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Impact of Hydroponics Technique on Root Characteristics and Physiological Parameters in Chrysanthemum

Sofior Rahman [a], Hridesh Harsha Sarma [b*], Ruby Sarmah [c] and Sangita Das [d]

[a] Department of Horticulture, Assam Agricultural University, Jorhat, Assam, India.
[b] Department of Agronomy, Assam Agricultural University, Jorhat, Assam, India.
[c] College of Horticulture, Nalbari, Assam, India.
[d] Department of Crop Physiology, Assam Agricultural University, Jorhat, Assam, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted at Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat to investigate the response of root characteristics and physiological parameters of chrysanthemum under hydroponics technique. It was laid out on factorial completely randomized design. Total of three replications were done. Experimental variety was chrysanthemum cv. "Rajkumari". Chrysanthemum plants were grown in seven different growing media combinations viz. M_1: coco peat, M_2: coarse sand, M_3: cinder, M_4: coarse sand cinder (1:1 v/v), M_5: coarse sand and coco peat (1:1 v/v), M_6: coco peat and cinder (1:1 v/v) and M_7: coco peat, coarse sand and cinder (1:1:1 v/v) and two different concentrations of nutrient solution (modified

**Corresponding author: E-mail: hrideshsarma.official@gmail.com;*

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Hoagland solution) viz. N1: EC 1.5 dS/m and N2: EC 1.8 dS/m. Results revealed that among different growing media, coco peat was found significantly superior to all other growing media in terms of favouring root characteristics which was followed by coco peat+ cinder. Meanwhile, among the nutrient solution concentrations, EC 1.5 dS/m was found superior to EC 1.8 dS/m. In terms of physiological characteristics, coco peat+ cinder was found significantly superior to all other growing media which was followed by coco peat + coarse sand + cinder. Meanwhile, among the nutrient solution concentrations, EC 1.8 dS/m was found superior to EC 1.5 dS/m for same parameters.

Keywords: Chrysanthemum; coco peat; hydroponics; physiology; root parameters.

1. INTRODUCTION

In a culturally diverse nation like India, flowers play a significant role in almost all festivals, religious ceremonies, and social gatherings. Today, the cultivation of ornamental plants represents a crucial aspect of agricultural entrepreneurship, contributing positively to the financial well-being of farmers and cultivators. They are widely recognized as symbols of happiness, elegance, and beauty, offering a delightful spectacle for our senses. They bring joy through their vibrant colors and enchanting fragrances [1]. This sector also creates substantial employment opportunities, both domestically and through exports, bolstering economic growth across the country. The florist's chrysanthemum (*Dendranthema grandiflora* Tzvelev), belonging to the Asteraceae family, holds significant global importance as a commercially cultivated flowering plant. It is valued for its extensive variety in size, shape, and vibrant colors, as well as its extended pre- and post-harvest longevity. Known as the "Queen of the East," chrysanthemums are commercially cultivated alongside roses and carnations in India for their economic and aesthetic contributions. In India, they are predominantly grown in open fields to produce loose or cut flowers, as well as potted plants for exhibitions. According to Dutt et al. [2], their studies suggest that combinations such as cocopeat + soilrite, soilrite + compost, and cocopeat + compost could be suggested as viable alternatives to soil for successful cultivation of chrysanthemums. Chrysanthemums have been cultivated in diverse colors, shapes, and textures, making them highly favored in the bouquet industry for mass markets [3]. They are also commonly grown as potted plants worldwide. In the international flower market rankings of 2014, chrysanthemums held the third position as a cut flower, following roses and carnations, and were ranked fifth as a potted plant [4].

