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ORIGINAL PAPER

Organic fertilizer effect on Lettuce (*Lactuca sativa* L.) cultivated in nutrient film technology

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Abstract

The survey was carried out in the Research Centre for the study of food products quality "HORTINVEST" between 2014-2015 using the Nutrient Film Technology (NFT) for the cultivation of lettuce. Three lettuce cultivars were used: Markies, Lollo bionda *and* Lollo rosa*, together with three types of fertilizers: two organic fertilizers and a chemical one. Biometrical measurements on lettuce growth were conducted; also at the end of the cultivation cycle biochemical measurements were performed in order to assess plant quality. Also correlations between various biometrical parameters and influencing vegetal factors were settled. The results led towards gains in the plant growth rate, in the development of the leaf number and eventually in the production growth. For all lettuce varieties under research the total plant mass was higher due to organic fertilizers in comparison with plants under chemical fertilizer treatment. The plants organically fertilized proved to be superior as to the biochemical quality. Research was carried out in order to assess the quantitative and qualitative feedback of lettuce cultivated in Nutrient Film Technology (NFT) to various organic fertilizers which might replace chemical fertilizers.*

Keywords: *Lactuca sativa* L., NFT system, organic fertilizers, quality.

1. Introduction

Lettuce *(Lactuca sativa L.)* is a highly appreciated vegetable, firstly due to its nutritional qualities; this plant may be cultivated all year long, in all seasons, in various culture systems (greenhouse, hothouse, open field). Recently, it has been largely cultivated in greenhouses either in various substrata or using the Nutrient Film Technology (NFT). The plant grows on a nutrient solution or on a nonreactive substratum. In either situation a fertilizer solution is applied. NFT is an efficient system as to the water intake and fertilizers (KRATKY, 2005 [8]); lettuce with an average mass of 150-250 g has been obtained with an uptake of 3-6 l nutrient solution per plant in this system. Cultivating lettuce without soil may lead to greater quantity and quality (SILBER et al., 2003 [10]; SIKAWA AND YAKUPITIYAGE, 2010 [10]) and also in a 6 to 8 weeks' period (AL-GHAWAS, and, AL-MAZIDI, 2004 [2]); (KRATKY 2009 [7]); (IBRAHIM, ZUKI, 2014 [4]). Researches have shown that organic fertilizers have improved both the quantity and the quality of lettuce. Lettuce quality can be influenced both by the fertilizer type (ABD-ELMONIEM and all., 1996 [1]); (KARIMAEI and all., 2004 [6]); (VILLAGA and all., 2012 [12]); (QIU et all., 2014 [9]) and by the light quality (ITO ,1989 [5]); (DANISH, 1994 [3]). The aim of this survey is to replace the chemical fertilizers with organic ones in the lettuce NFT cultivation.

2. Materials and methods

The experiments were carried out in the greenhouse of the Research Centre for the study of food products quality "HORTINVEST" between 2014-2015. The culture was grown using the Nutrient Film Technology (NFT) system. Four types of fertilizers were used: three organic fertilizers and a chemical one. The experimental fertilization variants were: V1 – Organic Grow; V2 – Bio Leafez; V3 – Formulex; V4 – chemical fertilization. The total cultivated area was of 160 m; 17.5 plants per one square meter in NFT. Three lettuce cultivars were used: Markies, Lollo Bionda and Lollo Rosa having the following features: Markies – a lettuce variety fit for indoor areas cultivated during autumn, winter or spring; head weight 400-600 g; vegetation period: 50-60 days since planting; Lollo Bionda – a leaf lettuce (*Lactuca Sativa var. crispa*) with shining light green colour and long and upright shape; it has crinkled and frilly leaves; average mass: 300 g; Lollo Rosa – an early lettuce cultivar, with crinkled and red leaves; vegetation period: 68 days; average mass: 250-300 g. The organic fertilizer Organic Grow used all along the research had the following features: NPK ratio: 8: 3: 3; microelements: nitrogen (total amount): 82.2 g/l, phosphorus: (P_2O_5) 30.3 g/l, potassium (K_2O) 32.1 g/l , boron 7 mg/l, calcium 390 mg/l, copper 2 mg/l, iron 120 mg/l, magnesium 850 mg/l, manganese 15 mg/l, zinc 12 mg/l, sodium 16.6 g/l, sulfides 0.4 g/l, pH 6.00. Bio Leafez, organic fertilizer with a NPK ratio of 8: 3: 3 and microelements. Formulex with a NPK ratio of 2.4: 0.9:3.4. For chemical fertilization Universol Green product was used having a NPK ratio of 4-1-2. The content of the chemical fertilizer is as follows: nitrogen (total amount 23 g/l; phosphorus (P_2O_5); potassium (K_2O) 10 g/l, boron 0.01 g/l, copper 0.01 g/l, iron 0.06 g/l, magnesium 2.5 g/l, manganese 0.04 g/l, zinc 0.01 g/l, pH 6.00. During the first week after planting the electroconductibility was maintained at 0.7 mS/cm² and then as the lettuce grew it was gradually reduced to 2.2 mS/cm². The solution pH level was constantly maintained at 6.00. Observations and measurements were conducted on the dynamics of leaf formation, lettuce leaf growth rate, plants' diameter and mass. The determination of nitrites and nitrates percentage was made in the agrochemistry laboratory of the Faculty of Biotechnologies. Results have been statistical interpreted by variance analysis (ANOVA) for $p<0.05$, according to Student test.

