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THE NUTRIENT SOLUTION OXYGENATION INFLUENCE ON THE GROWTH OF THE SPECIES *LACTUCA SATIVA* L. ROOT SYSTEM CULTIVATED IN THE NUTRIENT FILM TECHNIQUE (NFT) SYSTEM

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Abstract

Lettuce is a highly appreciated vegetable species as evidenced by the very high market demand, regardless of the season. Thus, it is cultivated in all cropping systems, both conventional and unconventional. Moreover, in order to meet the high demand, large-scale farmers are constantly working to find solutions to increase production, reduce the period of formation of the edible part, and reduce the number of fertilizers. Lettuce cultivation in the Nutrient Film Technique (NFT) system is most commonly used in all climatic zones. In the experiment performed at University of Agronomic Sciences and Veterinary Medicine of Bucharest, Hortinvest greenhouses, on lettuce culture in the NFT system we monitored the debit and oxygen content of the nutrient solution at the roots of lettuce plants and found that depending on its flow rate, the configuration the root system was different. We also found that there were correlations between the size of the root system and the mass of lettuce plants obtained in this system.

***Key words**: Lettuce, flow, roots, oxygenation.*

INTRODUCTION

The Nutrient Film Technique (NFT) cultivation system was developed in the late 1960s by Dr. Allan Cooper at the Glasshouse Crops Research Institute in Littlehampton, England (Graves, 1983). Over time, this cultivation system has proven to be the fastest type of liquid hydroponic system.

The main feature of the NFT system is that the nutrient solution flows like a thin film through a plastic channel that encloses the roots of the plants. Therefore, in the hydroponic system, the nutrient solution plays an essential role being the supplier of water, oxygen and all the essential mineral elements necessary to obtain high quality crops (Drew, 1997; Trejo-Téllez, 2012).

The importance of the oxygen availability in the plants root zone for their growth and development it is indicated by Moreno Roblero et al. (2020). In the same time, specific studies are required for different plant species in order to identify the necessary quantity of oxygen to maximize the benefits.

Concurrently, plant cultures in hydroponic system are not supplied at the maximum uptake water, nutrients, and oxygen (Blok et al, 2017; Gherghina et al., 2020; Al-Kinani et al. 2021; Jailawi et al., 2021).

In these conditions, in order to improve the lettuce crops, it is necessary to identify various methods and procedures for improving the oxygen uptake.

Moreno Roblero et al. (2020) outlined the necessity of the oxygen presence in the plant's roots zone in all their development stages and pointed out oxifertigation as an effects accelerator of the natural resources. Chun & Takakura (1994) revealed that in hydroponic cultures, it is necessary to have a high dissolved oxygen (DO) level in order to support a healthy roots respiration.

On the other hand, Urrestarazu & Mazuela (2005) identified that chemical oxygenation of the nutrient solution has positive effects on plants. Kurashina et al. (2019) studied the effects of the underwater ultrasound and DO supersaturation in the hydroponic cultures and demonstrated their direct effects on plants growth.

Another important aspect is the hydroponic technical structure. It was proved that the container gradient plays a big role in the nutrient solution oxygenation (López-Pozos et al., 2011). Colunje et al. (2021) studied the effects of nutrient solution oxygenation with ozone in pepper hydroponic cultures and identified the impact on plants growth.

The positive effect of oxygen on lettuce plant growth in a floating hydroponic system is identified by Goto et al. (1996). Suyantohadi et al. (2010) reveal that the lettuce plant hydroponic culture irrigated with low temperature water and with high concentrated dissolved oxygen (20-30 mg/L supply) gives a better harvest than in normal conditions.

Carrasco et al. (2011) identifies the necessary oxygen uptake using the peroxides or peracetic acid in nutrient solutions as a source in order to increase the fresh weight in the *rocket* (*Eruca sativa* Mill.) crop grown in floating system.

Kurashina (2019) study on lettuce cultivated in hydroponic system revealed that oxygen supersaturation is enhancing the plant growth, without degradating the chlorophyll from the leaves. According to Baiyin et al. (2021), in plants harvesting, the flow rate adjustment can improve the crop results.