Meanwhile, farmers in our country are facing significant challenges including unpredictable temperature changes due to global warming, limited cultivable land, and soil degradation from prolonged chemical use. As the Indian government aims to double farmers' incomes, there is potential for a transformative solution. Hydroponic farming emerges as a promising innovation that could benefit rural agricultural areas and urban populations affected by poor environmental conditions in cities. It has the potential to minimize farmers crisis.Hydroponic cultivation offers significant savings in time, labor, and expenses by eliminating the need for soil preparation, bed setup, and the application of fertilizers, herbicides, insecticides, and fungicides. Hydroponics involves cultivating plants without soil by using mineral nutrient solutions dissolved in water. In modern agriculture, hydroponic systems are considered highly efficient for crop production [5]. The term "hydroponic" originates from the Greek words "hydro," meaning water, and "ponos," meaning labour or work. A suitable growing medium must provide adequate support for plants, serve as a reservoir for water and nutrients, facilitate oxygen penetration to the roots, and allow for gas exchange between the roots and the surrounding atmosphere [6,7]. The hydroponics or soilless culture industry has seen rapid global expansion. In hydroponic aggregate systems, various organic and inorganic substrates such as cocopeat, perlite, vermiculite, and sand are commonly used alone or in combinations. These substrates are inert, free from diseases and pests, retain adequate moisture, and can be reused across multiple seasons. Soilless substrates typically exhibit superior physical and hydraulic properties compared to traditional soil mediums [8]. This method has traditionally been employed for growing vegetable crops such as lettuce, cucumber, and tomato. Additionally, popular cut flowers like roses, gerberas, and anthuriums have also been successfully grown hydroponically [9]. Chrysanthemums can likewise be produced using soilless culture systems. The optimal concentration of nutrients in a nutrient solution varies depending on factors such as the type of hydroponic system used, the species of crop being grown, the stage of growth, and the planting density [10-12]. Consequently, a research experiment was undertaken to systematically gather empirical evidence concerning the cultivation of chrysanthemum under hydroponics technique to study its impact effect on root characteristics and physiological parameters.

2. MATERIALS AND METHODS

An experiment was conducted at Experimental Farm, Department of Horticulture, AAU, Jorhat during 2021-2022 to examine the effect of hydroponics technique on root characteristics and physiological parameters of chrysanthemum. The total annual rainfall is around 2300 mm and average humidity is about 75 per cent to 88 per cent. The design of the experiment was Factorial Completely Randomized Design (CRD) with two factors. Seven different growing media were used for the experiment which were as follows: M_1: coco peat, M_2: coarse sand, M_3: cinder, M_4: coarse sand cinder (1:1 v/v), M_5: coarse sand and coco peat (1:1 v/v), M_6: coco peat and cinder (1:1 v/v) and M_7: coco peat, coarse sand and cinder (1:1:1 v/v) and two levels of hydroponic nutrient solution concentration viz., EC 1.5 dS/m and EC 1.8 dS/m. So, there were fourteen treatment combinations with three replication and one control (soil). Spray chrysanthemum was used as a planting material. Variety used was *Rajkumari*. Cocopeat, cinder, and coarse sand were obtained from a local supplier in Jorhat for use as growing substrates in this study. The cocopeat block was soaked in water overnight to hydrate it before being transferred into plastic pots. The substrates were manually mixed to create combinations: cocopeat with coarse sand, cocopeat with cinder, coarse sand with cinder in equal parts (1:1 ratio), and combinations of cocopeat with cinder and coarse sand in equal parts (1:1:1 ratio). These mixtures were then filled into 12-inch (30 cm) plastic pots, which were purchased from the market. Drainage holes were drilled in the pots prior to filling them with the prepared growing media. Broken crocks or stones were placed at the drainage holes to ensure proper drainage of excess water. Chrysanthemum seedlings were carefully removed from finger pots and transplanted into nursery pots filled with the same composition of growing media used for each treatment. After a period of 30 days, the established chrysanthemum plants were then moved into the main pots, which were 12 inches (30 cm) in diameter and filled with the corresponding growing media as per their respective treatments. The nutrient solution was administered manually at a rate of 20 ml per day at the base of each plant. The electrical conductivity (EC) of the nutrient solution was tailored to match the requirements of each treatment, and filtered water was used for irrigation on alternating days. Root characteristics were assessed as follows: Root volume (cc/ml) was determined using the water displacement method, where the total root volume of three selected plants from each treatment was measured using a standard graduated cylinder. Maximum root length (cm) was measured from the crown region to the tip of the longest root on three plants per treatment, cleaned with tap water and measured using a meter scale, with the mean length calculated. Root fresh weight (g) was immediately recorded after harvest for three plants per treatment, and the average weight calculated. Root dry weight (g) was obtained by drying the roots of three selected plants from each treatment in an oven at 60°C for 24 hours, followed by weighing. To determine chlorophyll content (mg/g FW), the method outlined by Aron (1949) [13] was followed. For relative leaf water content (%), the method described by Barrs and Weatherly (1962) [14] was employed. Data were statistically analyzed at 5 per cent significance level the mean separation was carried out by Duncan's Multiple Range Test (DMRT) by using Microsoft Excel.

