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PERFORMANCE OF FOLIAGE ORNAMENTALS ON DIFFERENT NUTRIENT SOLUTIONS UNDER PASSIVE HYDROPONIC VERTICAL CULTURE

D. Dhanasekaran

Department of Horticulture, Faculty of Agriculture, Annamalai University, Annamalai Nagar-608002 (T.N.) India.

Abstract

Hydroponics is a way of growing plants in a soilless environment with the use of nutrient solutions. In this method, plants may be grown with their roots in the mineral nutrient solution in an inert or organic medium. The fundamental component in hydroponic system is represented by the nutrient solution. The control of nutrient solution concentration, referred as electrical conductivity or osmotic pressure, allows the culture of a great diversity of species. Under hydroponics, some plants can be grown closer together than in the field because roots are directly fed. The important factor determines the growth and production of hydroponic plants is the quantum of nutrients and their combinations. Hence, an experiment was conducted with Hoagland and Arnon solution (1938), Cooper's solution (1979), Saparamadu's solution (2010) and Mattson and Peters solution (2014) and a control with Irrigation water for growing foliage ornamentals under passive hydroponic vertical garden module. The pH was monitored for acidity and basicity range and EC were monitored for salt concentration in all the nutrient solution periodically. Observation on physiological parameters *viz.,* Chlorophyll content, Membrane integrity (%) and Relative growth rate (g days^{-1}) was observed at 30, 60 and 90 days after planting. Results of the experiment revealed that the foliage ornamentals *viz.,* Devils ivy, Arrow head plant and Philodendron grown under treatment T_3 (Cooper's solution) recorded the maximum chlorophyll content and the other two *viz.,* Wandering jew and Boat lily recorded maximum chlorophyll content in T_2 (Hoagland solution) at all three stages of observation. The highest membrane integrity percent was observed under T_2 (Hoagland solution) at all three stages of observation and the lowest membrane integrity percent was observed in T_1 (Irrigation water) in devils ivy and T_4 (Saparamadu's solution) in Wandering jew, Arrow head plant, Philodendron and Boat lily at all the three stages of observations. Highest relative growth rate was observed in T_2(Hoagland solution) in all the foliage ornamentals and the lowest growth rate was found with T_4 (Saparamadu's solution).

Keywords: Hydroponic nutrient solution, vertical gardening, foliage ornamentals

Introduction

Climate change and energy depletion are two of the greatest risks humanity are facing in the 21st century. On the other hand the world population was expected to reach nine billion in 2050 and it is estimated that 80% of the world's population will grow from 6.8 billion people to 9 billion people will live in urban areas and metropolitan. Hence, much emphasis has been placed on land utilization for housing and commercial purposes, where land space is limited. Thus, there is an urgent need for newer technologies that efficiently utilizes land, water, fertilizer and energy without relying on external climatic conditions. Vertical farming in the form of indoor cultivation on high-rise buildings is being explored as a potential technology to provide reliable and healthy produce to consumers living in a dense urban environment. With the advent of the modern industrial city, planners, designers and urban advocates are once again turning to plants-green infrastructure-as a key strategy to provide cleaner air and water and to improve living environments, human health and mental well being. Vertical green walls and extended gardens offer a multitude of social, economic and environmental benefits such as adaptation to climate change, reduced greenhouse gas emission, improved air quality, increased habitat areas and improved Aesthetics. From an environmental point of view, living walls introduce greenery into modern cities with established strategies such as green corridors, urban parks and even green roofs.

***Author for correspondence :** E-mail: dhansflora@gmail.com

Plants from Araceae, Asparagacea and Commlinaceae families are matching to the concept of vertical gardening due to their textural properties, adoptability to grow in indoor conditions and for their ornamental features. Hence, the following five plants *viz*. Devil's ivy (*Epipremunm aureum*), Wandering jew (*Zebrina pendula*), Arrowhead plant (*Syngonium podophyllum*), Philodendron (*Philodendron erubescens*), Boat lily (*Tradescantia spathacea*) were chosen to the experiment.

