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Data generation for smart hydroponic system development in *Syngonium podophyllum* (Arrowhead vine)

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Abstract

Hydroponics, a young budding science which can be used as an alternative sustainable production system under limited resource availability conditions. High quality ornamental plants can be produced through hydroponics as it encourages faster growth. Arrowhead vine (*Syngonium podophyllum)* is a widely cultivated ornamental foliage plant as it eliminates polluting agents from inside households. An experiment on standardization of solution culture in Deep Flow Technique (DFT) of hydroponics in *Syngonium podophyllum* was carried out at College of Agriculture, Vellayani, Thiruvananthapuram during the year 2022. The experiment was laid out in completely randomized design. Four doses of Hoagland solution and cooper solution (50%, 100%, 150% and 200%) were given and replicated ten times. Data on growth parameters for development of a smart hydroponic system was collected in scheduled intervals. The electrical conductivity (EC) and pH were monitored at weekly intervals and observations on growth parameters were taken at every 15 days interval for four months. The treatment with 150% Hoagland solution in *Syngonium podophyllum* plants showed superior characteristics for number of leaves, leaf length, leaf breadth, plant height and plant spread. The data can be used for developing an automatic hydroponic system controlled by a mobile application and different ornamental foliage plants can be tested using it.

Keywords: Hydroponics, DFT, *Syngonium podophyllum,* Smart hydroponic system

Introduction

Hydroponics, a young budding science can be used as an alternative sustainable production system under limited resource availability conditions. The per capita availability of living space is reducing due to rapid increase in population explosion and become a major issue in urban communities. Selection of plants grown under indoor environments with limited space is gaining much importance now a days. High quality ornamental plants can be produced through hydroponics as it encourages faster growth (Lakhiar et al., 2018). *Syngonium podophyllum* is a widely cultivated ornamental foliage plant. It has a tremendous ornamental value as it eliminates polluting agents from inside households. It prefers low light conditions to grow hence it is very suitable for indoor gardening. In tropical countries, it is a plant with high export potential. Smart farming is seen to be the future of agriculture as production of high quality crops and intelligent sensing of the controlling parameters can be done efficiently. Development of sensor-based automation is emerging now a days with the help of mobile applications. It is a cheaper and more affordable way of developing small scale hydroponic systems (Modu et al., 2020). The present paper discusses the results of a preliminary study conducted for data generation with the aim of developing a smart hydroponic

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system for *Syngonium podophyllum* controlled by a mobile application.

Materials and Methods

The present experiment was carried out at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala during the year 2022. The experiment was laid out in completely randomized design. Four doses of Hoagland solution (Hoagland and Arnon, 1950) and cooper solution (Lakhiar et al., 2018)(50%, 100%, 150% and 200%) were given so that totally there were eight different treatments in the experiment and each treatment combinations replicated ten times. Generally, pH of the nutrient solution needs to be maintained between 5.5-6.5 (Tellez et al., 2007) and electrical conductivity (EC) between 1.5-2.5 (Sonneveld and Voogt, 2009).The pH and EC in the present study were monitored in all the nutrient solutions periodically. *Syngonium podophyllum*var. 'White Butterfly' was chosen for the experiment. The experiment unit was designed in PVC pipe closed at both ends. Plants were grown in 3 inch net pots.Observations on various growth parameters *viz.,* number of leaves, leaf length, leaf breadth, plant height and plant spread were observed every 15 days interval from 15th day after planting till 120 days after planting. Details about the treatments given are mentioned below.

Solutions

S_1 – Hoagland Solution

S_2 – Cooper's Solution

Doses

D_1 – 50% dose

D_2 – 100% dose

D_3- 150% dose

D_4- 200% dose

Treatment combinations

T_1 : S_1D_1

T_2 : S_1D_2

T_3 : S_1D_3

T_4 : S_1D_4

T_5 : S_2D_1

T_6 : S_2D_2

T_7 : S_2D_3

T_8 : S_2D_4

Results and Discussion

The study on the effect of nutrient solutions on the number of leaves of *Syngonium podophyllum* var. White Butterfly showed that there was a significant impact throughout the crop period. Hoagland solution was found superior to Cooper's solution (Table 1). The highest value was observed at 120 DAP (18.18). Significant effects of various nutrient doses on the number of leaves were observed from 15 DAP to 120 DAP. The 100% nutrient dose was found to be superior from 15 DAP to 45 DAP but that was found to be on par with all other nutrient doses. Superior values for number of leaves were observed for 150% dose of nutrients from 60 DAP to 120 DAP and highest number of leaves were observed at 120 DAP (17.25) which was found to be on par with 200% nutrient dose (16.05). The interaction effect of nutrient solutions and its doses were significant throughout the experiment (Table 2). A significantly higher number of leaves was observed at 120 DAP (24.70) for the plants grown in Hoagland solution applied at 150% dose. This might be due to the higher nutrient availability to plants when applied with 150% Hoagland solution application (Spehia et al., 2018).