3. RESULTS AND DISCUSSION

The maximum root volume (83.33 cc) was recorded in plants grown in coco peat (M_1) and minimum (50.17 cc) was recorded in coarse sand (M_2). Among the EC tested was statistically significant, EC 1.5 dS/m (N_1) recorded maximum root volume (69.62 cc) and EC 1.8 dS/m (N_2) resulted in minimum root volume (55.86 cc). Among the interaction effects, the maximum root volume (91.67 cc) was recorded in coco peat with EC 1.5 dS/m (M_1). However, minimum root volume (44.33 cc) was recorded in coarse sand with EC 1.8 dS/m (M_2N_2). This result supported by the findings of Khayat et al. [15]. He found that pothos grown in 100% coco peat medium exhibited the highest root count, consistent with findings by Rajera et al. [16] in LA hybrid lily and Singh et al. [17] in anthurium cv. 'Flame'. This is likely attributed to enhanced water and nutrient uptake facilitated by the physical and chemical properties of the substrate. Coco peat not only maintains optimal air-filled porosity but also retains moisture up to nine times its volume. In contrast, plants grown in control soil showed minimal root volume (12.33 cc), possibly due to inadequate nutrient availability and poor soil structure leading to insufficient drainage.

The maximum root length (56.00 cm) was recorded in coco peat+ coarse sand+ cinder (M_7) which was at par with coco peat+ cinder (M_6) (54.00 cm). Whereas, minimum root length (32.33 cm) was recorded in cinder (M_3). EC 1.5 dS/m (N_1) was recorded maximum root length (49.86 cm) and EC 1.8 dS/m (N_2) was recorded in minimum root length (40.19 cm). However, minimum root length (29.33 cm) was recorded in cinder with EC 1.8 dS/m (M_3N_2). The increase in root length can be attributed to both the physical and chemical properties of the substrate, as well as the macro and micronutrient content within the nutrient solution (Hoagland solution). The longest roots observed in the coco peat + cinder + coarse sand medium indicate the role of optimal aeration and porosity of these substrates, coupled with effective nutrient supply, which enhances nutrient uptake, expands leaf area, and boosts photosynthesis, facilitating the movement of photosynthates towards root development. Specifically, the greatest root length (49.86 cm) occurred under lower nutrient concentration (N_1), suggesting roots compensate for nutrient deficiency by maximizing volume and length. In interactions between nutrient solutions

Table 1. Effect of growing media and nutrient solution on root volume (cc)

Treatments	EC 1.5	EC 1.8	Mean
Coco peat (M_1)	91.67	75.00	83.33
Coarse sand (M_2)	56.00	44.33	50.17
Cinder (M_3)	62.00	48.67	55.33
Coarse sand+ Cinder (M_4)	66.33	51.00	58.67
Coarse sand+ Coco peat (M_5)	63.67	53.33	58.50
Coco peat+ Cinder (M_6)	78.67	64.00	71.33
Coco peat+ Coarse sand+ Cinder (M_7)	69.00	54.67	61.83
Mean	69.62	55.86	62.74
Control			12.33
	SE.d (±)		C.D. (5%)
Control Vs Rest	3.10		6.31
Nutrient (N)	2.23		4.58
Media (M)	1.19		2.45
Interaction (MxN)	3.16		6.47

