[a]
M5	42.23	26.55	7.51	18.49	1.23
SEm (±)	0.29	0.44	0.21	0.46	0.001
CD (0.05)	0.83	1.28	0.62	1.34	0.001

Table.2 Effect of biofertilizer on growth of ornamental foliage *Nephrolepis cordifolia* at 5MAP

Treatment	Plant height (cm)	Plant spread (cm)	Number of leaves per plant	Total biomass production (g/plant)	Total chlorophyll content (mg/g)
B1	36.61	37.43	12.27	16.44	1.30
B2	38.89	42.05	10.56	19.03	1.32
B3	36.85	38.72	9.35	17.31	1.31
SEm (±)	0.34	0.22	0.167	0.35	0.001
CD (0.05)	0.99	0.64	0.483	1.03	0.001

chemical properties *viz*., favorable pH, low electrical conductivity and cation exchange capacity) of cocopeat, contributed to the increased nutrient absorption.

M_4 and M_5 (coir pith+ newspaper bits + charcoal bits + vermicompost (1:1/2:1/2:1) were superior and on par in terms of plant height (44.33 and 42.23 cm respectively). The lowest plant height (34.38 cm) was recorded in M_1 (soil+ sand+ FYM in 1:1:1). The increased plant height could be due to the effective provision of aeration to plants which is an essential factor for the proper development of plants. The well-aerated environment enables roots to efficiently absorb nutrients and water, promoting overall plant growth. This conductive aeration also aids in the proper exchange of gases, facilitating crucial physiological functions within the plant (Ling and Ghaffarian, 2012).

Maximum number of leaves per plant(16.98 cm) was observed in M_4 while the lowest number of leaves (7.85 cm) were found in M_3. The increased leaf count in M_4 medium may be due to the combined effects of cocopeat and vermicompost. Cocopeat contributes to higher total pore space (TPS) and greater water holding capacity (WHC), while vermicompost is characterized by a higher concentration of humic compounds (Padhiyar et al., 2017). The presence of cocopeat and vermicompost improves the physical and nutrient status of the growing media. Such an enhancement of the vegetative parameters of indoor plants such as philodendron,spider plant, boston fern, *Tradescantia* and cordyline, growing in vertical system was reported by Ghosh and Talukdar (2021).

The total biomass production was found to be higher (24.71g) in M_4 and the lowest biomass production (11.00g) was observed in M_3at 5MAP. Enhanced growth occurs due to the multiplication and maturation of cells, leading to the synthesis of non-structural carbohydrates and increased biomass (Porra, 2002). The use of growing media characterized by reduced bulk density, elevated cation exchange capacity (CEC), and increased porosity promotes the absorption and retention of nutrients and water. This in turn, supports plant growth in coirpith and vermicompost, which might have contributed to the increased biomass production in the present study (Rameshkumar, 2018).

The total chlorophyll content was found to be significantly higher (1.38 mg/g) in M_4 and the lower chlorophyll content (1.23 mg/g) was observed in M_5. The higher chlorophyll content may be due to the presence of nitrogen available in coirpith; a similar effect was put by Sankar et al. (2006) who demonstrated that the plants which were grown in coirpith had high total chlorophyll content when compared to other media.

Among the treatment combinations it was found that vegetative parameters such as plant height, plant spread, total chlorophyll content and total biomass production was found to be significantly higher in M_4B_2, a combination of coirpith+ vermiculite + perlite+ vermicompost (1:0.5:0.5:1) and B_2 (VAM (3 g /pot). This could be due to the presence of VAM which enhances soil properties within the rhizosphere, enlarges the root areas of host plants, and boosts water absorption efficiency. Furthermore, VAM improves the absorption of phosphorus and other essential nutrients, ultimately enhancing the nutritional well-being of the host plant as indicated by Sahni et al. (2008).The nutritional properties provided by coirpith, perlite, vermiculite and vermicompost may have also contributed to the enhanced vegetative growth. Ability to retain moisture, inert chemical composition, moderate aeration levels, and effective cation

Table.3 Interaction effect of components and biofertilizers on properties of media

Treatment	Water holding capacity (%)	Porosity (%)	pH	EC (dSm^{-1})	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
M_1B_1	221.88	84.88	7.70	0.74	273.69	32.83	233.43
M_1B_2	223.27	84.61	7.62	0.94	287.78	35.09	255.47
M_1B_3	222.66	85.00	8.35	0.47	307.36	32.30	244.38
M_2B_1	273.16	90.66	8.06	0.23	173.53	32.20	255.10
M_2B_2	274.22	90.94	8.07	0.24	206.41	31.15	272.36
M_2B_3	256.77	90.94	8.11	0.43	177.85	33.74	265.40
M_3B_1	252.66	86.33	9.72	0.51	89.10	33.63	253.83
M_3B_2	254.11	86.77	7.90	0.93	114.87	25.11	253.62
M_3B_3	255.22	87.16	9.81	0.47	104.41	23.76	288.68
M_4B_1	312.16	93.11	7.94	0.57	314.08	32.93	313.25
M_4B_2	314.38	93.05	7.85	0.53	337.14	37.04	314.58
M_4B_3	313.83	93.27	7.76	0.75	327.18	33.32	313.39
M_5B_1	239.16	88.38	8.33	0.76	104.45	23.18	257.11
M_5B_2	269.84	89.05	8.26	0.53	136.78	23.56	265.81
M_5B_3	257.29	89.11	8.20	0.58	125.94	28.15	261.73
SEm (±)	3.36	0.18	0.05	0.009	0.54	0.93	4.84
CD (0.05)	9.72	0.35	0.15	0.027	1.56	2.71	3.10