Material and Methods

The present experiment was carried out in the Department of Horticulture, Faculty of Agriculture, Annamalai University, Annamalai Nagar and Tamil Nadu during 2017-2019 with four different nutrient formulations *viz.*, Hoagland and Arnon solution (1938), Cooper's solution (1979), Saparamadu's solution (2010) and Mattson and Peters solution (2014) and a control with Irrigation water for growing foliage ornamentals under passive hydroponic vertical garden module. The pH was monitored for acidity and basicity range and EC were monitored for salt concentration in all the nutrient solution periodically. Observation on Physiological parameters *viz.*, Chlorophyll content, Membrane integrity (%) and Relative growth rate (g days^{-1}) was observed at 30, 60 and 90 days after planting.

Results and Discussion

The chlorophyll content was estimated at monthly intervals and results are presented in table 1. All the five foliage ornamentals exerted significant variations among the nutrient solutions experimented.

The highest chlorophyll content in devils ivy was observed as 25.18, 52.12 and 64.78 was in those plants grown in T_3 (Cooper solution) at 30, 60 and 90 days of observations respectively. This was followed by Mattson and Peters solution (T_5) which recorded a chlorophyll content of 23.24, 45.56 and 58.45 at 30, 60 and 90 days of observations respectively. However, the lowest chlorophyll content (18.25, 21.23 and 23.22) was noticed in those plants grown under the treatment T_1 (Irrigation water) at all plants the three stages of observation. In wandering jew, those plants grown under Hoagland solution (T_2) recorded the maximum chlorophyll content (27.84, 29.32 and 31.51) which is followed by T_3 (Cooper solution) with 24.68, 26.12 and 27.91 at 30, 60 and 90 days of observations respectively. The lowest chlorophyll content (22.19, 22.84 and 23.16) was recorded under T_1 (Irrigation water) at all the three stages of observations.

The chlorophyll content observed on arrow head plant recorded maximum values (29.12, 31.04 and 32.42) in T_3 (Cooper solution) which is followed by Mattson and Peters solution (T_5) with 26.18, 27.36 and 28.98 in 30, 60 and 90 days of observations respectively. However, the lowest chlorophyll content (16.12, 17.32 and 18.67) was obtained under T_1 (Irrigation water) at all the three stages of observations.

The data pertaining to the chlorophyll content in philodendron showed maximum values (21.4823.68 and 27.92) in those plants grown under T_3 (Cooper solution) at 30, 60 and 90 days of observations respectively. This

Table 1: Effect of different nutrient solutions on Chlorophyll Content of ornamental plants grown in vertical passive hydroponics.

Tr. No.	Treatment Details	Devil's ivy *Epipremnum aureum*			Wandering jew *Zebrina pendula*			Arrowhead plant *Syngonium podophyllum*			Philodendron *Philodendron erubescens*			Boat lily *Tradescantia spathacea*		
		30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP
T_1	Irrigation water (Control)	18.25	21.23	23.22	22.19	22.84	23.16	16.12	17.32	18.67	14.09	14.86	15.22	14.01	14.25	14.39
T_2	Hoagland & Arnon solution	21.61	38.17	45.98	27.84	29.32	31.51	24.38	25.16	27.01	18.13	20.50	22.23	24.16	25.93	26.88
T_3	Cooper's solution	25.18	52.12	64.78	24.68	26.12	27.91	29.12	31.04	32.42	21.48	23.68	27.92	23.62	24.01	25.93
T_4	Saparamadu solution	20.04	25.15	26.14	23.01	23.69	24.18	20.16	21.92	23.09	16.36	17.98	18.31	19.37	20.54	21.42
T_5	Mattson and Peters solution	23.24	45.56	58.45	23.12	24.18	25.69	26.18	27.36	28.98	19.81	21.68	24.38	22.74	23.45	24.01
SE(d)		0.42	0.93	0.94	0.43	0.51	0.52	0.30	0.24	0.43	0.18	0.15	0.36	0.08	0.13	0.27
CD (P=0.05)		0.84	1.95	1.88	0.88	1.02	1.04	0.60	0.48	0.98	0.36	0.31	0.74	0.16	0.26	0.55

Table 2: Effect of different nutrient solutions on Membrane integrity (%) of ornamental plants grown in vertical passive hydroponics.

