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Hydroponic technology for lily flowers and bulbs production using rainwater and some common nutrient solutions

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This experiment was carried out to investigate the potential of nutrient film technique (NFT) hydroponic system for flowers and bulbs production of the Asiatic hybrid lily cv. "Blackout" using rainwater and some common nutrient solutions (Hoagland No. 2 Basal Salt Mixture, Murashige and Skoog Basal Salt Mixture and White's Basal Salt) with rock wool cubes as medium with or without removal of flower buds and mother bulb scales. The results show that the NFT hydroponic system was an excellent method to produce lily flowers in 55 days. The rainwater could be applied as nutrient solution in this system to produce lily flowers in a good quality making this system easier and cheaper way to get into cut lily production. The results of analytical chemistry indicated that the rainwater contained some amounts of macro and micro elements in forms that plants can absorb and had a good value of pH (6.20) with favorite high ratio of NO_3:NH_4 making this water to be more efficient for plant growth and development as nutrient solution. The analytical results of nutrient solutions at flowering time showed that these solutions had different amounts of nutrients, values of pH, electrical conductivity (EC) and the ratio of NO_3:NH_4. The present results indicate that the number and quality of flowers were influenced by different nutrient solutions even so the flowers of all treatments were in a good quality. The NFT hydroponic system was shown to be the most effective for bulblets and daughters production, but different solutions showed different results and the Hoag solution and MS solution gave the best results related to the production of these propagated storage organs.

Key word: Asiatic lily, nutrient film technique (NFT), hydroponic, rainwater, nutrient solutions, removal treatment, flower, bulblet, daughter.

INTRODUCTION

In recent years, hydroponic forcing techniques of cut flowers have significantly increased in flower industry around the world and a great progress have been done to these commercial forcing techniques which are widely

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Abbreviations: Hoag S, Hoagland No. 2 basal salt mixture solution; **MS S,** Murashige and Skoog basal salt mixture (MS) solution; **White S,** White's basal salt solution; **NFT system,** nutrient film technique system; **EC,** electrical conductivity.

used in Netherlands to produce cut flowers of some important ornamental crops such as tulip using the bulb fust hydroponic system (Grassotti and Gimelli, 2011; Miller, 2012; Gude, 2011; Rina and Hiroshi, 2012). It is well known that the nutrient film technique (NFT) system is highly productive, and can be used for cut production and for propagation; one of the best aspects of this system is that the plant roots were bathed constantly in thin film of an oxygen-rich nutrient solution which allow the roots to uptake adequate supplies of water, oxygen and nutrients (Libia et al., 2012). In hydroponic technology, there are many common nutrient solutions that were used however; they provide every nutrients necessary for plant growth within the common ranges of the macro and micro elements (mg/l) and for the most plants species, they are nitrogen (100 to 255), phosphorus (30 to 50), potassium (100 to 300), calcium (80 to 140), magnesium (30 to 70), sulfur (50 to 120), iron (1 to 3), copper (0.08 to 0.2), manganese (0.5 to 1), zinc (0.3 to 0.6), molybdenum (0.04 to 0.08), boron (0.2 to 0.5) furthermore; the plant growth can be affected by pH of solution , the pH range of 5.5 to 6.5 is optimal for the availability of nutrients in nutrient solutions for most plants (Libia et al., 2012; Toshiki, 2012).

Several studies focused on the chemical composition of rainwater indicated that it contains the elements plants need to grow; it contains a trace amounts of some macro and micro elements in forms that plants can absorb but the analysis of rainwater was different from region to region and the nitrogen compounds such as ammonium and nitrates, if they exist in the air, they can mix with water and come down with rainwater (Ellen et al., 2004; Wood et al., 1999). Lily can be propagated through many vegetative means; the bulblets is considered to be the key of lily propagation, it can be regenerated from bulb scale through scaling, from leaf through cutting propagation and from various organs through tissue culture technique *in vitro* (Duong et al., 2001). The technique of removal of some organs was used to stimulate the plants to produce more bulblets by remobilization of the carbohydrates between the sources and the sinks (Asker, 2013; Leclerc et al., 2005).

