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COMPARATIVE STUDY ON LETTUCE GROWING IN NFT AND EBB AND FLOW SYSTEM

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Abstract

The study was carried out in the Hortinvest greenhouses, within the Research Center for the Quality of Horticultural Products, on five varieties of lettuce ('Alanis'; 'Aleppo' - 'Lollo Bionda' type; 'Carmessi' - 'Lollo Rosa' type; 'Kristine' and 'Saturday' - 'Red salad bowl' type) grown in two types of unconventional systems, Nutrient Film Technology and Ebb and Flow. The varieties of lettuce were grown, and data on their growth were analysed. We determined the mass of the plants and found differences between them. The aim of the study was to follow the production differences for the analysed varieties grown in the two systems, NFT and Ebb and Flow.

Key words*: lettuce, cultivars. NFT, Ebb and Flow.*

INTRODUCTION

Lactuca sativa (Lettuce) is one of the most popular green vegetables. The species originates in the eastern Mediterranean basin, Turkey, the Caucasus and the Middle East. The wild form of lettuce (*Lactuca serriola*) was known about 4500 BC. The name *Lactuca* comes from the Latin word "lactis", meaning milk, due to the white sap and milky consistency contained in the wild forms of lettuce plants (Kesseli et al., 1991; Drăghici, 2015; Draghici, 2018; Wei et al., 2014; Wei et al., 2017). The first descriptions of the use of lettuce are given by the ancient Egyptians and from whose seeds an oil similar to oil was extracted and then began to be used for consumption.

Lettuce is an annual plant, from the group of green vegetables, highly appreciated for its qualities. It is cultivated on fairly large areas, both in the field and in greenhouses or solariums, in all systems. Lately, the areas cultivated with lettuce, in a soilless system, have increased a lot. Thus, in Romania this culture system has been extended, because several crop cycles can be achieved per year, so high yields, high economic efficiency, but also the security of offering guaranteed products on the market (Oliveira et al, 2010; Drăghici, 2016; Drăghici et al., 2018).

Any protected area can be adapted for NFT and Ebb and flow cropping systems, which are much more efficient for growing lettuce or other small vegetable species as they allow better plant monitoring, (Giacomelli, 1998; Jones and Tardieu, 1998; Kang Jeong, 2014; Chidiac 2017). Efficiency consists in using a smaller and more efficient amount of water (Gent and McAvoy. 2011; Chidiac, 2017).

In Europe, the NFT system is often practiced over large areas. In Romania the system is practiced only on areas under 2 ha, in specialized farms. The largest areas of about 281 ha (FAO 2017) are grown with lettuce in conventional system, on the soil.

In order to obtain a high salad production, it is necessary to ensure the optimal conditions of temperature, light, atmospheric humidity, quality of the nutrient solution, but also the choice of a suitable assortment. These factors can influence the growth rate of the plants, the time until the formation of the edible part, the appearance of the floral stem or the bitter taste of the leaves. All varieties of salad are unpretentious to temperature. The seeds

germinate in optimal temperature conditions between 18°C and 20°C. For some varieties of lettuce, temperatures above 25°C lead to decreased seed germination or even inhibition.

For varieties grown in protected areas, the minimum plant growth temperature is 16°C, and the optimum between 18-24°C. In culture, temperatures below 18°C cause a slight prolongation of the vegetation period, and those above 18°C an acceleration of the formation of the edible part. In many situations, at temperatures above 18°C in some varieties it forms only a rosette of leaves but without forming the head. In conditions of very high temperature and insufficient light, the leaves are etiolated, the head is no longer formed or it is too loose.

During the day, temperatures of 20-24°C in sunny weather and between 17-19°C in cloudy weather, and during the night 19°C will be ensured. Some varieties are very sensitive to temperatures above 22-25°C, causing the premature appearance of flower stalks. Also, in some varieties of 'Lollo rosa' type or oak leaf type, the very high temperatures associated with high light intensities influence the coloration of these leaves, no longer having a dark red colour but a light red to green colour.