Tr. No.	Treatment Details	Devil's ivy *Epipremnum aureum*			Wandering jew *Zebrina pendula*			Arrowhead plant *Syngonium podophyllum*			Philodendron *Philodendron erubescens*			Boat lily *Tradescantia spathacea*		
		30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP
T_1	Irrigation water (Control)	0.31	0.43	0.48	1.18	1.21	1.25	1.21	1.23	1.26	0.79	0.81	0.83	0.59	0.62	0.66
T_2	Hoagland & Arnon solution	2.52	2.71	2.91	1.39	1.54	1.69	1.54	1.59	1.62	1.93	2.02	2.13	0.85	0.89	0.93
T_3	Cooper's solution	2.45	2.57	2.61	1.26	1.49	1.52	1.34	1.38	1.47	1.53	1.69	1.78	0.74	0.79	0.82
T_4	Saparamadu solution	1.65	1.72	1.79	1.06	1.11	1.13	1.01	1.09	1.18	0.67	0.68	0.69	0.52	0.57	0.59
T_5	Mattson and Peters solution	1.76	1.82	1.84	1.21	1.36	1.41	1.28	1.31	1.52	0.85	1.13	1.28	0.64	1.03	1.14
SE(d)		0.01	0.04	0.04	0.05	0.02	0.06	0.09	0.09	0.06	0.10	0.13	0.14	0.04	0.04	0.04
CD (P=0.05)		0.03	0.08	0.08	0.11	0.04	0.12	0.18	0.18	0.12	0.21	0.26	0.28	0.09	0.08	0.09

is followed by Mattson and Peter's solution (T_5) which recorded 19.81, 21.68 and 24.38. However, the lowest chlorophyll content (14.09, 14.86 and 15.22) was recorded under T_1 (Irrigation water) at all the three stages of observations.

In Boat lily, maximum chlorophyll content was found in the treatment (T_2) Hoagland solution which recorded 24.16, 25.93 and 26.88 at 30, 60 and 90 days of observations respectively. This is followed by T_3 (Cooper solution) which recorded a chlorophyll content of 24.16, 25.93 and 26.88 at 30, 60 and 90 days of observations respectively. The lowest chlorophyll content was obtained from those plants grown under irrigation water (T_{10}) with 14.01, 14.25 and 14.39 at all the three stages of observations.

Chlorophyll is the important pigment that takes part in photosynthesis, which is an essential process of plant system and also its growth and development. Unlike other crop plants, chlorophyll content is an important criterion which determines the ornamental importance. The content of chlorophyll in plants is greatly influenced by nutrition. In the present experiment, the highest chlorophyll content (25.18, 52.12 and 64.78 in devils ivy, 29.12, 31.04 and 32.42 in arrow head plant and 21.48, 23.68 and 27.92 in philodendron) was observed in those plants grown in T_3 (Cooper solution) at 30, 60 and 90 days of observations respectively. The higher chlorophyll content present in Cooper's solution (T_3) which contains more N, Mg, Fe and Mn, since they are related to a higher photosynthetic rate (Salisbury and Ross, 1992; Reyes *et al*., 1999). Further, nitrogen which is a major compound which influences the chloride ion may possible play a role in nitrogen metabolism. In addition, nitrogen is an essential element to form amino acids, proteins, nucleic acids and coenzymes in production of more leaves and magnesium is an essential component of chlorophyll molecule which is required by many enzymes involved in respiration, photosynthesis and the synthesis of DNA. Similar observations were also noticed by Grace Lin (2016), Calatayud *et al*., (2008) in rose and Ashari and Gholami, (2010) in strawberry.

The response of another two foliage ornamentals (Wandering jew and boat lily) regarding the chlorophyll content exerted a different result. Maximum chlorophyll content (27.84, 29.32, 31.51 and 24.16, 25.93, 26.88) was obtained under the treatment (T_2) Hoagland solution in wandering jew and boat lily at 30, 60 and 90 days of observations respectively. Both the foliage ornamentals belongs to family commelinaceae which produces slightly brownish leaves exhibited similar responses for chlorophyll content. The increased chlorophyll content in both the 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 are in consonance with the present results.