Edwards & Asher (1974) have proven the importance of the nutrient solution flow rate on the hydroponic cultures. They have also outlined that lower nutrient solution flow rate reduces among others the plants nitrogen uptake.

Van Rooyen & Nicol (2022) identified that online plants pH measurement supports the control on plants nitrogen concentration in nitrification-hydroponic systems.

Sago & Shigemura (2018), have studied the nitrate content of the plants cultivated in controlled cultures. Their study conclusions were that including the necessary nitrate content in the nutrient solution at the beginning of the cultivation can lead to lower nitrate content butterhead lettuces crops.

Our objectives were to monitor the debit and oxygen content of the nutrient solution at the roots of lettuce plants cultivated in the NFT(Nutrient Film Technology) system and to analyse the results depending on its flow rate, the configuration the root system. Another objective was to analyse the correlations between the size of the root system and the mass of lettuce plants obtained in this system. In the same time, the nitrate content was calculated for each variant in order to analyse impact of the nutrient solution flow rate on the nitrate content.

MATERIALS AND METHODS

The experiment took place at University of Agronomic Sciences and Veterinary Medicine of Bucharest, Hortinvest greenhouses, on lettuce culture in the NFT system (Nutrient Film Technology), during the 10th March- 08th April 2020.For the experiment have been used the following lettuce assortments: Alanis, Aleppo and Kiribati, from seeds made available by Holland Farming Agro S.R.L. (Figure 1).

V1- Alanis V2 - Aleppo V3- Kiribati

Figure 1. The biological material used in the experiment

The oxygenation of the nutrient solution was achieved by increasing its flow rate. No oxygen from other sources was used for the experiment. The nutrient solution composition is presented in Table 1.

Table 1. Composition of nutrient solution used for fertilizing of lettuce seedlings in NFT crops and on perlite substrate

Components	Kg/1000 L H_2O
Fertilizer A	
Calcium nitrate	92.50
Potassium nitrate	25.00
Chelated iron (13%)	0.85
Ammonium nitrate	1.20
Fertilizer B	
Potassium nitrate	50.00
Potassium sulphate	4.00
Monopotassium phosphate	10.00
Ammonium monophosphate	6.00
Magnesium sulphate	35.00
Microelements	
Manganese	0.2
Boron	0.29
Zinc	0.09
Copper	0.02
Molybdenum	0.01

The flow rate variants (conventionally named F1, F2, F3 and F4) of the nutrient solution for each assortment were 1.0 L/min, 2.0 L/min, 2.5 L/min and 3.0 L/min (Table 2).

Table 2. Experimental variants

Cultivars	Nutrient solution flow (L/min)			
	Flow rate (F1)	Flow rate (F2)	Flow rate (F3)	Flow rate (F4)
V1 - Alanis	1.0	2.0	2.5	3.0
V2 - Aleppo	1.0	2.0	2.5	3.0
V3 - Kiribati	1.0	2.0	2.5	3.0

The seedlings were produced in a greenhouse in Jiffy seven pots and were 25 days old at planting. Planting in the NFT system took place in the greenhouse during the 10th March- 08th April 2020. All climatic factors, light, atmospheric humidity and temperature as well as the temperature of the nutrient solution were monitored. The observations and determinations made were aimed, in dynamics, at the growth of plants in diameter, the formation of the number of leaves. After 25 days from planting in the NFT system, the plants were harvested, on variants, their mass was determined by weighing, the length of the roots was measured. For each variant the dry matter content and the nitrate content were performed. Data were analysed statistically according to analysis of variance technique using analytical software and treatment means were compared using Tukey's test (Steel et al., 1997).

RESULTS AND DISCUSSIONS

The highest average edible mass of lettuce plants was recorded in the flow rate variant in which we distributed the nutrient solution at the value of 2.5 L/min, of 378.33 g/plant in the Alanis variety, head lettuce, 190.67 g Aleppo blond Lollo and 237.33 g of Kiribati oak leaf. The control flow rate variant, at a flow rate of 1 L/min, showed the lowest average edible mass of 228 g for F1 Alanis variety, 141 g/plant for F2 Aleppo variety and 201.67 g/plant for F3 Kiribati variety (Figure 2).