It is recommended that the temperature of the nutrient solution be kept constant at 20°C, as the dissolved oxygen content may change. The oxygen content of the nutrient solution is a very important factor in the growth and development of lettuce plants. The increase of the temperature of the nutrient solution over 20°C determines a decrease of the oxygen content, at the same time it is stimulated, the development of anaerobic pathogens, in particular, of the root rot favored by *Pythium*. If the temperature of the nutrient solution falls below the normal limit, the amount of dissolved oxygen increases, but the absorption of nutrients decreases.

Depending on the variety, the salad needs 8-10 hours of direct sunlight daily, especially during the vegetative growth period. Appropriate productions are obtained if a light intensity in the range of 12-17 mol/m^2 is ensured correlated with a good ventilation. Increasing light intensity can lead to improper plant development (Kang et al., 2014). Some varieties require higher light intensity, but grown in low light conditions the plants grow with difficulty. That is why it is good to choose the variety assortment depending on the season and destination, for the greenhouse, solarium or only for the field. Additional use of light over 16 hours to 24 hours, at an intensity of 100-200 µmol/m^2/s (17 mol/m^2/day) during the winter leads to an increase in plant biomass so the crop cycle is reduced by about 25%.

Also, increasing the duration of lighting reduces the nitrate content of salad by 10-26% (Gaudreau et al., 1994). Lettuce is a major consumer of nitrogen. The administration of an insufficient amount of nitrogen influences the vegetative growth of the plants. The concentration of the nutrient solution must be increased progressively, depending on the stage of development of the salad plants. The electrical conductivity (EC) will be maintained between: 1.0-1.2 mS in the first week after planting; 1.4-1.6 mS from the second week after planting; and 1.8-2.0 mS from the third week until the salad is harvested.

Throughout the vegetation period, the pH of the solution will remain constant at 5.6-6.0 (Morgan et al., 2012). In case of pH fluctuations, problems of blocking the absorption of nutrients may occur.

The cultivation of lettuce in NFT system at EC values of 3.2 dS m^{-1} - 5.2 dS m^{-1} led to the production of unsuitable lettuce plants (Jung et al., 2016; Hammady et al. 2015) as well as at high salinity levels. Studying the performance of lettuce cultivars subjected to different salinity levels of the irrigation water, Oliveira et al. (2010) observed that growth parameters decreased linearly with the increase in salinity (Soares et al., 2010; Santos et al., 2011; Santos, 2017; Alves et al., 2011). The quality of lettuce seedlings largely depends on the substrate and the management of the crop. In modern technology the nutritive substrates are processed in specialized farms.

In the case of lettuce cultivation in an unconventional system, the mass of the plants but also the dry matter content are high (Barbosa, 2015; Han et al., 2016).

The main objective of the study was to characterize some varieties of lettuce grown in the NFT system in terms of yields.

MATERIALS AND METHODS

The study was carried out within the Hortinvest research greenhouses, which belong to the Research Center for quality control of horticultural products, Faculty of Horticulture,. USAMV Bucharest.

During the research we followed the behaviour of some varieties of lettuce grown in the NFT system in terms of production. We followed the development of lettuce plants in NFT and Ebb and Flow systems.

Biological material used in the experiment was 5 varieties of lettuce. **V1 - 'Alanis'** is a variety of head lettuce, intended to be grown in autumn, winter and early spring, in protected areas (greenhouses or high tunnels). The leaves are green, the average mass of the head can reach about 400-600 g. **V2 - 'Aleppo'** variety ('Lollo Bionda' type). It is a variety of lettuce (*Lactuca sativa* var. *crispa*) with light green leaves. The leaves are wrinkled at the edge and lacy. The average mass of the plant reaches about 300 g.

V3 - 'Carmessi' ('Lollo Rossa' type) is an early variety of leaf lettuce, red, with a vegetation period of 65-68 days. It is recommended for spring crops, summer and autumn both in the field and in protected areas. The leaves are dark green with a reddish-brown tinge and at maturity the average mass can have values between 250 and 300 g. **V4 - 'Kristine RZ'** is an oak leaf type. It can be grown all year round. It forms a large rosette with many green leaves. The variety weighs 500-600 g and is resistant to flowering.