Table 3: Effect of different nutrient solutions on relative growth rate (g day^{-1}) of ornamental plants grown in vertical passive hydroponics.

Tr. No.	Treatment Details	Devil's ivy *Epipremnum aureum*		Wandering jew *Zebrina pendula*		Arrowhead plant *Syngonium podophyllum*		Philodendron *Philodendron erubescens*		Boat lily *Tradescantia spathacea*	
		60 DAP	90 DAP	60 DAP	90 DAP	60 DAP	90 DAP	60 DAP	90 DAP	60 DAP	90 DAP
T_1	Irrigation water (Control)	0.05	0.05	0.005	0.013	0.003	0.028	0.020	0.023	0.016	0.018
T_2	Hoagland & Arnon solution	0.12	0.21	0.023	0.082	0.040	0.062	0.041	0.056	0.055	0.077
T_3	Cooper's solution	0.08	0.20	0.019	0.032	0.036	0.049	0.039	0.052	0.045	0.059
T_4	Saparamadu solution	0.06	0.04	0.015	0.015	0.009	0.006	0.030	0.030	0.020	0.026
T_5	Mattson and Peters solution	0.07	0.07	0.018	0.019	0.034	0.044	0.035	0.033	0.036	0.051
	SE(d)	0.009	0.06	0.001	0.01	0.001	0.005	0.001	0.001	0.005	0.007
	CD (P=0.05)	0.02	0.12	0.003	0.02	0.002	0.011	0.002	0.002	0.01	0.016

The data on membrane integrity was estimated at monthly interval and the results are presented in table 2. All the nutrition solution treatments showed significant variations among the foliage ornamentals.

The highest membrane integrity (2.52%, 2.71% and 2.91%) of devils ivy was found in those plants grown under T_2 (Hoagland solution) at 30, 60 and 90 days of observations respectively. This was followed by T_3 (Cooper solution) which recorded 2.45%, 2.57% and 2.61% at 30, 60 and 90 days of observations respectively. However, the lowest membrane integrity (0.31%, 0.43% and 0.48%) was observed in the treatment T_1 (Irrigation water) at all the three stages of observations.

In wandering jew, the treatment T_2 (Hoagland solution) recorded the highest membrane integrity content with 1.39%, 1.54% and 1.69% which is followed by T_3 (Cooper solution) which recorded 1.26%, 1.49% and 1.52% in 30, 60 and 90 days of observations respectively. However, the lowest membrane integrity (1.06%, 1.11% and 1.13%) was recorded under the treatment T_4 (Saparamadu solution) at all the three stages of observations.

The data on membrane integrity for arrow head plant recorded maximum values (1.54%, 1.59% and 1.62%) in the treatment T_2 (Hoagland solution) which is followed by T_3 (Cooper solution) which recorded 1.34%, 1.38% and 1.47 in 30, 60 and 90 days of observations respectively. The treatment T_4 (Saparamadu solution) recorded the lowest membrane integrity 1.01%, 1.09% and 1.18% at all the three stages of observations.

In Philodendron, maximum membrane integrity (1.93%, 2.02% and 2.13%) in those plants grown under T_2 (Hoagland solution) which is followed by T_3 (Cooper solution) which recorded 1.53%, 1.69% and 1.78% in 30, 60 and 90 days of observations respectively. However, the lowest membrane integrity (0.67%, 0.68%and 0.69%) was observed in the treatment T_4 (Saparamadu solution) at all the three stages of observations.

The data pertaining to membrane integrity in boat lily showed maximum values (0.85%, 0.89% and 0.93%) in the treatment T_2 (Hoagland solution) in 30, 60 and 90 days of observations respectively. This is followed by T_3 (Cooper solution) which recorded 0.74%, 0.79% and 0.82% in 30, 60 and 90 days of observations respectively. However, the treatment T_4 (Saparamadu solution) recorded the lowest membrane integrity 0.52%, 0.57% and 0.59% at all the three stages of observations.