Table 2. Effect of growing media and nutrient solution on maximum root length (cm)

Treatments	EC 1.5	EC 1.8	Mean
Coco peat (M_1)	52.33	39.67	46.00
Coarse sand (M_2)	39.33	29.67	34.50
Cinder (M_3)	35.33	29.33	32.33
Coarse sand+ Cinder (M_4)	47.67	36.33	42.00
Coarse sand+ Coco peat (M_5)	53.67	47.00	50.33
Coco peat+ Cinder (M_6)	60.00	48.00	54.00
Coco peat+ Coarse sand+ Cinder (M_7)	60.67	51.33	56.00
Mean	49.86	40.19	45.02
Control			24.33
	SE.d (±)		C.D. (5%)
Control Vs Rest	2.72		5.53
Nutrient (N)	1.96		4.02
Media (M)	1.05		2.15
Interaction (MxN)	2.77		5.68

Table 3. Effect of growing media and nutrient solution on fresh weight of root (g)

Treatments	EC 1.5	EC 1.8	Mean
Coco peat (M_1)	93.44	80.63	87.04
Coarse sand (M_2)	44.44	36.22	40.33
Cinder (M_3)	47.55	37.77	42.66
Coarse sand+ Cinder (M_4)	48.13	39.38	43.75
Coarse sand+ Coco peat (M_5)	49.85	43.02	46.44
Coco peat+ Cinder (M_6)	59.90	44.71	52.31
Coco peat+ Coarse sand+ Cinder (M_7)	72.27	58.40	65.34
Mean	59.37	48.59	53.98
Control			9.17
	SE.d (±)		C.D. (5%)
Control Vs Rest	2.19		4.47
Nutrient (N)	1.54		3.15
Media (M)	0.82		1.68
Interaction (MxN)	2.18		4.46

Table 4. Effect of growing media and nutrient solution on dry weight of root (g)

Treatments	EC 1.5	EC 1.8	Mean
Coco peat (M_1)	17.80	12.95	15.37
Coarse sand (M_2)	6.60	5.64	6.12
Cinder (M_3)	8.28	5.90	7.09
Coarse sand+ Cinder (M_4)	8.23	6.94	7.58
Coarse sand+ Coco peat (M_5)	10.08	6.72	8.40
Coco peat+ Cinder (M_6)	10.28	8.55	9.41
Coco peat+ Coarse sand+ Cinder (M_7)	13.74	10.86	12.30
Mean	10.72	8.22	9.47
Control			0.63
	SE.d (±)		C.D. (5%)
Control Vs Rest	0.99		2.02
Nutrient (N)	0.72		1.48
Media (M)	0.39		0.79
Interaction (MxN)	1.02		2.10

and growing media, maximum root length (60.67 cm) was achieved in coco peat + coarse sand + cinder with an electrical conductivity (EC) of 1.5 dS/m (M_7N_1). These findings align with Khayat et al. [15], who observed maximum root length in pothos using a peat moss + coco peat blend in a 1:3 ratio, and with Renuka et al. [18], who noted similar results in carnation, where coco peat mixed with other media promoted longer roots.

The maximum fresh weight of root (87.04 g) was recorded in coco peat (M_1) and minimum (40.33 g) was in coarse sand (M_2). The maximum fresh weight of root (59.37 g) was recorded in EC 1.5 dS/m (N_1) and minimum (48.59 g) was in EC 1.8 dS/m (N_2). The maximum fresh weight of the root (93.44 g) was recorded in the treatment combination coco peat with EC 1.5 dS/m (M_1) and minimum (36.22 g) was recorded in cinder with EC 1.8 dS/m (M_3N_2). The physicochemical properties of the substrate play a crucial role in this context. Coco peat, known for its excellent aeration and high-water retention capacity, ensures a steady supply of optimal nutrients, oxygen, and water to the root zone, thereby promoting accelerated root growth. This is likely a contributing factor to the increased fresh weight of chrysanthemum roots observed in this study. Conversely, the lowest fresh and dry weights of roots were observed in plants grown in coarse sand, possibly due to the rapid vertical movement of water and nutrients through larger pore spaces, which may prevent roots from efficiently absorbing the necessary nutrients and water. These findings align with Renuka et al. [18], who reported maximum root fresh weight in carnations grown in coco peat mixed with vermicompost, and with Sameei et al. [19], who found similar results in pothos, where media incorporating coco peat resulted in higher fresh and dry weights of roots.