3. Results and discussions

During the cultivation period for each fertilizer an EC of 1.5 Microsiemens for the first week and an EC of 1.8 Microsiemens for the rest of the vegetation period were provided. A constant pH of 6.5 was observed during the entire period of time (Table 1). The light regime was relatively constant for all cultivars under survey. The light intensity was measured on a daily basis and the average of the recorded data, i.e. 7.92 Klux, exceeded the minimum intensity level for lettuce (Soare Rodica, 2008).

Table 1. Data regarding EC, pH and the average light intensity during 2014-2015

Fertilizer	EC 1st Stage (Microsiemens)	EC 2nd Stage (Microsiemens)	pH	Light intensity (micromols)	Light intensity (Klux)
V1 Organic Grow	1,5	1,8	6,5	206,52	7,92
V2 Bio Leafez	1,5	1,8	6,5	206,52	7,92
V3 Formulex	1,5	1,8	6,5	206,52	7,92
V4 Chemical	1,5	1,8	6,5	206,52	7,92

The results of the lettuce plant growing of the analysed cultivars are presented in figures 1-3 while the statistic interpretation of the results are recorded in tables 2-4. For the Markies cultivar (figure 1, table 2), the data obtained regarding the number of leaves grown on the plant after 30 days from planting in NFT system showed that the chemical fertilized variety developed the lowest number of leaves (17,66). It was further noticed that at all cultivars for which organic fertilizers had been used, the plants formed a greater number of leaves ranging from 21.33 (Formulex) to 24.11 (Bio Leafez) leaves, figure1.

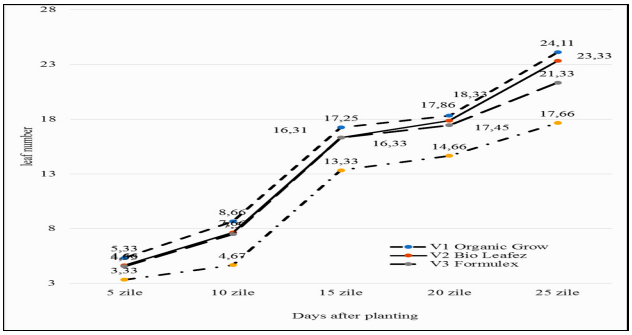


Figure 1. Dynamics of leaf formed on plant at Markies cultivar

Table 2. Synthesis of the results regarding leaf formation – Markies cultivar

Variant	Leaves number No.	Difference		Significance
		Number	(%)	
V 0 Average	21.61	3.95	122.35	***
V1	23.33	5.67	132.11	***
V2	24.11	6.45	136.52	***
V3	21.33	3.67	120.78	***
V4	17.66	0.00	100.00	Control

DL5% = 0.560 DL5% in % = 3.1710; DL1% = 0.810 DL1% in % = 4.5866; DL01% = 1.190 DL01% in %= 6.7384

In relation to Lollo bionda cultivar (figure 2, table 3), the lowest number of leaves was registered at the chemical fertilized variety (9.66 leaves). All the organic fertilized varieties formed a greater number of leaves in comparison with the chemical fertilized one. The obtained values range from 10.33 leaves at the variant fertiliezed with Organic Grow to 11.66 leaves at the one fertilized with Bio Leafez.

The same trend was recorded at the Lollo Rosa cultivar, organic fertilized variants having a greater number of leaves than the chemical fertilized one. The values have been as follows: 10.33 leaves at the chemical fertilized variant and 12.33 leaves at the variant for which Organic Grow fertilizer was applied (figure 3).

Highly significant differences may be noticed at the Organic Grow fertilized variant of the Lollo Rosa cultivar (table 4).