Membrane integrity is defined as the quality or state of the complete membrane in perfect condition. The development of any adverse processes is associated with disorders or any stress in cell metabolisms, structures and disintegration of the barrier and structural functions of the cell membrane. Therefore, the maintenance of cell-membrane integrity under stress conditions is essential not only for cells to transform external signals but also for them to survive. In the present study, highest membrane integrity percent (2.52%, 2.71% and 2.91% of devils ivy, 1.39%, 1.54% and 1.69% in wandering jew, 1.54%, 1.59% and 1.62% in arrow head plant, 1.93%, 2.02% and 2.13% in philodendron and 0.85%, 0.89% and 0.93% in boat lily) was found in those plants grown under T_2 (Hoagland solution) at 30, 60 and 90 days of observations respectively. The positive effect of Hoagland solution containing essential nutrients such as N, P, K and Ca helps in improving the membrane integrity of leaves and roots. Calcium has a very prominent role in the maintenance of cell structure and acts as a second messenger in metabolic regulation. It activates the plasma membrane enzyme ATPase which pumps back the nutrients lost during cell membrane damage. It is evident from the nutritional formulation of Hoagland solution which contains calcium in larger concentration influenced the membrane integrity of foliage ornamentals. These findings

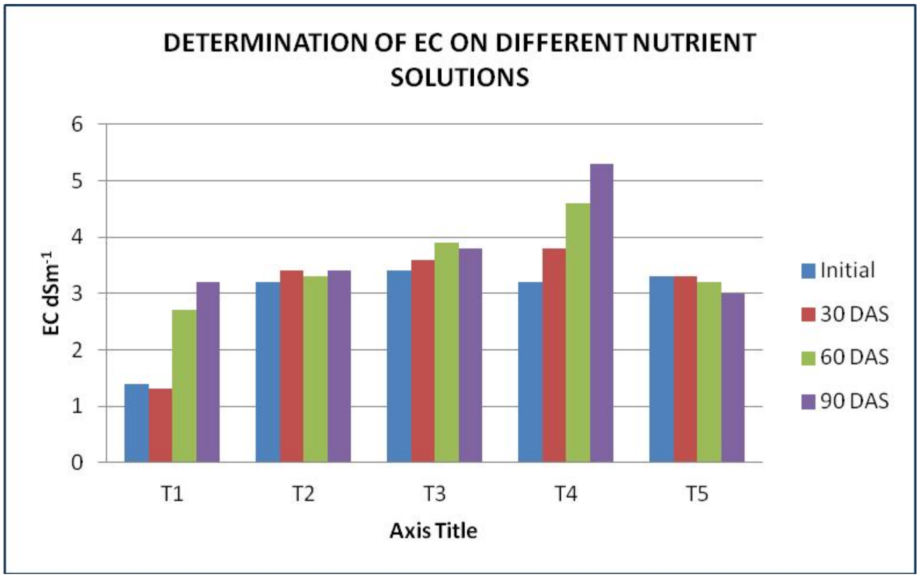

Fig. 1: Effect of pH and EC on performance of foliage ornamental plants in vertical passive hydroponics.

are in consonance with the findings of Tomati *et al.*, (1990) in lettuce, Xu *et al.*, (2014) in rice, Hamann (2015) and Kawasaki *et al.,* (2018) in wheat.

The lowest membrane integrity percent (0.31%, 0.43% and 0.48%) was recorded in T_1 (Irrigation water) in devils ivy. However, the other four foliage ornamentals recorded a varied result of producing the lowest membrane integrity percent (1.06%, 1.11% and 1.13% in wandering jew, 1.01%, 1.09% and 1.18% in arrow head plant, 0.67%, 0.68%and 0.69% in philodendron and 0.52%, 0.57% and 0.59% in boat lily) was observed under those plants grown in Saparamadu's solution (T_4) at 30, 60 and 90 days of observation respectively. Poor performance of plants may be due to the combination of nutrients and ionic reaction in the solution which inhibits the root production thereby reduced the uptake of nutrients and kept the plants under stress. Therefore, the maintenance of cell-membrane integrity under stress conditions is essential not only for cells to transform external signals but also for them to survive. Membrane stability was expressed in terms of the electrolytic conductivity. The development of any adverse processes is associated with disorders in cell metabolisms, structures and disintegration of the barrier and structural functions of the cell membrane. The state of cell membranes is one of the most important factors in regulating biochemical and physical processes and maintaining homeostasis in cells. Increased lipid peroxidation has been known to occur during senescence. This may reflect a decline of the anti-oxidative enzymes. Lipid membrane peroxidation might alter the cell membrane permeability resulting in solute leakage, membrane damage and consequently a loss of cellular physiological functions. In the present experiment, the data on EC (Fig.1), it is clear that the EC value of saparamadu's solution was in an increasing trend which hinders growth and development of shoot as well as roots of the foliage ornamentals. Similar statements were also given by Gavrilov *et al.*, (2000), Xu *et al.*, (2005) Saadalla *et al.*, (1990) and Xu *et al.*, (2014).