Table 1. Main effect of nutrient solutions and its various doses on number of leaves of *Syngonium podophyllum* var. White Butterfly grown under DFT system of hydroponics

Treatment	Days after planting (DAP)							
	15	30	45	60	75	90	105	120
Solution (S)								
S_1	4.975	7.1	8.825	11.800	13.475	14.875	16.70	18.18
S_2	4.175	6.3	7.050	8.225	9.300	9.975	10.65	11.18
CD (0.05)	0.516	0.794	0.906	1.095	1.162	1.181	1.207	1.09
SEm(±)	0.183	0.282	0.322	0.388	0.412	0.419	0.428	0.39
Dose (D)								
D_1	4.65	6.25	7.30	8.60	9.80	10.65	11.65	12.40
D_2	4.90	7.30	8.35	9.55	10.80	11.40	12.15	13.00
D_3	4.65	6.75	7.85	11.80	13.35	14.70	16.10	17.25
D_4	4.10	6.50	8.25	10.10	11.60	12.95	14.80	16.05
CD (0.05)	1.315	1.398	1.425	1.549	1.644	1.671	1.706	1.542
SEm (±)	0.259	0.398	0.455	0.549	0.583	0.593	0.605	0.547

Table 2. Interaction effect of nutrient solutions and its various doses on number of leaves of *Syngonium podophyllum* var. White Butterfly grown under DFT system of hydroponics

Treat-ment	Days after planting (DAP)							
	15	30	45	60	75	90	105	120
S1D1	4.7	5.8	6.9	8.1	8.4	9.4	10.2	11.0
S1D2	5.4	7.6	8.8	9.8	11.5	12.7	13.3	14.4
S1D3	5.2	8.0	9.9	16.4	18.8	20.3	22.9	24.70
S1D4	4.6	7.0	9.7	12.9	15.2	17.1	20.4	22.6
S2D1	4.6	6.7	7.7	9.1	11.2	11.9	13.1	13.8
S2D2	4.4	7.0	7.9	9.3	10.1	10.1	11.0	11.6
S2D3	4.1	5.5	5.8	7.2	7.9	9.1	9.3	9.8
S2D4	3.6	6.0	6.8	7.3	8.0	8.8	9.2	9.5
CD (0.05)	1.030	1.589	1.813	2.19	2.325	2.363	2.413	2.181
SEm (±)	0.366	0.563	0.643	0.777	0.825	0.838	0.856	0.774

The effect of nutrient solutions on leaf length of *Syngonium podophyllum* was significant throughout the experiment with highest value at 120 DAP (24.90 cm) for Hoagland solution (Table 3). The nutrient doses were also significant on leaf length with highest value for 100% dose throughout the experiment. The highest among it was after 120 DAP (23.62 cm). The interaction effect of nutrient solutions and its doses was significant, but the highest value varied in each observation. This might be due to the significant increase in growth when different nutrient solution doses were applied as stated by Maruo et al., (2002). Significantly higher leaf length was observed 120 DAP (28.62 cm) for plants grown in Hoagland solution with 200% nutrient dose and it was on par with Hoagland solution of 150% dose (27.90 cm) application.

Effect of nutrient solutions on leaf breadth was significant throughout the experiment and found to have highest value at 120 DAP (23.47 cm) for Hoagland solution (Table 4). The effect of nutrient dose on leaf breadth was significant throughout the experiment and significantly higher values were observed for100% nutrient dose

Table 3. Effect of nutrient solutions and its various doses on leaf length (cm) of *Syngonium podophyllum* var. White Butterfly grown under DFT system of hydroponics

Treatment	Days after planting (DAP)							
	15	30	45	60	75	90	105	120
Solution (S)								
S_1	14.16	16.13	18.65	20.01	21.38	22.36	23.87	24.90
S_2	13.94	15.11	16.05	16.85	17.96	18.40	18.99	19.39
CD (0.05)	0.685	0.994	0.718	0.739	0.68	0.67	0.631	0.624
SEm (±)	0.35	0.353	0.255	0.262	0.241	0.238	0.224	0.221
Dose (D)								
D1	13.18	14.56	16.13	17.16	18.48	19.44	20.20	20.77
D2	16.14	17.89	19.44	20.25	21.42	22.22	23.11	23.62
D3	13.35	14.99	16.89	17.78	19.05	19.44	20.95	21.67
D4	13.52	15.02	16.95	18.53	19.73	20.44	21.47	22.54
CD	1.397	1.406	1.015	1.045	0.962	0.947	0.893	0.882
SEm (±)	0.495	0.499	0.36	0.371	0.341	0.336	0.317	0.313
S×D								
S1D1	11.64	12.57	13.64	14.55	15.07	16.42	17.46	18.00
S1D2	15.55	17.94	20.24	20.94	21.81	23.10	24.49	25.08
S1D3	15.58	17.83	20.99	21.97	24.06	24.28	26.83	27.90
S1D4	13.86	16.16	19.73	22.58	24.58	25.65	26.68	28.62
S2D1	14.72	16.54	18.61	19.76	21.88	22.46	22.94	23.54
S2D2	16.73	17.84	18.64	19.56	21.02	21.33	21.72	22.15
S2D3	11.12	12.16	12.79	13.58	14.04	14.59	15.07	15.43
S2D4	13.17	13.88	14.17	14.48	14.89	15.22	16.26	16.45
CD	1.975	1.988	1.435	1.477	1.36	1.34	1.263	1.248
SEm (±)	0.701	0.705	0.509	0.524	0.482	0.475	0.448	0.443

