Australian Journal of Crop Science AJCS

AJCS 12(03):386-392 (2018) ISSN:1835-2707
doi: 10.21475/ajcs.18.12.03.pne761

Production of lettuce genotypes in hydroponic system using different organo-mineral nutrient solutions

Antonio Fernandes Monteiro Filho[1], Carlos Alberto Vieira de Azevedo[2*,4], Márcia Rejane de Queiroz Almeida Azevedo[1], Josely Dantas Fernandes[1], Severina de Sousa[3], Élida Barbosa Correa[1], Trycia Neroyldes Farias[1], Pedro Dantas Fernandes[2,5]

[1]State University of Paraíba, Center of Environmental and Agrarian Sciences, Lagoa Seca, 58.117-000, Paraíba, Brazil
[2]Federal University of Campina Grande, Academic Unit of Agricultural Engineering, Campina Grande, 58.429-140, Paraíba, Brazil
[3]Federal University of Campina Grande, Academic Unit of Food Engineering, Campina Grande, 58.429-140, Paraíba, Brazil
[4]Fellow of CNPq Research Productivity, level 1B, Brazil
[5]Fellow of CNPq Research Productivity, level 1A, Brazil

***Corresponding author: cvieiradeazevedo@gmail.com**

Abstract

Mineral solutions are widely used in hydroponic cultivation but little is known about the use of organo-mineral solutions. With this focus, the present study aimed to evaluate the production of three green-leaf lettuce genotypes (Thaís, Vanda and Verônica) in eight nutrient solutions, in NFT hydroponic system, set up in gutters. Four mineral solutions were used in this experiment, referred to as the respective names of the authors (Bernardes, Furlani, Castellane and Araújo, and Ueda). Moreover, four organo-mineral solutions (using biofertilizers in their formulation) were applied, totally eight nutrient solutions. The experiment was carried out in randomized blocks in split plots with three replicates. The main plots consisted of eight nutrient solutions and three lettuce cultivars were assigned in subplots (including six plants per subplot). Lettuce production was evaluated 25 days after transplanting, through the determination of shoot fresh phytomass (SFP), root fresh phytomass (RFP), shoot dry phytomass (SDP) and root dry phytomass (RDP). Production variables were not influenced by the interactive effect of the studied factors. Individually, the nutrient solutions influenced the production parameters and there was variation among the lettuce cultivars only for root fresh phytomass. Higher commercial production of lettuce was obtained with the mineral solutions of Bernardes, Furlani, and Castellane and Araújo.

Keywords: *Lactuca sativa,* L.; biofertilizer, agronomic indices.
Abbreviations: NFT_Nutrient Film Technique; T1_mineral nutrient solution of Bernardes (1997); T3_mineral nutrient solution of Furlani (1995); T5_mineral nutrient solution of Castellane and Araújo (1994); T7_mineral nutrient solution of Ueda (1990); T2_organo-mineral nutrient solution of Bernardes (1997); T4_organo-mineral nutrient solution of Furlani (1995); T6_organo-mineral nutrient solution of Castellane and Araújo (1994); T8_organo-mineral nutrient solution of Ueda (1990); BIO1_biofertilizer used in the organo-mineral solution of Bernardes (1997); BIO2_biofertilizer used in the modified solution of Furlani (1995); BIO3_biofertilizer used in the organo-mineral solution of Castellane and Araújo (1994); BIO4_biofertilizer used in the organo-mineral solution of Ueda (1990); TH_cultivar Thaís; VA_cultivar Vanda; VE_cultivar Verônica; SFP_shoot fresh phytomass; RFP_root fresh phytomass; SDP_shoot dry phytomass; RDP_root dry phytomass.

Introduction

A large area of Northeast of Brazil is located in the semi-arid region, characterized by low and irregular rainfall in most of its areas (Silva et al., 2011). In the 'Brejo Paraibano' region, the water situation is aggravated by limited water storage sources despite having higher rainfall levels. The local populations in this region exclusively depend on family farming, among which lettuce is the most cultivated crop (Santos et al., 2011).