For the Markies and Lollo Rosa cultivars a very significant relation has been noted between the fertilization variants and the number of leaves formed on the plant. The relation is $R^2 = 0.7868$ for the Markies cultivar and $R^2 = 0.942$ for Lollo rosa variety (figures 4 *a* and *b*.). The number of leaves formed on Lollo Rosa cultivar has not been significantly influenced by the applied fertilizer (figure 5).

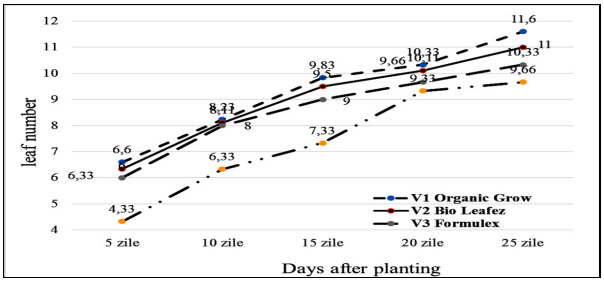


Figure 2. Dynamics of leaf formed on plant at Lollo Bionda cultivar

Table 3. Synthesis of the results regarding leaf formation – Lollo bionda cultivar

Variant	Leaves number No.	Difference		Significance
		number	(%)	
V 0 Average	10.66	1.00	110.38	*
V1	10.33	0.67	106.94	N
V2	11.66	2.00	120.70	***
V3	11.00	1.34	113.87	**
V4	9.66	0.00	100.00	Control

DL5% = 0.820 DL5% in % = 8.4886; DL1% = 1.180 DL1% in % = 12.2153; DL01% = 1.730 DL01% in % = 17.9089

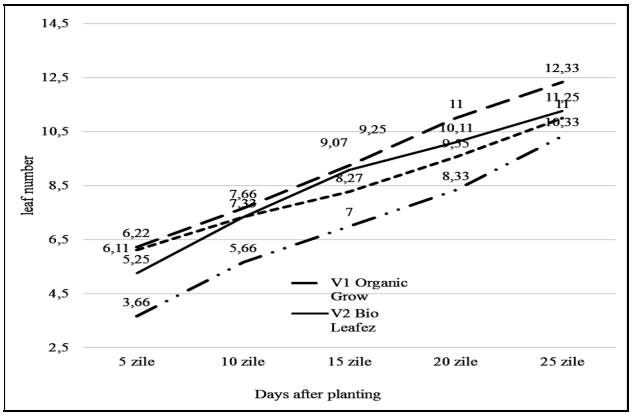
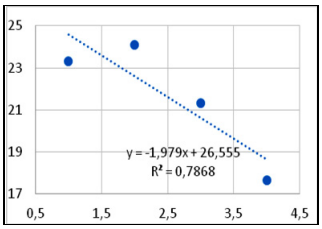


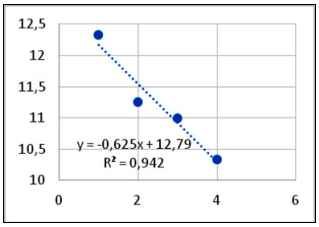
Figure 3. Dynamics of formed leaf on plant at Lollo Rosa cultivar

Table 4. Synthesis of the results regarding leaf formation - Lollo Rosa cultivar

Variant	Leaves number No.	Difference		Significance
		Number	(%)	
V 0 Average	11.23	0.90	108.69	*
V1	12.33	2.00	119.36	***
V2	11.25	0.92	108.91	**
V3	11.00	0.67	106.49	*
V4	10.33	0.00	100.00	Mt

DL5% = 0.640 DL5% in % = 6.1955; DL1% = 0.920 DL1% in % = 8.9061; DL01% = 1.350 DL01% in % = 13.0687





a **b**

Figure 4. Influence of fertilizers on number of leaves at Markies (**a**) and Lollo rosa (**b**) cultivars

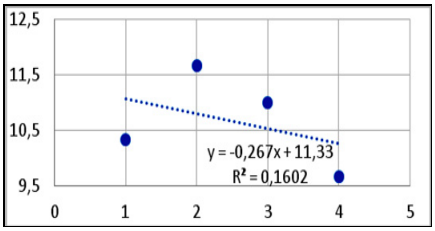


Figure 5. Influence of fertilizers on number of leaves at Lollo Bionda cultivar

As for the plant total mass (figure 6, table 5-7) it has been noted that the Markies cultivar registered the highest average mass for the variant at which the organic fertilizer Organic Grow was applied (422.25 g/plant), and the lowest average mass of 397.11g was recorded at the chemical fertilized variant. For Lollo bionda and Lollo rosa cultivars, the lowest average mass has also been found for the chemical fertilized variant: Lollo bionda – 201.33 g and Lollo Rosa cultivar – 187.25 g. When the BioLeafez fertilizer was applied, plants with an average mass of 413.15 g were obtained at the Markies cultivar, while for Lollo bionda and Lollo rosa varieties plants registered an average mass of 255.33 g and respectively 258.25 g.