The data recorded on the influence of different nutrient solutions on relative growth rate of foliage ornamentals are presented in table 3. Maximum growth rate (0.12 g day^{-1} and 0.34 g day^{-1}) was recorded in the treatment T_2 (Hoagland solution) which is followed by T_3 (Cooper's solution) with 0.08 g day^{-1} and 0.30 g day^{-1} in devils ivy at 60 and 90 days of observations respectively. The lowest relative growth was noticed in T_1 (Irrigation water) with 0.05 g day^{-1} in both 60 and 90 days of observations respectively. Similarly, in wandering jew, maximum relative growth rate (0.023 g day^{-1} and 0.082 g day^{-1}) was observed in T_2 (Hoagland solution) which is followed by T_3 (Cooper's solution) with 0.019 g day^{-1} and 0.032 g day^{-1} at 60 and 90 days of observations respectively.

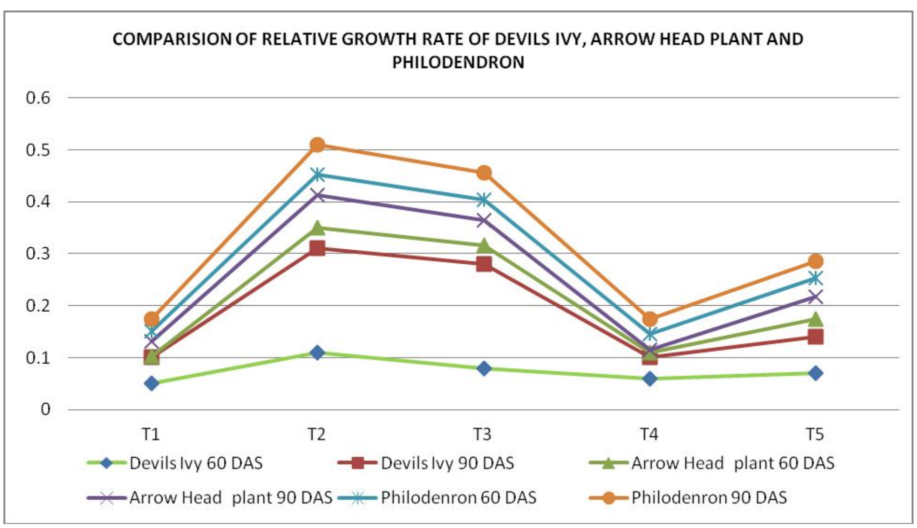

Fig. 2: Effect of different nutrient solutions on relative growth rate of Devils ivy, Arrow head plant and Philodendron.