Table 4. Effect of nutrient solutions and its various doses on leaf breadth (cm) of *Syngonium podophyllum* var. White Butterfly grown under DFT system of hydroponics

Treatment	Days after planting (DAP)							
	15	30	45	60	75	90	105	120
Solution (S)								
S_1	14.158	16.125	18.650	20.010	21.380	22.363	23.865	24.900
S_2	13.935	15.105	16.052	16.845	17.958	18.400	18.997	19.392
CD (0.05)	0.786	0.994	0.718	0.739	0.68	0.67	0.631	0.624
SEm (±)	0.35	0.353	0.255	0.262	0.241	0.238	0.224	0.221
Dose (D)								
D1	13.180	14.555	16.125	17.155	18.475	19.440	20.200	20.770
D2	16.140	17.890	19.440	20.250	21.415	22.215	23.105	23.615
D3	13.350	14.995	16.890	17.775	19.050	19.435	20.950	21.665
D4	13.515	15.020	16.950	18.530	19.735	20.435	21.470	22.535
CD	1.397	1.406	1.015	1.045	0.962	0.947	0.893	0.882
SEm (±)	0.495	0.499	0.36	0.371	0.341	0.336	0.317	0.313
S×D								
S1D1	7.06	7.45	8.32	8.74	8.93	9.16	9.37	9.76
S1D2	9.56	10.21	10.54	10.81	11.01	11.65	12.37	12.67
S1D3	9.18	10.55	11.69	11.95	12.22	13.50	16.01	16.54
S1D4	8.61	9.83	10.44	12.24	12.60	14.22	14.39	14.90
S2D1	9.23	10.27	10.45	11.64	12.11	12.84	13.05	13.35
S2D2	10.44	11.51	11.61	11.71	11.85	12.99	13.14	13.36
S2D3	6.99	7.65	7.99	8.06	8.24	9.15	9.39	9.66
S2D4	7.61	7.94	8.17	8.46	8.55	9.88	10.26	10.60
CD	0.949	0.878	0.943	0.911	0.841	0.976	1.375	1.382
SEm (±)	0.336	0.311	0.334	0.323	0.298	0.346	0.488	0.49

from 15 DAP to 105 DAP. But significantly highest value was observed for 150% dose at 120 DAP (13.10 cm) and which was on par with 100% nutrient dose (13.02 cm). The interaction effect of nutrient solutions and nutrient doses were also found significant throughout the experiment. Significantly higher leaf breadth was observed for plants grown in Hoagland solution of 150% nutrient dose (16.54 cm) at 120 DAP. This result was in conformity with the findings of Kang and Iersel (2004).

The effect of nutrient solutions on plant height was significant throughout the experiment and found to have highest value at 120 DAP (35.22 cm) for Hoagland solution (Table 5). The effect of nutrient dose on plant height was significant throughout the experiment and significantly higher values were observed for100% nutrient dose from 15 DAP to 105 DAP. But significantly highest value was observed for 150% dose at 120 DAP (31.91 cm). The interaction effect of nutrient solutions and nutrient doses on plant height was also found significant throughout the experiment. Significantly higher value was observed for Hoagland solution at 150% nutrient dose (43.99 cm) at 120 DAP. The variation in plant growth showed that not only the nutrient content creates difference but the ratio of different ions in the nutrient solution also influences the plant growth (Li and Cheng, 2014).This might be due to interaction among various ions influencing EC and pH in different nutrient solutions and this can lead to accumulation of plant tissues (Dhanraj, 2020).