The objective of the present experiment on Asiatic hybrid lily cv. Blackout was to develop efficient and low cost system for lily flowers and bulbs production using nutrient Film technique with application of rainwater as nutrient solution and some common nutrient solutions with or without flower buds and bulb scales removal.

MATERIALS AND METHODS

This experiment was conducted at the computerized greenhouses with environmental control systems at School of Biomedical and Biological Sciences, University of Plymouth during the year 2014 in a range of temperature around 20 to 25°C. It is designed to study the utilization of the hydroponic technology to produce flower and bulb of Asiatic hybrid cv." Blackout" using rainwater as nutrient solution in addition to some common nutrient solutions: Hoagland No. 2 Basal Salt Mixture, Murashige and Skoog Basal Salt Mixture (MS) and White's Basal Salt which were prepared in concentration of 1/6 strength at pH 6. The experiment had eight treatments, which included four nutrient solutions with or without removal treatments; each treatment contains 9 plants, the flower buds were removed when they became 2 cm long and mother bulb scales were removed at the same time in treated plants. To investigate the chemical analysis of nutrient solutions, the highly modern equipments ICP- MS Instrument and ICP- OES Instrument were used to determine all nutrient elements except nitrogen compounds which were determined by Colorimetric Assay Kits using UV spectrophotometer. The pH and electrical conductivity EC (mS- cm^{-1}) values of solutions were determined using pH meter during the experiment.

NFT tanks with constant flow of nutrient solution were used with rock wool cubes as growing medium; the tang measures were 112 cm long × 49 cm wide × 21 cm high) and holds 20 L of solution and with a tray on top were used which was fed by a pump to create a constant flow of solution for plants, and these solutions were changed once during the experiment. The healthy bulbs were purchased from Hyde and Sons Nursery-UK, rock wall cubes from hydro grow com. nutrient solutions from Sigma-Aldrich Company Ltd, and the composition of these solutions was as follow: A) Hoagland No. 2 Basal Salt Mixture: ingredients include potassium nitrate, calcium nitrate, magnesium sulphate, ammonium phosphate monobasic, manganese chloride.$4H_2O$, boric acid, molybdenum trioxide, zinc sulphate.$7H_2O$, copper sulphate.$5H_2O$, ferric tartrate 606.60, 656.40, 240.76, 115.03, 1.81, 2.86, 0.016, 0.22, 0.08 and 5.00 mg/L respectively, and this was formulated to contain 1.63 g of powder per liter of medium, pH 4.2 to 5.2. B) Murashige and Skoog Basal Salt Mixture (MS) and the ingredients included ammonium nitrate, boric acid, calcium chloride (anhydrous), cobalt chloride hexahydrate, cupric sulfate pentahydrate, disodium EDTA dihydrate, ferrous sulfate heptahydrate, magnesium sulfate (anhydrous), manganese sulfate monohydrate, potassium iodide, potassium nitrate, potassium phosphate monobasic, sodium molybdate dihydrate, Zinc sulfate heptahydrate with 1,650.0, 6.20, 332.20, 0.0250, 0.0250, 37.260, 27.80, 180.70, 16.90, 0.830, 1900, 170.0, 0.250 and 8.60 mg/L respectively, and this was formulated by 4.33 g of powder per liter of medium, pH 3.5 to 4.5. C) White's Basal Salt Mixture and the ingredients: boric acid, calcium nitrate (vacuum-dried), Ferric sulfate, magnesium sulfate anhydrous, manganese sulfate monohydrate, potassium chloride, potassium iodide, potassium nitrate, sodium phosphate monobasic, sodium sulfate anhydrous, zinc sulfate heptahydrate 1.50, 200.0, 2.50, 360.0, 5.040, 65.0, 0.750, 80.0, 16.50, 200.0 and 2.670 mg/L respectively, and this was formulated by 0.934 g of powder per liter of medium, pH 4.2 to 5.2. Data of number of flowers per plant and number, weight (g) length (cm) surface area (cm^2) of petals per flower were collected at flowering time of untreated plants. Data of bulblets number and weight (g), daughter's number and weight (g) and weight of bulb roots, stem roots, bulblets roots per plant were collected after 16 weeks from planting of all experiment plants.