In the case of Alanis assortment, we have obtained average masses of lettuce plants between 228 g in F1 and 378.33 g in F3. We found that the differences in mass increased with the increase of the flow of the nutrient solution, being between 47.67 g at F2, by 20.91% over the flow rate control variant and by 150.33 g, respectively by 65.94% at F3. In the case of F4 the increase was by 123 g respectively by 54.24% over the flow rate control variant. From a statistical point of view, there were significant positive differences at F2 and distinctly very positive differences at very significant at F3 and F4 (Table 3).

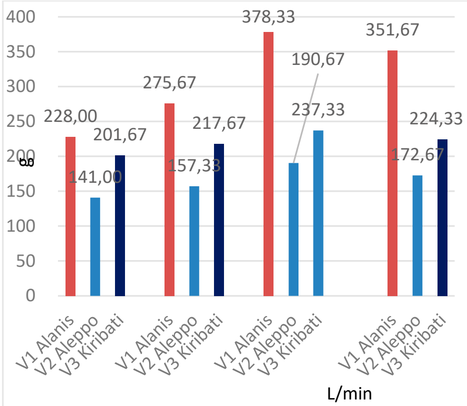


Figure 2. Average edible lettuce mass calculated for each assortment and for all four (4) flow rate variants (L/min)

Table 3. Average mass of lettuce plants in the Alanis assortment

Variants Alanis	Mass (g)	Difference (g)	Difference (%)	Significance
F(0) average	308.42	80.42	135.27	**
F(1)	228.00	0.00	100.00	Ct
F(2)	275.67	47.67	120.91	*
F(3)	378.33	150.33	165.94	***
F(4)	351.67	123.67	154.24	***

DL5% = 45.310 DL5% in % = 19.8728
DL1% = 68.550 DL1% in % = 30.0658
DL01% = 109.210 DL01% in %= 47.8991

In the case of the Aleppo variety (Lollo bionda type) we found that the highest average mass of the plants was recorded in flow rate variant 3 where the flow of the nutrient solution was 2.5 L/min. In this flow rate variant, the difference in mass was 49.67 g and 35%, respectively, over the flow rate control variant aspect found by the statistical significance, very significant. In the case of F2, at a nutrient solution flow rate of 2.0 L/min the plant mass increases were insignificant (Table 4).

Also, in the case of the Kiribati variety, we found the same aspect regarding the average mass of the plants. At F3, at a flow rate of 2.5 L/min, the highest average mass of lettuce plants of 237.33 g was obtained compared to F1 of 201.67 g. Statistically, the differences were positively distinctly significant at F3 (Table 5).

Table 4. Average mass of lettuce plants in the Aleppo variety

Variants Aleppo	Mass (g)	Difference (g)	Difference (%)	Significance
F(0) average	165.42	24.42	117.32	*
F(1)	141.00	0.00	100.00	Ct
F(2)	157.33	16.33	111.58	N
F(3)	190.67	49.67	135.22	**
F(4)	172.67	31.67	122.46	*

DL5% = 21.240 DL5% in % = 15.0638
DL1% = 32.140 DL1% in % = 22.7943
DL0.1% = 51.200 DL0.1% in % = 36.3121

Table 5. Average mass of lettuce plants in the Kiribati variety

Variants Kiribati	Mass (g)	Difference (g)	Difference (%)	Significance
F(0) average	220.25	18.58	109.21	**
F(1)	201.67	0.00	100.00	Ct
F(2)	217.67	16.00	107.93	*
F(3)	237.33	35.67	117.69	***
F(4)	224.33	22.67	111.24	**

DL5% = 11.360 DL5% in % = 5.6331
DL1% = 17.190 DL1% in % = 8.5240
DL0.1% = 27.390 DL 0.1% in %= 13.5818

Figure 3 shows the aspect of the assortments Alanis and Kiribati at the best flow rate variant (F3) 2.5 L/min.