V5 - 'Saturday' ('Red salad bowl' is oak leaf type). The rosette has cherry-green leaves. It can be harvested either whole or regularly in the form of individual leaves, and thus will continue to produce until the end of the season.

During the experience we followed and determined:

- dynamics of seedling leaf formation;
- dynamics of lettuce leaf growth;
- dynamics of salad rosette growth;
- total and edible mass of salads obtained

Lettuce seedlings were produced in the greenhouse. The seeds were sown on 23.10. 2019. The seedling were 22 days old at planting.

RESULTS AND DISCUSSIONS

During the growth of lettuce plants we maintained in the greenhouse temperature conditions of 21°C during the day and 19°C at night. Data on lettuce growing conditions are recorded in the Table 1.

Table 1. Parameters of growing lettuce plants

Parameters	Number of days after planting				
	5	10	15	20	25
Temperature (°C) days	21	21	21	21	21
Temperature (°C) in the night	19	19	19	19	19
CO_2 content	300	300	300	300	300
EC (micromoli/cm)	0.8	1.2	1.8	2.0	2.2
pH	6.0	6.0	6.0	6.0	6.0
The flow (l/min)	2	2	2	2	2

We found that the seeds sprouted after 4 days from sowing in a percentage of 84.61% for the 'Carmessi' ('Lollo Rosa' type) and 93.45% for the 'Aleppo' variety ('Lollo Bionda' type), Figure 1.

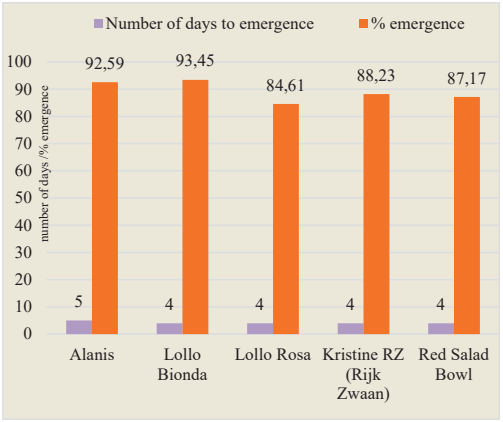

Figure 1. Number of days until emergence and percentage of salad emergence

In the Table 2, data are presented, from which it can be observed, the formation of the number of leaves in the analyzed varieties, from emergence to the end of cultivation. On 28.10.2019, for the 'Alanis', 'Aleppo' ('Lollo Bionda' type), 'Carmessi' ('Lollo Rossa' type) and 'Kristine' varieties, on the plant, on average, 2 leaves were formed and for the 'Saturday' variety ('Red Salad Bowl' type), 2.25 leaves. On November 10, 2019, the

'Alanis', 'Kristine' and 'Saturday' varieties had a number of leaves between 4 and 4.5 leaves, and the 'Lollo' type varieties had a number of 3.5 leaves. On 15.11.2019 at the time of planting in the culture troughs of the NFT system the seedlings had between 4 leaves for the varieties 'Aleppo' ('Lollo Bionda' type) and 'Carmessi' ('Lollo Rossa' type) and 4.5 leaves for the varieties 'Alanis'. 'Kristine' and 'Saturday' ('Red Salad Bowl' type), Table 2.

Table 2. Dynamics of leaf formation in lettuce seedlings

Date of determination	Number of leaves formed per plant - nr.				
	V1 Alanis	V2 Aleppo	V3 Carmesi	V4 Kristine	V5 Saturday
28.10. 2019	2	2	2	2.0	2.25
05.11.2019	3	3	3	2.8	3
10. 11.2019	4.0	3.5	3.5	4.15	4.25
15.11.2019	4.5	4	4	4.5	4.5
30.11.2019	10.67	8.25	8.0	9.25	11.25
15.12.2019	20.25	11.25	15.15	13.33	17
20.12.2019	23.55	18.25	21.33	16.25	18.55