exchange capacity are well reported properties of vermiculite. Additionally, it has the capacity to hold positively charged nutrients like potassium (K), magnesium (Mg), and calcium (Ca), reaching 3 to 4 times its weight (Sathyanarayana et al., 2017).

Analysis of properties of growing media such as pH, EC, water holding capacity, porosity and available N, P, K at 5 MAP showed significant variation among the different treatments (Table 3). The results revealed that the treatments significantly influenced the water holding capacity of media. The treatment combination, M_4B_2 (coirpith + vermiculite + perlite + vermicompost -1:0.5:0.5:1) + VAM (3 g/ container) (314.38%) was on par with M_4B_3(313.83%) and M_4B_1(312.16 %) in terms of water holding capacity. Vermiculite is recognized as a commonly utilized physical growth substrate, distinguished by its significant traits, such as high-water retention capacity, inert chemical nature, and moderate aeration. Coir pith, a by-product of the coconut processing industry, derived from agricultural waste, possesses properties like low bulk density, high porosity, and increased water retention capacity. The combined effect of these components might have contributed to optimum water holding capacity of the treatment.

Porosity is a crucial factor in growing media as it influences aeration, water drainage, and the availability of oxygen to plant roots. In the present study it was noted that treatment combination, M_4B_3 (coirpith + vermiculite + perlite + vermicompost) (1:0.5:0.5:1) + PGPR-1 (2g/ pot) (93.27 %) was on par with treatments, M_4B_1 and M_4B_2 (93.11 % and 93.05%) in terms of total porosity. These treatment combinations had perlite, which was marked by its significant porosity, light weight, neutral pH, excellent permeability and higher water retention, that contributed to better plant growth. Despite having a lower nutrient content, when used in conjunction with other media components, perlite could enhance the physical characteristics of the growing medium. Similar finding reported in Gerbera by Khalaj et al., (2011). The optimum pH range of growing medium for potted ornamental foliage in general is at 5.5-7.0 (Chen and Mc Connel, 2002). When the growing medium falls within this optimal range, there will be enhanced nutrient availability for the plants. In the present study, treatment M_1B_1(soil + sand + FYM) in 1:1:1), M_1B_2 (soil + sand + FYM) in 1:1:1) + (VAM (3g/ container), and M_4B_3 (coirpith + vermiculite + perlite + vermicompost) (1:0.5:0.5:1) + PGPR-1 (2g/ pot) was having a pH of 7.70, 7.62 and 7.76 respectively. Treatments M_3B_1 (soil + rock sand + vermicompost (1:1) + hydrogel (25 g)) and M_3B_3 (soil + rock sand + vermicompost (1:1) + hydrogel (25g) + PGPR-1 (2g/ container)) are in alkaline range (9.72 and 9.81), which might have reduced the availability of nutrients to the plants leading to their poor growth.

Proper control of electrical conductivity helps in managing nutrient concentrations, preventing over-fertilization or under-fertilization, and ensuring optimal conditions for plant growth. In this study it was observed that EC was found to be significantly higher in treatment M_1B_2 (0.94 dSm^{-1}) which was found on par with M_3B_2 (0.93dSm^{-1}). Generally, in the vegetative phase, EC should be in a range of 1.0 - 2.5 dSm^{-1}. The reduced electrical conductivity (EC) levels observed in the media combinations could be attributed to the inclusion of components like cocopeat and vermicompost in composite form. This composite state may lead to a decrease in EC, possibly because of the composting process. This observation was similar in African marigold as reported by Sankar et al., (2024).

Among the different treatment combinations, M_4B_2 showed higher N content (337.14 kg/ha), higher amount of available P (37.04 kg/ha) and available K (314.58 kg /ha), which was a combination of coirpith+ vermiculite + perlite+ vermicompost (1:0.5:0.5:1) and VAM (3 g/ pot). The inclusion of organic fertilizers such as vermicompost resulted in an enhancement of nutrient levels in the growing media. Additionally, cocopeat, known to contain primary and secondary nutrients, may have further contributed to the improved nutrient status of these media.

Conclusion

In the present study, the media containing coirpith, vermiculite, perlite and vermicompost in 1:0.5:0.5:1 ratio, along with biofertilizer VAM @ 3 g /pot provided an effective organic source of nutrients which resulted in better plant spread, plant height, number of leaves per plant, total biomass production and total chlorophyll content in *Nephrolepis cordifolia* under vertical garden system. Hence this combination can be recommended for use in vertical system of growing indoor foliage plants.

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