Figure 3. Aspect of lettuce culture for Alanis and Kiribati assortments

Figure 4 shows schematically the differences in the average mass of the plants compared to the flow rate control variant.

Analysing the length of lettuce roots after harvest in the Alanis variety, we found differences between flow rate variants. Thus, the longest root length (29.00 cm) was obtained in the flow rate variant where the flow was 1 L/min. At F4 at a nutrient solution flow rate of 3.0 L/min. the root length showed the lowest value (16.00 cm).

From a statistical point of view, flow rate variants 3 and 4 show the biggest differences and the difference from the flow rate control variant was negatively distinctly significant (Table 6).

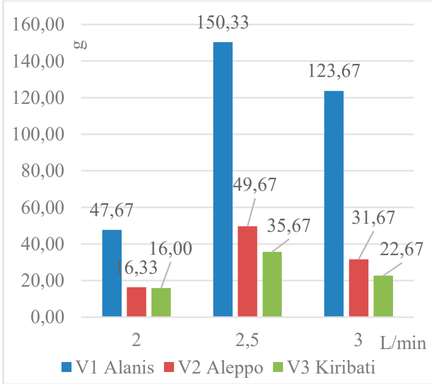


Figure 4. The difference in mass of the plants from the flow rate is 1 L/min (the flow rate control variant)

Table 6. The length of the lettuce roots in the Alanis variety at the flow rate of 1 L/minute

Variants Alanis	Roots (cm)	Difference (cm)	Difference (%)	Significance
F(0) average	23.25	-5.75	80.17	000
F(1)	29.00	0.00	100.00	Ct
F(2)	26.00	-3.00	89.66	00
F(3)	22.00	-7.00	75.86	000
F(4)	16.00	-13.00	55.17	000

DL5% = 1.880 DL5% in % = 6.4828
DL1% = 2.850 DL1% in % = 9.8276
DL0.1% = 4.550 DL0.1% in %= 15.6897

In the case of the Aleppo variety, we noticed a situation similar to the Alanis variety. In this case the longest roots were recorded at F1 (27.00 cm) and the shortest at F4 (18.50 cm). From a statistical point of view, we have noticed distinctly significant negative differences (Table 7).

Table 7. The length of the lettuce roots of the Aleppo variety

Variants Aleppo	Roots (cm)	Difference (cm)	Difference (%)	Significance
F(0) average	22.86	-4.14	84.68	000
F(1)	27.00	0.00	100.00	Ct
F(2)	23.70	-3.30	87.78	000
F(3)	22.25	-4.75	82.41	000
F(4)	18.50	-8.50	68.52	000

DL5% = 0.880 DL5% in % = 3.2593
DL1% = 1.330 DL1% in % = 4.9259
DL0.1% = 2.120 DL0.1% in %= 7.8519

In the Kiribati variety, the plants have developed a higher root system if the nutrient solution flow rate was 1 L/min. (28.75 cm) and lower with the increase of the flow rate through the culture trough of 24.50 cm at F2 with 2 L/min, 22.50 cm, at F3 with 2.5 L/min and 20.33 cm at F4 with 3 L/min. All data are also statistically confirmed and are significantly different from the flow rate control variant.

Table 8. Length of lettuce roots in the Kiribati variety

Variants Kiribati	Roots (cm)	Difference (cm)	(%)	Significance
F(0) average	24.02	-4.73	83.55	000
F(1)	28.75	0.00	100.00	Ct
F(2)	24.50	-4.25	85.22	000
F(3)	22.50	-6.25	78.26	000
F(4)	20.33	-8.42	70.71	000

DL5% =	1.230	DL5% in % =	4.2783
DL1% =	1.860	DL1% in % =	6.4696
DL0.1% =	2.960	DL0.1% in %=	10.2957

Figure 5 shows schematically the values regarding the length of the roots for the experimental flow rate variants. The highest values are observed at F1 with a flow rate of 1 L/min and the lowest at F4. In the F1 flow rate of 1 L/min, the length of the roots is 29.0 cm for Alanis, 27.0 cm for Aleppo, 28.75 cm for Kiribati assortment. On the other hand, in the case of a flow rate of 3 L/min, the length of the roots is 16 cm for Alanis, 18.50 cm for Aleppo, 20.33 cm for Kiribati assortment. At the flow rates of 2 L/min and 2.5 L/min, the length of the roots varies between the abovementioned values, as it is presented in the Figure 5.