Table 5. Effect of growing media and nutrient solution on chlorophyll content (mg/g fresh weight)

Treatments	EC1.5	EC 1.8	Mean
Coco peat (M_1)	1.33	1.39	1.36
Coarse sand (M_2)	0.92	1.00	0.96
Cinder (M_3)	0.93	1.08	1.01
Coarse sand+ Cinder (M_4)	1.08	1.39	1.24
Coarse sand+ Coco peat (M_5)	1.32	1.47	1.39
Coco peat+ Cinder (M_6)	1.55	1.77	1.66
Coco peat+ Coarse sand+ Cinder (M_7)	1.52	1.69	1.61
Mean	1.24	1.40	1.32
Control			0.75
	SE.d (±)		C.D. (5%)
Control Vs Rest	0.05		0.10
Nutrient (N)	0.03		0.07
Media (M)	0.02		0.04
Interaction (MxN)	0.05		0.10

Table 6. Effect of growing media and nutrient solution on relative leaf water content (%)

Treatments	EC 1.5	EC 1.8	Mean
Coco peat (M_1)	77.90	81.40	79.65
Coarse sand (M_2)	70.20	73.18	71.69
Cinder (M_3)	74.91	80.01	77.46
Coarse sand+ Cinder (M_4)	76.64	80.26	78.45
Coarse sand+ Coco peat (M_5)	77.82	81.57	79.70
Coco peat+ Cinder (M_6)	77.82	84.61	81.21
Coco peat+ Coarse sand+ Cinder (M_7)	79.20	81.97	80.58
Mean	76.21	80.57	78.39
Control			51.97
	SE.d (±)		C.D. (5%)
Control Vs Rest	2.07		4.22
Nutrient (N)	1.30		2.66
Media (M)	0.69		1.42
Interaction (MxN)	1.83		3.76

The maximum dry weight of root (15.37 g) was recorded in coco peat (M_1), which was significantly different among all the treatments and minimum dry weight of root (6.12 g) was recorded in coarse sand (M_2). The maximum dry weight of root (10.72 g) was recorded in EC 1.5 dS/m (N1) and minimum (8.22 g) was in EC 1.8 dS/m (N_2). Among the interaction, the maximum dry weight of the root (17.80 g) was recorded in the treatment combination coco peat with EC 1.5 dS/m (M_1) and minimum (5.64 g) was recorded in coarse sand with EC 1.8 dS/m (M_2N_2). Merrow [20] observed that root dry weight reached its peak in coir-based media when studying *Pentas lanceolata* and *Ixora coccinea*. Similarly, Saha et al. [21] found that in chrysanthemums, both fresh and dry weights of flowers were highest in a growing medium composed of sand, coco peat, vermicompost, vermiculite, and perlite in specific proportions (1:2:2:0.25:0.25). Regarding nutrient concentration, the highest fresh weight (59.37 g) and dry weight (10.72 g) of roots were recorded under lower electrical conductivity (EC) levels (1.5 dS/m). This could be attributed to the roots compensating for lower nutrient availability by increasing both their volume and length, consequently leading to maximum fresh root weight. Al-Ghawanmeh et al. [22] noted a decrease in root fresh mass as the EC of the nutrient solution increased, further supporting the influence of nutrient strength on root development.