Analyzing the data in the Table 3, on plant height at the end of the crop we could see that lettuce grown in the NFT system showed a higher height in all cultivated varieties compared to lettuce grown in the Flux Reflux system. The 'Alanis' variety obtained 4.5 leaves more than the cultivated variant in the NFT system. Also, for the 'Lollo' type salad varieties, we obtained a plant height of 16.66 for the 'Aleppo' variety ('Lollo Bionda' type) and 15.25 cm for the 'Carmessi' variety ('Lollo Rossa' type). The difference was 3.95 cm and 15.25, respectively. The variant in the Flux Reflux system was with 80.73%, respectively 77.22% under the variant from the UASMV Bucharest greenhouses - growing in the NFT system.

Table 3. Height of lettuce plants

Specification	V1 Alanis	V2 Aleppo	V3 Carmessi	V4 Kristine	V5 Saturday
	cm	cm	cm	cm	cm
NFT	**21.75**	**20.5**	**19.75**	**25.5**	**21.25**
Ebb and Flow	17.25	16.55	15.25	20	17
Diference between NFT and Ebb and Flow	4.50	3.95	4.50	5.50	4.25
Diference in percent to NFT (%)	79.31	80.73	77.22	78.43	80.00

The diameter of the lettuce plants was at the end of the crop of 27.16 cm for the (V1) 'Alanis' (head lettuce variety), 18.55 cm for (V2) 'Aleppo' (Table 4).

Table 4. The dynamics of increase in the diameter of lettuce plants grown in NFT system

Date	V1 Alanis	V2 Aleppo	V3 Carmessi	V4 Kristine	V5 Saturday
	cm	cm	cm	cm	cm
15.11.2019	8.5	8.5	9.25	10.25	10.25
30.11.2019	13.4	12.25	14	15.25	18.67
15.11.2019	20.75	15.5	16.75	18.55	22.15
20.11.2019	27.16	18.55	19.33	23.25	24.25

By comparison, in the Reflux Flux system with floodable tables, although the culture conditions and the quality of the nutrient solution were similar, the plants showed a weaker growth. The diameter of the plants is between 14 cm for the 'Aleppo' variety ('Lollo Bionda') and 16.5 cm for the 'Alanis' variety (Figure 2).

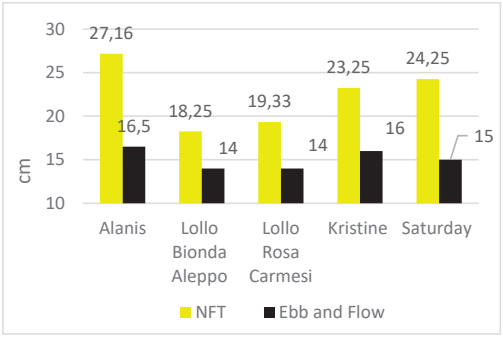

Figure 2. The diameter of the lettuce plants in NFT and Ebb and Flow systems

Regarding the diameter of the plants, in the Ebb and Flow system the lettuce plants were 10.66 cm smaller for the 'Alanis variety' and with 4.25 cm for the 'Aleppo' variety type 'Lollo Bionda' (Figure 3).

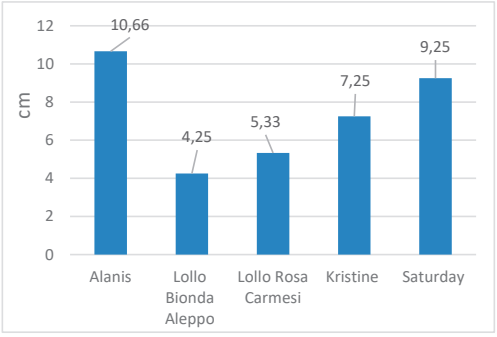

Figure 3. The difference between the two systems NFT and Ebb and Flow

The data on the quality of the salad complied with the marketing standard - Regulation (EC) no. 1221/2008 of the European Commission amending Regulation (EC) no. 1580/2007, which establishes the rules for the application of Regulations (EC) no. 2200/96. (EC) no. 2201/96 and (EC) no. Council Regulation (EC) No 1182/2007 on marketing standards in the fruit and vegetables sector (Table 5).