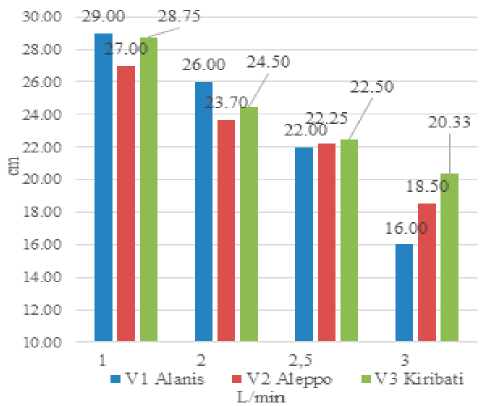


Figure 5. Root length in experimental flow rate variants

The correlation between plant mass and nutrient solution flow rate indicated a significantly different influence with the assortment. Thus, the Aleppo assortment showed a higher influence ($R^2 = 0.7846$) compared to the other varieties where the ratio was $R^2 = 0.5818$ for the Kiribati variety and $R^2 = 0.6092$ for the Aleppo assortment (Figure 6).

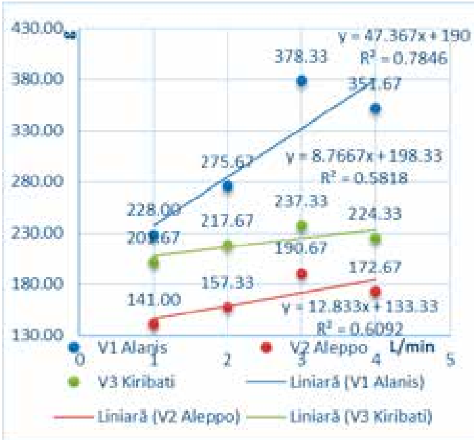


Figure 6. Influence of nutrient solution runoff velocity on average lettuce mass

The correlations between the length of the roots and the flow rate of the nutrient solution for the analysed varieties indicated very significant negative relations, which means that at low flow rates of 1 L/min the root length is higher and decreases with increasing nutrient flow rate. (Figure 7).

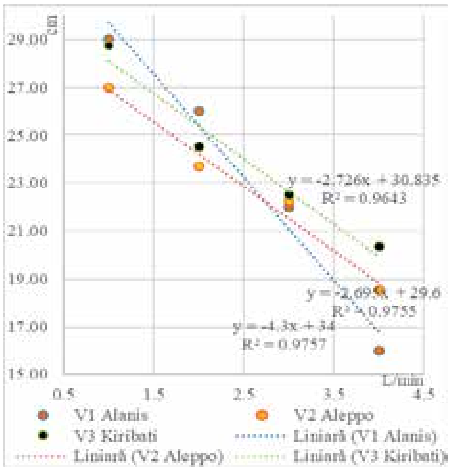
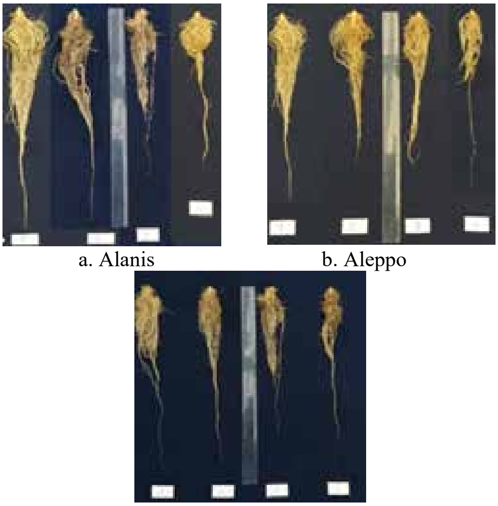