The statistical analysis system (SAS, 2012) was used to effect different factors in study parameters. Significant difference-LSD test was used in this study to significantly compare between means at the (0.05) level of significance.

RESULTS

Plate 1, shows the Asiatic lily plants cv. "Blackout" grown in NFT hydroponic system in different nutrient solutions in greenhouse. The flowers completely opened after 55 days from planting with good quality in all treatments. Plate 2, showing the Asiatic lily plants cv. "Blackout"

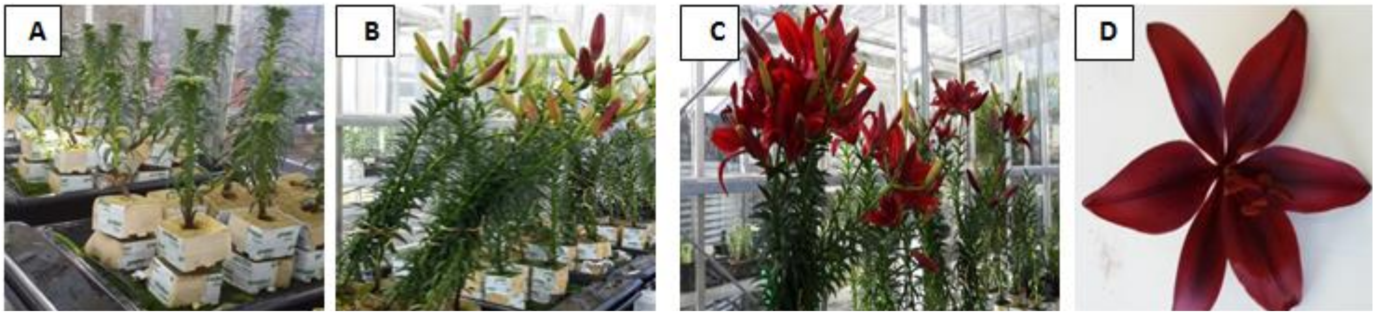

Plate 1. Showing that the Asiatic lily plants cv. "Blackout" grown in NFT hydroponic system in different nutrient solutions in greenhouse. The flowers completely opened after 55 days from planting. **A)** The growing system contained the NFT tanks, with constant flow of nutrient solutions circulation where the rock wool cubes were used as growing medium. **B)** The Asiatic hybrid lily plants grown in NFT hydroponic system in greenhouse at developmental stage of flower buds coloring. **C)** The plants with full open flowers in 55 days. **D)** The flowers had a good quality.

Plate 2. Showing that the Asiatic lily plants cv. "Blackout" grown in NFT hydroponic system in different nutrient solutions in greenhouse. The plants produced very large bulblets, daughters and three types of roots systems after 16 weeks from planting. **A)** The plants produced many bulblets on stem just above the mother bulbs. **B)** Large bulblets with high growth of bulblet root system were formation. **C)** The NFT hydroponic system produced a large daughter. **D)** Three types of roots were developed of the Asiatic plants, bulb roots, stem roots and bulblets roots. **E)** The bulblets of plants of Asiatic lily plants cv. "Blackout" produced many new sprouts without undergo to dormancy process.