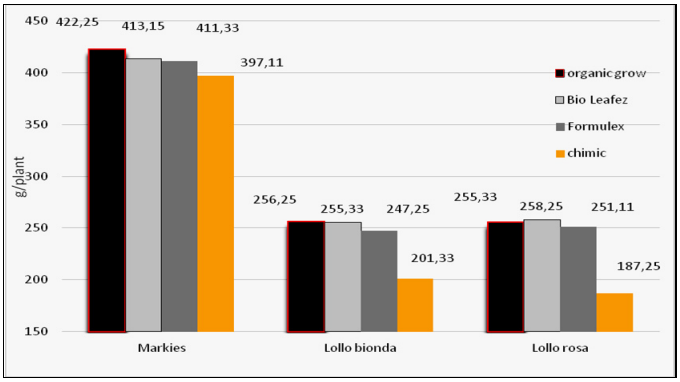


Figure 6. Average mass of lettuce plants

The statistical analysis (Duncan test) for Markies cultivar highlighted the V1 variant that was fertilized with Organic Grow and a distinct statistical difference was observed (Table 5).

Table 5. Synthesis of the results on average lettuce mass – MARKIES cultivar

Variant	Total mass (g)	Difference		Significance
		(g)	(%)	
V 0 AVERAGE	410.96	13.85	103.49	N
V1	422.25	25.14	106.33	**
V2	413.15	16.04	104.04	*
V3	411.33	14.22	103.58	*
V4	397.11	0.00	100.00	Mt

DL5% = 14.020 DL5% in % = 3.5305; DL1% = 20.150 DL1% in % = 5.0742; DL01% = 29.600 DL01% in % = 7.4539

As for Lollo Bionda and Lollo Rosa cultivars highly significant statistical differences have been recorded for the plant mass in comparison with control variant 4 (Tables 6 and 7).

Table 6. Synthesis of the results on average lettuce mass – Lollo Bionda cultivar

Variant	Total mass (g)	Difference		Significance
		(g)	(%)	
V 0 - average	240.04	38.71	119.23	***
V1	256.25	54.92	127.28	***
V2	255.33	54.00	126.82	***
V3	247.25	45.92	122.81	***
V4	201.33	0.00	100.00	Mt

DL5% = 7.210 ; L5% in % = 3.5812; DL1% = 10.360; DL1% in % = 5.1458; DL01% = 15.220; DL01% in %= 7.5597

Table 7. Synthesis of the results on average lettuce mass – Lollo Rosa cultivar

Variant	Total mass (g)	Difference		Significance
		(g)	(%)	
V 0 - average	237.99	50.74	127.10	***
V1	255.33	68.08	136.36	***
V2	258.25	71.00	137.92	***
V3	251.11	63.86	134.10	***
V4	187.25	0.00	100.00	Mt

DL5% = 9.150; DL5% in % = 4.8865; DL1% = 13.150; DL1% in % = 7.0227; DL01% = 19.310 DL01% in %= 10.3124

Analyzing the correlations between the fertilizers and the average mass of the plants, it has been concluded that the fertilizer has a important influence. For the cultivars in question the correlations have been as follows: $R^2 = 0.9201$ for Markies, $R^2 = 0.7297$ for Lollo Bionda and $R^2 = 0.6461$ for Lollo Rosa (figures 7-9).

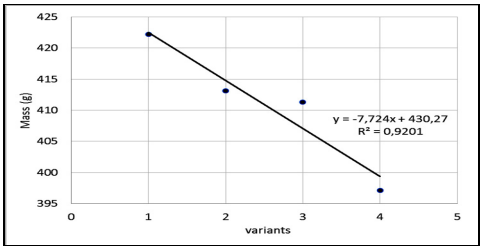


Figure 7. Influence of the fertilizer upon the average mass of the lettuce heads – Markies

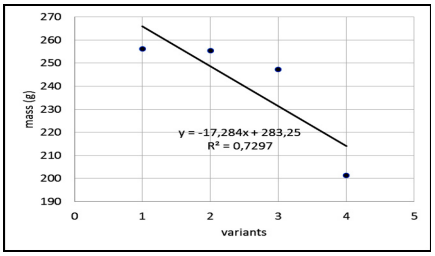


Figure 8. Influence of the fertilizer upon the average mass of the lettuce rosette – Lollo bionda