Table 5. The quality Standard of lettuce

Quality requirements	Category	For Head lettuce	For Leaf lettuce
Standard	I	300-450 g	150-200 g
	II	under the 150 g	under the 150 g

In the 'Alanis' variety, we noticed that only one plant out of the 10 examined had a very high average mass of 387 g, 87 g more than the quality standard I.
In the rest of the variant, the average mass varied between 315 g and 345 g. The lowest average mass was 257 g. We can also note that only 10% of the harvested plants had an average mass below the standard of 300 g but with an insignificant weight of only 3 g below the standard. In the case of cultivation in the Ebb and Flow system the mass of the plants was much lower (Figures 4, 5).

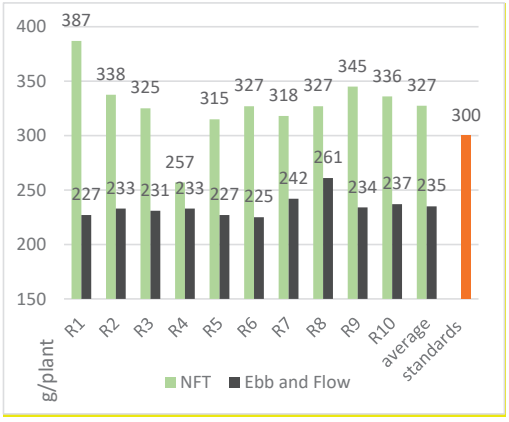

Figure 4. Lettuce plants mass, variety 'Alanis'

In the case of the 'Aleppo' variety, for the 10 plants examined, we recorded average masses between 127 g and 180 g and with an average of 160 g. We found that at the time of harvest, 30% of the plants had average masses, below the standard of 150 g. In the case of cultivation in the Ebb and Flow system, the average mass of the plants was 122 g (Figures 6, 7).

Figure 5. The appearance of head lettuce variety 'Alanis'. NFT; Ebb and Flow

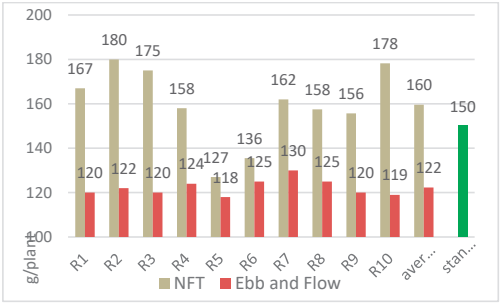

Figure 6. Lettuce plants mass, variety 'Aleppo' ('Lollo Bionda' type)

Figure 7. The appearance of the lettuce plant variety 'Aleppo' ('Lollo Bionda' type)

For the 'Carmessi' variety ('Lollo Rosa' type) we obtained average masses of over 150 g for most plants. In only 3 plants we found average masses under 150 g. In the Ebb and Flow system, the average plant mass was 128 g (Figures 8, 9).

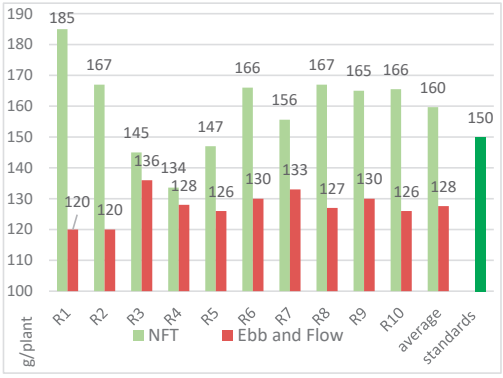

Figure 8. The mass of the lettuce - variety 'Carmessi' ('Lollo Rosa' type)

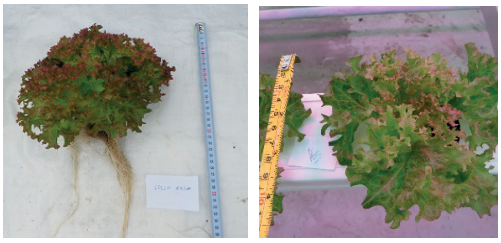

Figure 9. The appearance of the lettuce plant variety 'Carmessi' ('Lollo Rossa' type)

In the 'Kristine' variety the average mass of the plants was on average 317 g, this varied between 211 g 365 g. In the case of this variety 20% of the plants had average masses below 300 g. In the case of cultivation in the Ebb and Flow system, the average mass of the plants was 253 g (Figures 10, 11).