Figure 7. Influence of nutrient solution flow rate on lettuce root length

Figure 8 shows the roots of lettuce plants by varieties and flow rate variants:



a. Alanis b. Aleppo

c. Kiribati

Figure 8. Appearance of roots in experimental flow rate variants a. Alanis; b. Aleppo; c Kiribati

The root volume varied between 14.18 cm^3 for the Alanis variety at the flow rate of the nutrient solution of 1.0 L/min and of 10.00 cm^3 for the flow rate variant with the flow of 3.0 L/min. In the case of the Aleppo variety, the root volume varied between 10.00 cm^3, the flow rate of 2.0 and 2.5 cm^3 and 12.00 cm^3, respectively, in flow rate variants 1 and 4. The Kiribati variety showed the largest root volume between 16.3 cm^3, a flow of 1.0 L/min and 14.00 cm^3 at a flow rate of 3.0 L/min (Figure 9).

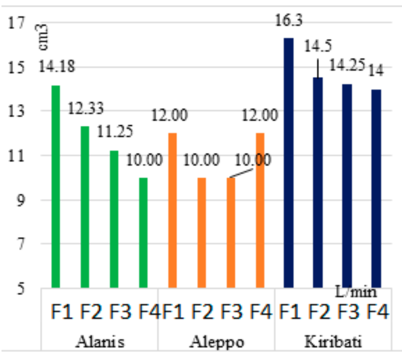


Figure 9. Root volume in experimental flow rate variants (F1, F2, F3, F4)

Regarding the average mass of the roots, it was found that the highest weight was achieved in all varieties at the variant with a flow rate of 1 L/min (Figure 10).

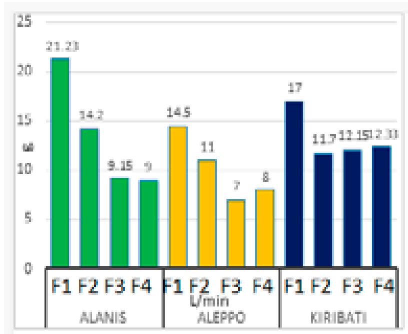


Figure 10. Average mass of lettuce roots in experimental flow rate variants (F1, F2, F3, F4)

The dissolved oxygen level (DO) was determined with a portable oxygen meter. Oxygen levels were determined upon entering and leaving the culture trough. We found that at the entrance the oxygen level was 7.0 mg/L. As the nutrient solution flowed through the culture trough, the roots of the plants consumed the initial oxygen and at the exit of the trough its level was different depending on its flow rate. In the case of the flow rate variant where the flow rate was 1 L/min at the outlet, the oxygen content of the nutrient solution was 4.1 mg /L and at 3 L/min 5.8 mg/L (Table 9).

Thus, the water temperature increases, the solubility of oxygen decreases.

Table 9. Oxygen consumption of plants in the nutrient solution

Flow rate	The amount of oxygen in the nutrient solution in the drain	Inlet solution temperature	Outlet solution temperature
L/min	mg/L	ºC	ºC
1.0	4.10	20.8	21.2
2.0	5.08	20.8	21.0
2.5	5.20	20.8	21.6
3.0	5.80	20.8	21.5

Concerning the nitrate content, it is to be specified that it was calculated in order to identify the nitrate content on plants cultivated in the system presented above. In the same time, the impact of the nutrient solution flow rate was the sole parameter taken into consideration for this analyse.

The nitrate content of lettuce plants was determined in the lowest amount for all lettuce varieties at a flow rate of 1 L/min. The highest nitrate content was identified in lettuces where the solution flow rate was 2.5 L/min. In the case of all flow rate variants, the nitrate content was below the limit allowed by the quality standard of 2,000 mg/kg for lettuce crops in the greenhouse during the winter.

According to the REGULATION (EU) NO. 1258/2011 OF THE COMMISSION of December 2/ 2011 amending Regulation (EC) No.1881/2006 as regards the maximum levels for nitrates in food, for fresh lettuce (*Lactuca sativa* L.), Lettuce grown in the greenhouse and lettuce grown in the air free, the maximum accepted nitrate level during the chosen culture period (during the 10th March- 08th April 2020) is 4,000 mg NO_3/kg except for the head lettuce (2,500 mg NO_3/kg) (Figure 11).