grown in NFT hydroponic system in different nutrient solutions in greenhouse. The plants produced very large bulblets, daughters and three types of roots systems after 16 weeks from planting. Table 1 indicates the results of chemical analysis of nutrient solutions at flowering time and these solutions had different amounts of macro and micro elements, however; in all nutrient solutions at flowering time, there were still high proportion of the nutrients were not used by plants, the MS S. had highest concentrations of all elements except molybdenum compared to other nutrient solutions. The results of chemical analysis of rainwater of Plymouth city indicated that this water contained macro and micro elements in concentrations (mg/L): NO_3 (0.063), NH4 (0.01), other K (0.288575), P (0.094), Ca (1.0655), Mg (0.658075), S (0.7789), Mn (0.006491) Cu (0.000089), Zn (0.06349), Mo (0.000052), and B (0.0043618). At the same table, the nitrate amount was higher than ammonium in all nutrient solutions, the highest value of NO_3:NH_4 ratio was found in Hoag solution compared to others. Figure 1 shows the time course of electrical conductivity ($mS.cm^{-1}$) and pH of second nutrient solutions (the solutions were changed one time after 20 days from planting). The pH of second solutions were dropped through the period between 20 to 55 days of planting from 6.20 to 5.95, 6 to 5.45, 6 to 4.1, 6 to 5.8 and the EC ($mS.cm^{-1}$) were changed from 0.071 to 0.11, 0.502 to 0.306, 1.33 to 1.004, 0.406 to 0.296, in rainwater, Hoag, MS, and White solutions, respectively, however; the MS S. had the maximum value of EC and the minimum value of pH compared to other solutions.

Figure 2 shows that the number and quality of lily flowers as influenced by different nutrient solutions; the highest flower number per plant (6) was observed on plants grown in White S. while the lowest flower number (5) was found on plants of rainwater. The highest flower quality parameters were obtained in plants grown in Hoag S. compared to other plants which grow in other solutions, the flowers of plants in this solution had petals with weight of 5.91 g, length of 56.2 cm, width of 21.47 cm and surface area of 126.11 cm^2 per flower. Table 2 results show that the application of flower buds and bulb

Table 1. Indicates that the chemistry of analysis of rainwater and some common nutrient solutions in hydroponic system of Asiatic hybrid lily "Black out" at the start of experiment and after 55 days of planting.

Time after planting	Nutrient Solutions	Elements (mg/L)														
		NO3-N	NO2-N	NH4-N	K	P	Ca	Mg	S	Na	Fe	Mn	Cu	Zn	Mo	B
At the start	Rainwater	0.063	0.008	0.01	0.288575	0.094	1.0655	0.658075	0.7789	3.491	—	0.006491	0.000089	0.06349	0.000052	0.0043618
After 55 days	Rainwater	0.648	0.015	0.093	0.5668	0.189289	3.31975	1.368	0.995575	6.897	0.0344525	0.01253	0.0012018	0.042845	0.00006	0.008722
	Hoag S.	11.6	0.048	0.188	2.22375	—	21.845	7.08425	1.0617	8.55225	0.0526025	0.0018693	0.0036068	0.0061415	0.07689	0.0552475
	MS S.	82.4	0.027	11.92	65.43	—	37.765	11.52	2.71975	9.63	4.88625	0.897375	0.0111605	0.2316	0.008	0.130875
	White S.	0.554	0.018	0.074	0.1263	0.2355	10.5375	11.6	3.63225	11.97	0.0618225	0.001342	0.0033533	0.0163975	0.000005	0.033075

Table 2. Indicates that the effect of types of nutrient solutions and removal treatment on the development of bulblets , daughters and roots in Asiatic hybrid lily" Blackout" in hydroponic system