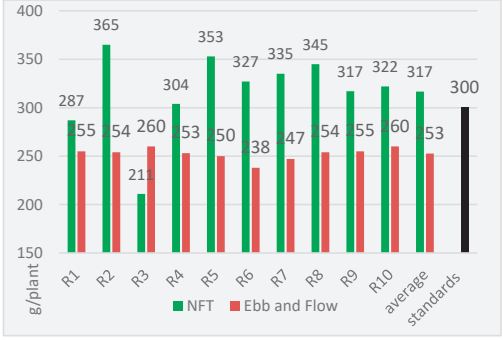

Figure 10. The total mass of plants in the 'Kristine' variety

Figure 11. The appearance of lettuce 'Kristine' variety

In the 'Saturday' variety ('Red Salad Bowl' type) 30% of the plants had average masses under 300 g. The mass of the plants varied between 305 g and 334 g. On average, the plants had a mass of 282 g, below the Quality I of Standard (300 g). In the case of cultivation in the Ebb and Flow system, the average mass of the plants was 185 g (Figures 12, 13).

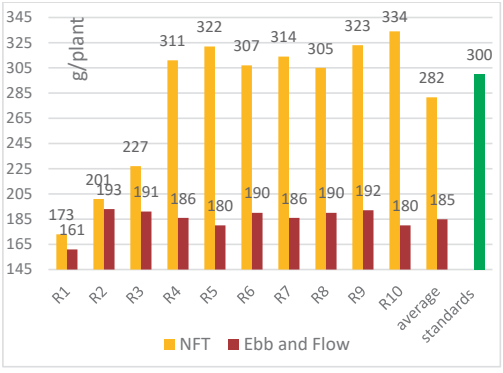

Figure 12. The total mass of plants in the 'Saturday' variety

Figure 13. The appearance of salad plants in the 'Saturday' variety ('Red Salad Bowl' type)

In summary, the average data on the mass of lettuce plants obtaine'd in the two cultivation variants are presented graphically in Figure 14.

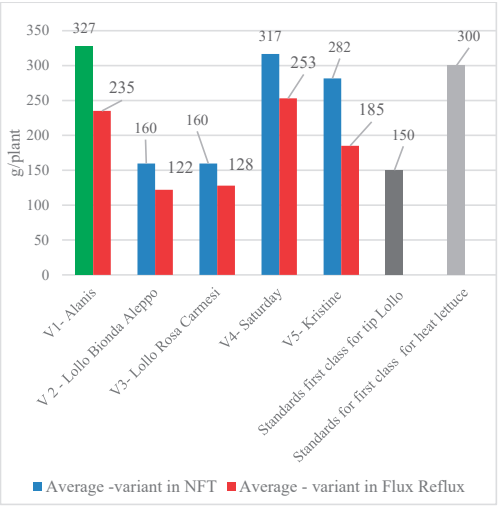

Figure 14. The average weight of plants in NFT and Ebb and Flow

CONCLUSIONS

Lettuce seedlings were uniform at planting. They had an average number of leaves between 4 and 4.5 leaves.

During the growth of the plants a greater number of leaves were formed in the variant cultivated in the NFT system because the temperature at the root system was constant of 20-21ºC. In the Ebb and Flow system as the interval between watering's is longer the nutrient substrate transmits roots a temperature lower than 20ºC which leads to an extension of the growing season.

The formation time of the edible part was shorter in the variant cultivated in NFT compared to Ebb and Flow.

In the NFT system we obtained average masses which met the marketing standard in 25 days and in the Ebb and Flow system the plants reached the commercialization standard after 35 and 40 days, respectively.

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