Effect of nutrient solutions on plant spread was significant throughout the experiment and was highest for the plants at 120 DAP (56.95 cm) in Hoagland solution. The effect of nutrient dose on plant spread was significant throughout the experiment and significantly higher values were observed for100% nutrient dose from 15 DAP to 105 DAP (Table 6). But significantly higher value was observed for 150% dose at 120 DAP (52.66 cm) and which was on par with 100% nutrient dose (51.26 cm). The interaction effect of nutrient solutions and nutrient doses on plant spreadwas also found significant throughout the experiment. At 150% nutrient dose, significantly higher plant spread (74.03 cm) was observed for plants in Hoagland solution at 120 DAP. Various chemical compositions of nutrient solutions can influence the accumulation of biomass, and this is in accordance with the findings of Li and Cheng (2014).

Table 5. Main effect of nutrient solutions and its various doses on plant height (cm) of *Syngonium podophyllum* var. White Butterfly grown under DFT system of hydroponics

Treatment	Days after planting (DAP)							
	15	30	45	60	75	90	105	120
Solutions (S)								
S1	15.262	18.418	21.105	22.89	26.925	29.490	31.580	35.22
S2	13.020	14.608	16.815	18.42	19.970	21.702	22.452	23.735
CD	1.31	1.196	1.012	1.103	1.246	1.104	0.946	1.37
SEm(±)	0.465	0.424	0.359	0.391	0.442	0.392	0.336	0.486
Dose (D)								
D1	13.195	14.760	16.370	18.710	20.880	23.230	24.460	26.10
D2	16.810	19.470	22.030	24.375	26.545	28.245	29.545	30.79
D3	13.765	16.465	18.865	20.470	22.935	25.745	27.940	31.91
D4	12.795	15.355	18.575	19.065	23.430	25.165	26.120	29.11
CD	1.853	1.691	1.431	1.56	1.762	1.561	1.338	1.938
SEm (±)	0.657	0.6	0.508	0.553	0.625	0.554	0.475	0.687

Table 6. Effect of nutrient solutions and its various doses on plant spread (cm) of *Syngonium podophyllum* var. White Butterfly grown under DFT system of hydroponics

Treatment	Days after planting (DAP)							
	15	30	45	60	75	90	105	120
Solutions (S)								
S1	31.773	34.562	39.270	43.025	45.132	48.522	52.852	56.95
S2	25.542	28.090	31.198	32.945	34.737	36.142	37.525	39.90
CD	1.641	1.73	1.501	1.63	1.566	1.473	1.439	1.772
SEm(±)	0.582	0.613	0.532	0.578	0.556	0.523	0.511	0.629
Dose (D)								
D1	24.955	27.210	30.850	33.060	34.960	36.83	39.080	42.53
D2	35.290	38.620	41.460	42.845	44.840	47.33	49.560	51.26
D3	26.830	29.565	34.670	39.060	41.345	44.13	48.230	52.66
D4	27.555	29.910	33.955	36.975	38.594	41.04	43.885	47.26
CD	2.321	2.446	2.122	2.305	2.215	2.083	2.035	2.506
SEm (±)	0.823	0.868	0.753	0.818	0.786	0.739	0.722	0.889
S×D								
S1D1	21.59	23.03	25.11	26.53	28.300	30.65	32.74	35.46
S1D2	39.11	42.97	43.74	44.51	46.540	49.67	53.41	55.39
S1D3	32.99	36.25	44.98	52.50	55.000	59.85	66.89	74.03
S1D4	33.40	36.00	43.25	48.56	50.690	53.92	58.37	62.93
S2D1	28.32	31.39	36.59	39.59	41.620	43.01	45.42	49.59
S2D2	31.47	34.27	39.18	41.18	43.140	44.99	45.71	47.12
S2D3	20.67	22.88	24.36	25.62	27.690	28.41	29.57	31.32
S2D4	21.71	23.82	24.66	25.39	26.498	28.16	29.40	31.58
CD	3.282	3.459	3.001	3.26	3.132	2.946	2.879	3.544
SEm (±)	1.164	1.227	1.065	1.157	1.111	1.045	1.021	1.257

The present study revealed that the vegetative characters of *Syngonium podophyllum* var. White Butterfly grown under hydroponics were superior in Hoagland solution applied at 150% dose. It was also observed that plant growth was promoted till 150% of Hoagland solution and 100% Cooper's solution, but beyond this optimum concentration, the growth decreased and these results are akin to those of Baiyin et al., (2021). Indoor plant production systems were promoted largely by advancements in nutrient solution technologies.

Conclusion

The vegetative parameters *viz.,* number of leaves, leaf length, leaf breadth, plant height and plant spread were maximum for the plants grown with Hoagland solution at 150% concentration and Cooper's solution was found inferior toHoagland solution. The generated data in this study for growth parameters of *Syngonium podophyllum* var. White Butterfly can be used for developing a plant simulation model and different ornamental foliage plants can be tested in a sensor based automatic hydroponic system controlled by a mobile application.The testing can be extended to other ornamental foliage plants also, including those in Ipomoea genus of family Convolvulaceae most known as morning glories.

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