Factors		Parameters						
		Bulblets		Daughters		Bulb roots	Stem roots	Bulblet roots
		No.	WT (g)	No.	WT (g)	WT (g)	WT (g)	WT (g)
Treatments	Control	8.72	5.81	2.03	25.11	9.5	1.86	1.33
	Removal	8.91	10.34	1.97	23.74	9.92	4.04	2.58
LSD value	--	1.27	1.75 *	0.181	3.42	1.68	0.566 *	0.409 *
Nutrient	Rainwater	7.78	6.48	1.77	18.9	9.29	2.44	1.66
Solutions	Hoag S.	9.11	8.52	2.11	30.64	10.08	4.56	2.89
	MS S.	10.22	11.42	2.11	25.59	7.97	2.35	1.45
	White S.	8.16	5.88	2	22.57	11.51	2.47	1.83
LSD value	--	1.79*	2.48*	0.257*	4.84 *	2.38*	0.801*	0.578*
Solutions x	1 rainwater	7.22	3.76	1.77	19.27	8.17	1.29	0.75
Treatments	2 rainwater	8.33	9.2	1.77	18.53	10.4	3.59	2.57
	1 Hoag S.	9.22	6.02	2	29.87	10.32	1.88	2.11
	2 Hoag S.	9	11.01	2.22	31.4	9.83	7.23	3.66
	1 MS S.	9.66	8.85	2.11	27.36	8.32	2.15	1.06
	2 MS S.	10.77	13.99	2.11	23.82	7.62	2.54	1.84
	1 White S.	8.77	4.62	2.22	23.95	11.18	2.13	1.41
	2 White S.	7.55	7.14	1.77	21.18	11.83	2.81	2.24
LSD value	--	2.545 *	3.51 *	0.363*	6.85 *	3.37 *	1.13 *	0.818*

LSD test was used to significant compare between means at the 5% level of significance. *NS. Significant at P > 0.05 and not significant, respectively. Treatment 1 = Control. Treatment 2 = Flower buds and bulb scale removal.