Such results are corroborated with the results on the average daily growth rate and also with the results on the average daily rate growth of mass accumulation at the level of the lettuce rosette – see Table 8. Noticeable is the Markies head because of the average daily rate growth – which is almost twice higher – and the daily rate growth of mass accumulation which is at least 70% higher in comparison with the rate of leaf lettuce varieties (Lollo bionda

and Lollo rosa), irrespective of the applied fertilizer. Figure 10 shows the strong bondage between the two synthetical indices (R^2=0.9178) irrespective of the applied fertilizers.

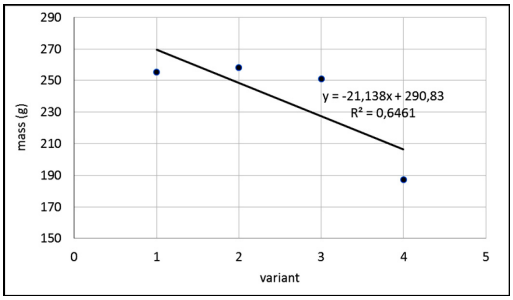


Figure 9. Influence of the fertilizer upon the average mass of the lettuce rosette – Lollo rosa

Table 8. Average daily rate of growth and average daily rate of mass accumulation of lettuce rosettes

Cultivars	Variants	Average daily growth rate (no. leaf / day)	Average daily rate of mass accumulation (g/day)
Markies	V0 average	*0.72*	*13.69*
	V1	0.78	14.07
	V2	0.80	13.77
	V3	0.71	13.71
	V4	0.59	13.23
Lollo bionda	V0 average	*0.35*	*8.00*
	V1	0.34	8.54
	V2	0.39	8.51
	V3	0.37	8.24
	V4	0.32	6.71
Lollo rosa	V0 average	*0.37*	*7.93*
	V1	0.41	8.51
	V2	0.37	8.61
	V3	0.37	8.37
	V4	0.34	6.24

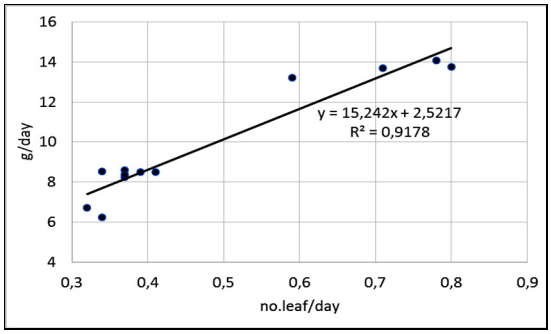


Figure 10. Relationship between average daily rate of growth and average daily rate of mass accumulation

The marketing quality of the lettuce is appreciated mainly considering the plant mass according to the quality standards and considering the percentage of nitrates and nitrites. It has been assessed that the plant mass of all NFT cultivated variants is within the limits of the quality standards. Data on nitrates and nitrites percentage calculated for the NFT-cultivated lettuce are displayed in Table 9. Tests have shown lower values for variants with organic fertilizers. Also it is noticeable that the culture period may have influenced the percentage of nitrates and nitrites – possibly due to the decrease of the daylight period.

Table 9. Nitrates and nitrites percentage calculated for the NFT-cultivated lettuce

Type of fertilization	Cultivar	mg NO_2^- / kg	mg NO_3^- / kg
Organic fertilization	Markies	0,69	138,1
	Lollo bionda	0,39	99,3
	Lollo rosa	0,41	93,6
Chemical fertilization	Markies	0,83	177,6
	Lollo bionda	0,66	163,2
	Lollo rosa	0,68	161,6

4. Conclusions

In an overall regard over the obtained results, we can notice that the NFT-cultivated lettuce variants have differentiated feedbacks as to various fertilizers. The result analysis and statistical apprehension have shown that, irrespective of the cultivated lettuce variants and irrespective of the genetic specificity, the organic fertilization is significantly superior to the control variant, with mineral fertilization, for all studied indices. The Markies cultivar (which is a lettuce variety cultivated for its head) had a special growth and development in comparison with leaf lettuce such as Lollo bionda and Lollo rosa. This growth and development specificity has shown a clearer influence of fertilizers used for Markies in comparison with Lollo bionda and Lollo rosa. Consequently, irrespective of the analysed index, variants organically fertilized are significantly superior to the control variant.

5. Acknowledgements

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