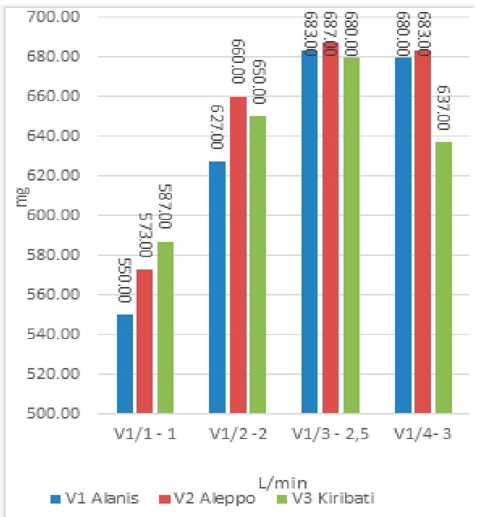


Figure 11. Nitrate content of lettuce plants

CONCLUSIONS

The aim of the study was to identify the best way to ensure the level of oxygen to obtain the best quality lettuce plants.

The results of the experiment are the followings:

1. Concerning the average mass of the lettuce plants:

-The largest average mass of the assortments was identified at the flow rate of 2.5 L/min,

-The lowest average mass of the assortments was identified at the flow rate of 1.0 L/min,

-Therefore, a flow rate of the nutrient solution higher than 2.5 L/min is not justified.

2. Related to the average length of the plant roots:

-The longest length of the plant roots was identified at the flow rate of 1.0 L/min,

-Withal, there is a significant relationship between the length of the plant root and the rate of drainage of the nutrient solution.

3. The impact of oxygen availability in the plants root zone: during the study was demonstrated that there is a direct connection between the increasing of the flow rate of the nutrient solution and the increasing of the concentration of oxygen. However, considering the above-mentioned results, a flow rate of the nutrient solution higher than 2.5 L/min is not justified.

4. The nitrate content of lettuce plants was in all the cases below the limit allowed by the quality standard of 2,000 mg / kg for lettuce crops in the greenhouse during the winter time and increased in the same time with the nutrient solution flow rate.

The lowest amount of nitrate content was evidenced for all lettuce varieties at a flow rate of 1.0 L / min.

The highest nitrate content was identified in lettuces where the solution flow rate was 2.5 L/min.

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REFERENCES

Al-Kinani, H. A. A, Jerca, O.I., Bobuțac, V., Drăghici, E.M. (2021). Comparative study on lettuce growing in nft and ebb and flow system, *Scientific Papers. Series B, Horticulture, LXV*(1), 369 -376.

Baiyin, B., Tagawa, K., Yamada, M., Wang, X., Yamada, S.,Yamamoto, S., Ibaraki, Y. (2021). Study on Plant Growth and Nutrient Uptake under Different Aeration Intensity in Hydroponics with the Application of Particle Image Velocimetry, *Agriculture,11*,1140.

Baiyin, B., Tagawa, K., Yamada, M., Wang, X., Yamada, S., Yamamoto, S., Ibaraki, Y. (2021). Effect of the Flow Rate on Plant Growth and Flow Visualization of Nutrient Solution in Hydroponics. *Horticulturae 7*, 225.

Blok, C., Jackson, B. E., Guo, X., de Visser, P.H.B., Marcelis, L.F.M. (2017). Maximum Plant Uptakes for

Water, Nutrients, and Oxygen Are Not Always Met by Irrigation Rate and Distribution in Water-based Cultivation Systems. *Frontiers in Plant Science, 8,* 562.

Carrasco, G., Gajardo, J.M., Álvaro, J.E., Urrestarazu, M. (2011). Rocket production (eruca sativa mill.) in a floating system using peracetic acid as oxygen source compared with substrate culture, *Journal of Plant Nutrition, 34.9*, 1397-1401.