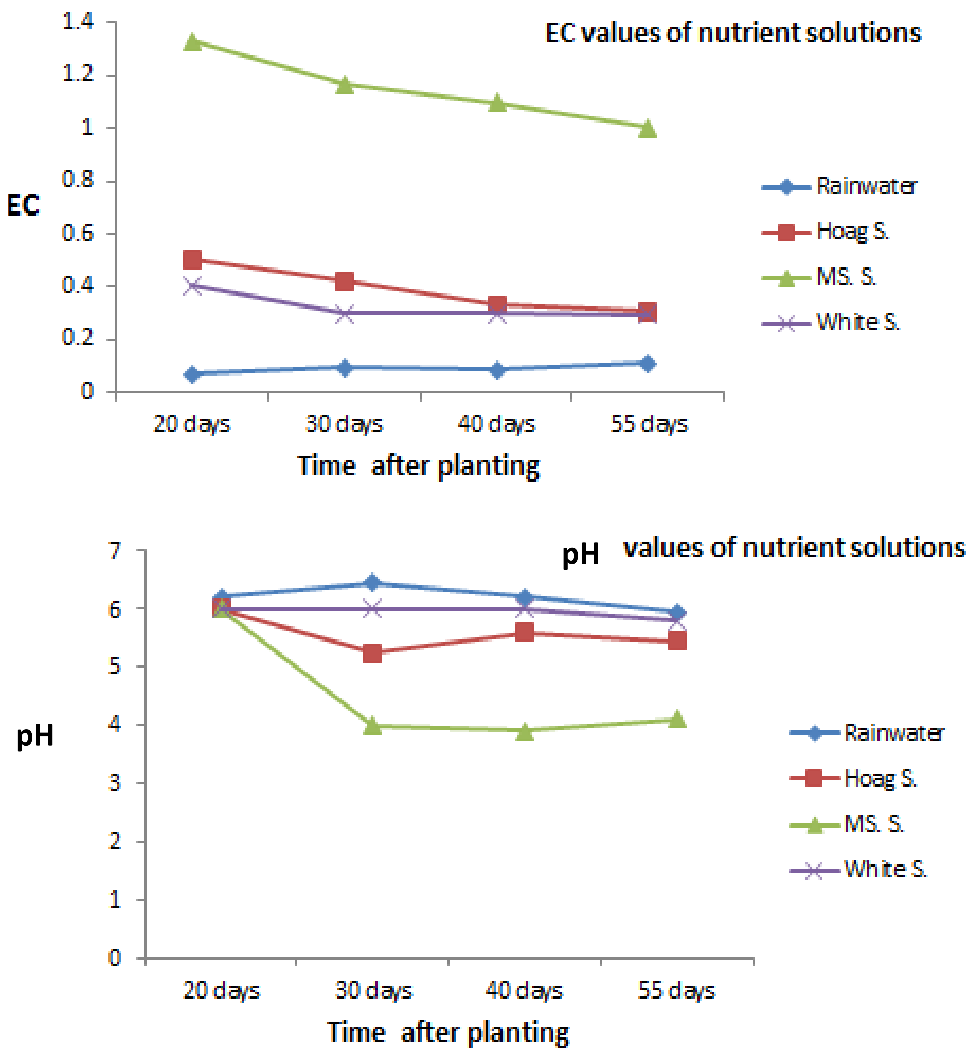

Figure 1. Indicating that the time course of pH and EC electrical conductivity mS.cm^{-1} of the rainwater and some common nutrient solutions (second solutions) during the experiment. The solutions were changed one time after 20 days from planting.

scales removal practice greatly increased the weight of bulblets by 77.97% and the weight of stem roots by 117.2%; the development of bulblets, daughters and roots were influenced by the type of nutrient solutions however; the plants grown in MS S. produced highest weight (11.42 g) and number (10.22) of bulblets with the minimum value of all types of roots while Hoag S plants gave the maximum weights of daughters (30.64 g), stem roots (4.56) and bulblets roots (2.89). The rainwater plants showed the minimum values of the daughters by number (1.77), weight (18.9 g) and the bulblets by number (7.78), while the largest bulb roots (11.51) were recorded in White S compared to others. The removal treatments showed the best results for bulblets production by number (10.77), weight (13.99 g) in MS S and for daughter formation by number (2.22) and weight (31.4 g) in Hoag S.

DISCUSSION

The present results show that the (NFT) hydroponic system achieved optimal performance to produce lily flowers in 55 days and that may be because the plant roots were bathed constantly in thin film of an oxygen-rich nutrient solution which allow the roots to uptake adequate supplies of water, oxygen and nutrients in this system. The results of analytical chemistry indicated that the rainwater contained some amounts of macro and micro elements in forms that plants can absorb and the pH was 6.22; the NO_3:NH_4 ratio was high. All these points clearly suggest that rainwater is good for plant growth and that may explain the results of this experiment which show that the rainwater could be applied in NFT hydroponic system as nutrient solution to produce lily flower in a good quality at low cost. The chemistry of nutrient