The maximum chlorophyll content (1.66 mg/g fresh weight) was recorded in coco peat+ cinder (M_6) and minimum (0.96 mg/g fresh weight) was recorded in coarse sand (M_2). However, the maximum chlorophyll content (1.40 mg/g FW) was recorded in EC 1.8 dS/m (N_2) and minimum (1.24 mg/g FW) was in EC 1.5 dS/m (N_1). The interaction of growing media and nutrient solution was also found significant. Chlorophyll is a crucially important biomolecule that is required for photosynthesis, which allows plants to absorb the light energy. Maximum chlorophyll content (1.66 mg g^{-1} FW) was obtained in coco peat+ cinder. The enhanced chlorophyll content observed can be attributed to the physical properties of coco peat and cinder. Coco peat, known for its ability to stimulate root development and improve nutrient absorption, particularly nitrogen, plays a vital role. Nitrogen is essential for chlorophyll synthesis, which is crucial for photosynthesis as it binds to proteins in the photosynthetic apparatus [23]. Higher chlorophyll levels in leaf tissue are directly linked to increased nitrogen availability, thereby boosting photosynthetic capacity [24]. This heightened chlorophyll content contributes to greater carbohydrate accumulation and overall plant growth.

Under higher nutrient concentration (N_2), the maximum chlorophyll content was recorded, indicating efficient nutrient uptake and utilization. In interactions between nutrients and growing media, the highest chlorophyll content (1.77 mg g^{-1} FW) was observed in coco peat combined with cinder under an EC of 1.8 dS/m (M_6N_2). This outcome is likely due to the optimal nutrient levels and the beneficial physical properties of the growth substrates. These findings align with Asil [25], who found maximum chlorophyll content in lilium plants grown in a mixture of peat and perlite, and with Saha et al. [21], who reported similar results in chrysanthemums using a blend of sand, coco peat, vermicompost, vermiculite, and perlite in specified proportions.

The maximum relative leaf water content (81.21%) was recorded in coco peat+ cinder (M_6) and which was at par with (80.58%) in coco peat+ coarse sand+ cinder (M_7). However, minimum relative leaf water content (71.69%) was recorded in coarse sand (M_2). In hydroponic nutrient solution differences, there was significant effect on relative leaf water content, however at N_2 (EC 1.8 dS/m) had shown better result (80.57%) than N_1 (EC 1.5 dS/m) (76.21%). The maximum relative leaf water content (84.61%) was recorded in the treatment combination coco peat+ cinder with EC 1.8 dS/m (M_6N_2) which was at par with coco peat+ EC 1.8 dS/m (M_1N_2), coarse sand+ coco peat with EC 1.8 dS/m (M_5N_2) and coco peat+ coarse sand+ cinder with EC 1.8 dS/m (M_7N_2). However, minimum value (70.20%) was recorded in coarse sand with EC 1.5 dS/m (M_2N_1). Relative leaf water content (RLWC) serves as a crucial indicator of leaf water retention ability, crucial for maintaining leaf turgidity and supporting overall plant metabolism. It is also a reliable measure of drought tolerance, reflecting the plant's capacity for osmotic regulation. RLWC provides insights into cellular hydration, influenced by factors such as leaf water potential and osmotic adjustments within the plant. In the current study, the highest RLWC (81.21%) was observed in plants grown in a coco peat and cinder mixture (M_6). This superior RLWC can be attributed to the beneficial physicochemical properties of coco peat and cinder, which enhance root development, leading to improved water and nutrient uptake. A higher root-to-shoot ratio contributes to maintaining optimal water balance in plants. Conversely, the lowest RLWC (71.69%) was noted in plants grown in coarse sand (M_2), a finding supported by Urooj-Ul-Nissa [26] in dahlia. Regarding nutrient solution concentration, the maximum RLWC (80.43%) was recorded at an electrical conductivity (EC) of 1.8 dS/m. The interaction between coco peat and cinder with EC 1.8 dS/m (M_6N_2) resulted in the highest RLWC (84.61%). This outcome is likely due to increased availability of essential minerals, particularly phosphorus, which facilitates enhanced root feeding, rapid nutrient absorption, and overall root growth.

4. CONCLUSION

The results indicate that using a growing medium composed of coco peat and cinder with an electrical conductivity (EC) of 1.8 dS/m enhances both root characteristics and physiological parameters of chrysanthemums. This promotes overall flower productivity.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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