Chun, C., Takakura, T. (1994). Rate of Root Respiration of Lettuce under Various Dissolved Oxygen Concentrations in Hydroponics. *Environ. Control. Biol., 32*, 125–135

Colunje, J.; Garcia-Caparros, P.; Moreira, J.F.; Lao, M.T. (2021). Effect of Ozonated Fertigation in Pepper Cultivation under Greenhouse Conditions. *Agronomy 11*, 544.

Drew, M.C. (1997). Oxygen deficiency and root metabolism: Injury and Acclimation Under Hypoxia and Anoxia, *Annual Review of Plant Physiology and Plant Molecular Biology*, *48*,.223-250.

Edwards, D.G., Asher, C. J. (1974). The significance of solution flow rate in flowing culture experiments, *Plant and Soil, 41*, 161-175.

Gherghina, E., Luţă, G., Dobrin, E., Drăghici, E.M., Bălan D., Martinez Sanmartin A. (2020). Biochemical changes under artificial led lighting in some Lactuca Sativa L varieties, *AgroLife Scientific Journal 9,* 1.

Goto E, Both AJ, Albright LD, Langhans RW, Leed, A.R. (1996). Effect of dissolved oxygen concentration on lettuce growth in floating hydroponics. *Acta Hortic. 440*, 205-210.

Graves, Chris (1983). The Nutrient Film Technique, *Horticultural Reviews*, 5,. 1-44.

Jailawi, A., Jerca, O.I., Badea, M.L., Drăghici, E.M. (2021). Comparative study regarding the behavior of some varieties of basil cultivated in NFT system (nutrient film technology), *Scientific Papers, Series B, Horticulture*, *LXV (1),* 485-491.

Kurashina, Y., Yamashita, T., Kurabayashi, S., Takemura, K., Ando, K.(2019). Growth control of leaf lettuce with exposure to underwater ultrasound and dissolved oxygen supersaturation, *Ultrasonics Sonochemistry*, *51*, 292-297.

López-Pozos, R., Martínez-Gutiérrez, G.A., Pérez-Pacheco R., Urrestarazu, M. (2011). The Effects of Slope and Channel Nutrient Solution Gap Number on the Yield of Tomato Crops by a Nutrient Film Technique System under a Warm Climate, *HortScience, 46,* 727–729

Moreno Roblero, M.J., Pineda Pineda, J.; Colinas Leon, M.T., Sahagun Castellanos, J., (2020). Oxygen in the root zone and its effect on plants. *Rev. Mex. Cienc. Agríc. 11*(4), 931-943.

Sago, Y., Shigemura A. (2018) Quantitative Nutrient Management Reduces Nitrate Accumulation in Hydroponic Butterhead Lettuces Grown under Artificial Lighting, *HortScience, 53*(7), 5

Steel, R.G.D., Torrie J.H., Dicky, D.A. (1997). Principles and Procedures of Statistics, A Biometrical Approach. 3rd Edition, McGraw Hill, *Inc. Book Co.*, 352-358.

Suyantohadi, A., Kyoren, T., Hariadi, M., Purnomo M.H., Morimoto T., (2010). Effect of high concentrated dissolved oxygen on the plant growth in a deep hydroponic culture under a low temperature, *IFAC Proceedings*, *43*(26), 251-255,

Trejo-Téllez, L.I., Gómez-Merino, F.C. (2012). Nutrient Solutions for Hydroponic Systems, Hydroponics -A Standard Methodology for Plant Biological Researches, *Dr. Toshiki Asao In Tech*. 22

Urrestarazu, M., Mazuela, P.C. (2005). Effect of slow-release oxygen supply by fertigation on horticultural crops under soilless culture, *Scientia Horticulturae*. *106*. 484–490.

Van Rooyen, I.L., Nicol W., (2022) Nitrogen management in nitrification-hydroponic systems by utilizing their pH characteristics, *Environmental Technology & Innovation, 26,* 102360.

REGULATION (EU) NO. 1258/2011 OF THE COMMISSION of December 2, 2011 amending Regulation (EC) No 1881/2006 as regards the maximum levels for nitrates in food, *OJ L 320*, 15–17.