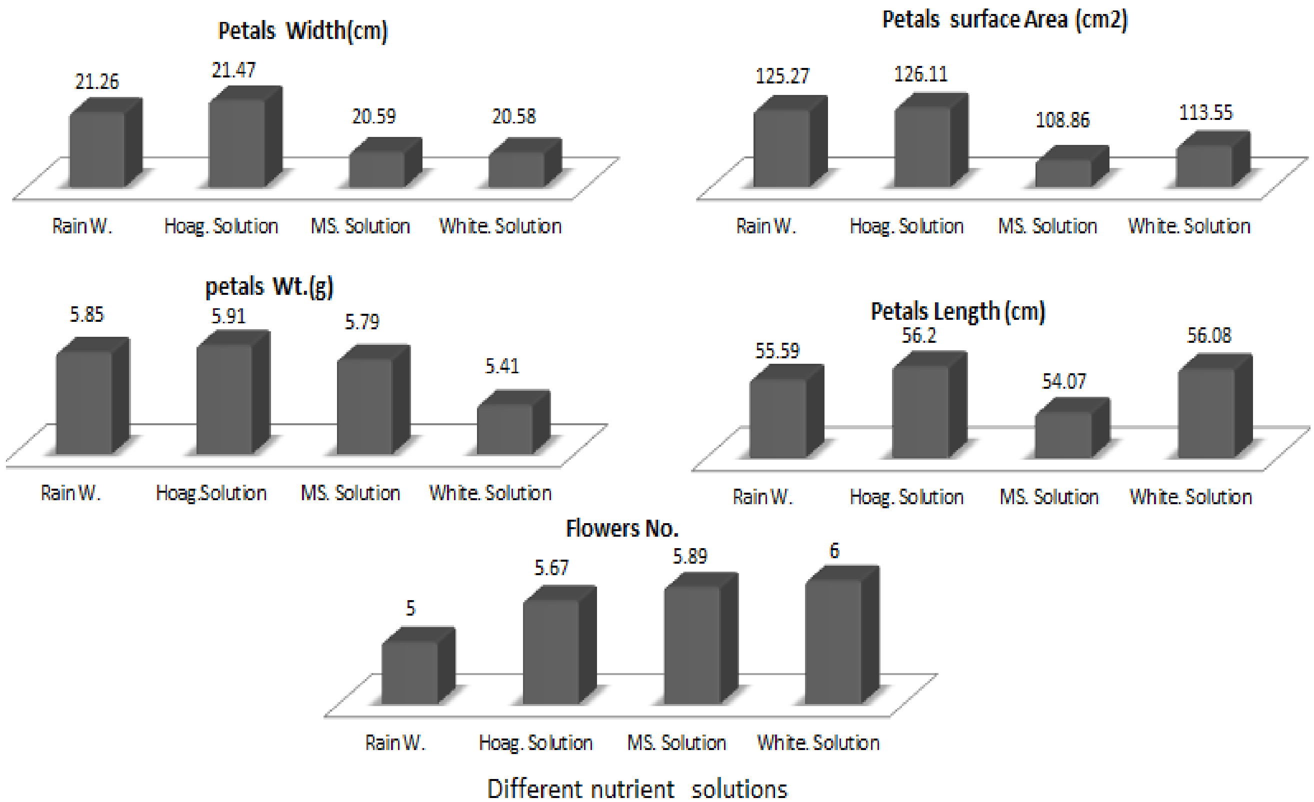

Figure 2. The effect of different nutrient solutions on number of flowers per plant and flower quality parameters such as weight (g), length (cm), width (cm), surface area (cm^2) of petals per flower of Asiatic hybrid lily cv ' blackout' plants grown in NFT hydroponic system. LSD at (p <0.05) of flowers No. 0.943,* LSD at (p <0.05) of petals wt. (g) 0.439*, length 1.740 *, width 0.723* and surface area 8.656 *,*NS. Significant at p < 0.05 and not significant, respectively.

solutions at flowering time indicated that there were still high proportion of the nutrients not used by plants and that may be because the NFT hydroponic system was efficient and precise system to feed the plant roots by nutrient, water and oxygen, hence, the lost amounts of nutrients were low during the experiment and the nutrient requirements of plants grown in this system were low and this conclusion agrees with several studies done on Anthurium, gerbera and geranium which mentioned that when nutrient solutions are applied continuously, plants can uptake ions at very low concentration (Dufour and Guerin, 2005; Zheng et al., 2005; Rouhpael and Colla, 2009).

The nutrient solutions had different results related to flowers and bulb development and that may be due to their differences in amounts of nutrients, values of pH, EC and the NO_3:NH_4 ratio of solutions. It is well known that these factors have great effect on plant development (Chad et al., 2009; Miller, 2012; Toshiki, 2012). In case of bulb production, the plants grown in rainwater had less and smaller daughters with less bulblets compared to others. That may be because the nutrient requirements of lily plants during bulbing stage were high and the low nutrients amount in rainwater were able to cover the nutrient demand of lily plants to produce stem, leafs and flower with assistant of mother bulbs but were not enough to cover the nutrient requirements of plants to produce bulbs and this conclusion agrees with the results of Wu et al. (2012) which reported that the mother bulb is mainly considered as a carbohydrate source for vegetative development in early developmental stage and flowering stage; the flowers utilize and consume the carbohydrate which is received from the current photosynthesis and bulb scales and the bulb in this stage is considered as a combination of sink and source and finally as a sink in bulbing stage. It seemed that removal treatment was effective tool to stimulate the lily plants to produce more bulblets which is the vital key for lily propagation and this results agrees with that reported by Asker (2013) and Leclerc et al. (2005).

Conflict of interests

The author(s) did not declare any conflict of interest.

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