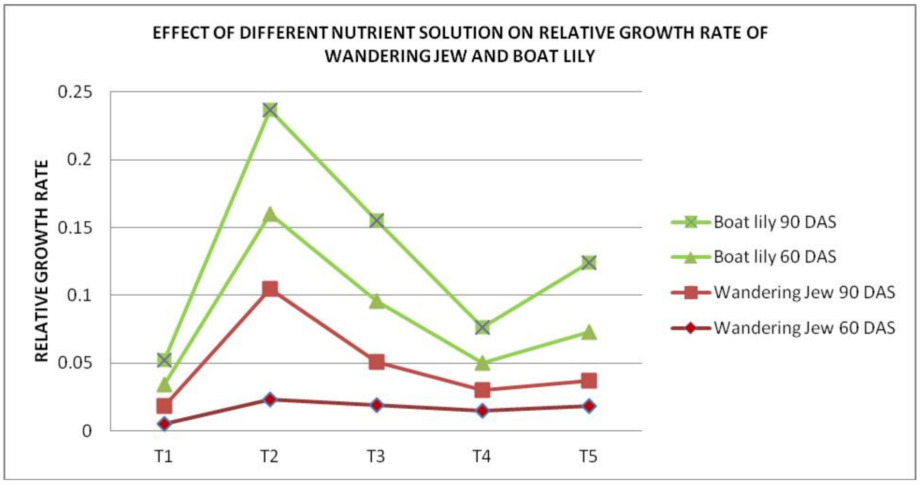

Fig. 3: Effect of different nutrient solutions on relative growth rate of Wandering Jew and Boat lily.

However, the lowest relative growth rate was noticed under T_1 (Irrigation water) with 0.005 g day^{-1} and 0.013 g day^{-1} in 60 and 90 days of observations respectively.

In Arrowhead plant, maximum growth rate (0.040 g day^{-1} and 0.062 g day^{-1})was T_2 (Hoagland solution) which is followed by T_3 (Cooper's solution) with 0.036 g day^{-1} and 0.049 g day^{-1} at 60 and 90 days of observations respectively. The lowest relative growth was noticed in T_1 (Irrigation water) with 0.003 g day^{-1} and 0.028 g day^{-1} in 60 and 90 days of observations respectively.

Among the treatments, the philodendron plants grown under T_2 (Hoagland solution) recorded the maximum growth rate (0.041 g day^{-1} and 0.056 g day^{-1}) which is followed by T_3 (Cooper's solution) with 0.039 g day^{-1} and 0.052 g day^{-1} at 60 and 90 days of observations respectively. The lowest relative growth was noticed in T_1 (Irrigation water) with 0.020 g day^{-1} and 0.023g day^{-1} in 60 and 90 days of observations respectively.

Similar results was observed for boat lily which recorded maximum values (0.055 g day^{-1} and 0.077 g day^{-1}) in those plants grown under T_2 (Hoagland solution) which is followed by T_3 (Cooper's solution) with 0.045 g day^{-1} and 0.059 g day^{-1} at 60 and 90 days of observations respectively. However, minimum growth rate (0.016 g day^{-1} and 0.018 g day^{-1}) was recorded under T_1 (Irrigation water) at 60 and 90 days of observations respectively.

Relative growth rate (RGR) is a measure used to quantify the speed of plant growth and are measured as the mass increase per above ground biomass per day. Among the treatments, all the five foliage ornamentals responded in a gradual and linear growth phase. From the fig. 2, it is evident that, the treatment T_2 (Hoagland solution) showed its superiority in producing the maximum relative growth rate in devils ivy, arrow head plant and in philodendron. However, all the three plants showed poor response under the treatment T_4 (Saparamadu's solution). Similarly, in wandering jew and boat lily, increased growth rate was recorded under the treatment T_2 (Hoagland solution) and poor growth rate was recorded under T_4 (Saparamadu's solution) in 60 and 90 days of observations. The increased trend noticed from the Hoagland solution may be due to the increased nutrient availability to plants which produces more biomass through photosynthesis and increased the growth rate. However, a careful observation of the poor response of Saparamadu's solution may be due to the fact that, increased EC of hydroponic solution has a negative impact on growth of crop plants as suggested by Tellez and Merino, (2012) and Steiner, (1968).

From the results, it could be concluded that the foliage ornamentals *viz.*, Devils ivy, Arrow head plant and Philodendron grown under treatment T_3 (Cooper's solution) recorded the maximum chlorophyll content and the other two *viz.*, Wandering jew and Boat lily recorded maximum chlorophyll content in T_2 (Hoagland solution) at all three stages of observation.

The highest membrane integrity percent was observed under T_2 (Hoagland solution) at all three stages of observation and the lowest membrane integrity percent was observed in T_1 (Irrigation water) in devils ivy and T_4 (Saparamadu's solution) in Wandering jew, Arrow head plant, Philodendron and Boat lily at all the three stages of observations. Highest relative growth rate was observed in T_2(Hoagland solution) in all the foliage ornamentals and the lowest growth rate was found with T_4 (Saparamadu's solution).

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