The lettuce crop (*Lactuca sativa* L.) has undeniable importance for human diet, being exploited in the entire national territory due to its pleasant taste, low cost and nutritional quality, since it is rich in vitamins, minerals and fibers. It is the most popular vegetable among those whose leaves are eaten raw and still fresh (Fernandes et al., 2002; Cometti et al., 2004; Helbel Junior et al., 2007).

Seasonality of production, depends on climate, land as a production factor among others, being peculiar characteristics of the agricultural sector that limit food production and increase the risks of rural activities. Vegetable production is an advantageous agricultural activity, when practiced under adequate environmental conditions and close to marketing centers. Hence, it is essential to seek new alternatives of cultivation and technologies that contribute to the increase of yield (Araújo et al., 2009).

Food production in hydroponic systems stands out in Brazil and in various countries as an alternative to increase the yield of different crops (Ohse et al., 2001). Many studies have already been carried out with the hydroponic cultivation of lettuce, such as Paulus et al. (2010), Paulus et al. (2012), Alves et al. (2011), Santos et al. (2011) and Sarmento et al. (2014). Nonetheless, all refers to the use of mineral nutrient solutions, especially that of Furlani (1995). There are few studies relating the use of organic or organo-mineral solutions for lettuce growth and production in a hydroponic system.

Recently, studies have been carried out to substitute the use of mineral fertilizers in nutrient solution composition (totally or partially) using alternative sources that are more economic and available in rural properties (Charoenpakdee, 2014). Dias et al. (2009), recommended the use of biofertilizers as substitution to mineral nutrient solutions due to their high nutritional composition. Sikawa and Yakupitiyage (2010) indicated that there is a great potential in using pond in hydroponic production of lettuce.

Biofertilizer is one of the main organic inputs being used in agroecological systems. But the lack of information for standardization limits its application, since each crop has a specific nutritional requirement, which is not taken into consideration during the preparation (Lovatto et al., 2011).

According to Ribeiro et al. (2007), it is feasible to use organo-mineral solutions based on biofertilizer in the hydroponic cultivation of lettuce. However, the great challenge to formulate such solution is the calculation to balance the nutrients, because the inorganic ingredients have macro- and micronutrients at different concentrations.

Since there is little information on the use of organic fertilizers in hydroponics, this study aimed to evaluate the cultivation of three green-leaf lettuce cultivars in the NFT hydroponic system, with different mineral and organo-mineral nutrient solutions.

Results and discussion

Root fresh and dry phytomass production

Production variables were not influenced by the interactive effects of the studied factors. Individually, the nutrient solutions influenced ($p < 0.01$) the production parameters and there was variation among the lettuce cultivars only for root fresh phytomass ($p < 0.05$), according to the results of the analysis of variance (Table 1).

Regarding root fresh phytomass (Fig. 1), the cultivar Verônica was outstanding (39.63 g plant^{-1}), while the cultivar Vanda showed the smallest root system (35.30 g plant^{-1}) and the cultivar Thaís showed intermediate value (36.24 g plant^{-1}). However, there was no significant difference between the latter and the cultivar Verônica. Evaluating different cultivars of green-leaf lettuce in hydroponic cultivation, Blat et al. (2011) also found superiority of the cultivar Verônica regarding root fresh phytomass (27.2 g plant^{-1}) in comparison to the cultivars 'Belíssima' and 'Pira Roxa', which showed mean values of 18.9 and 16.9 g plant^{-1}, respectively.

The mineral solutions of Bernardes (T_1) and Furlani (T_3) favored higher root fresh phytomass. The lowest results were observed using the other nutrient solutions (Fig. 2A).

Regarding the root fresh phytomass, we compared solutions with the same chemical composition and we observed better performance in root fresh phytomass using Bernardes mineral (T_1) over Bernardes organo-mineral (T_2), Furlani mineral (T_3) over Furlani organo-mineral (T_4) and Ueda mineral (T_7) over Ueda organo-mineral (T_8), respectively.

The lowest mean values of root dry phytomass were obtained with the use of organo-mineral solution, except the treatments with Furlani mineral (T_3) and organo-mineral (T_4) solutions, in which the roots did not differ for phytomass. Kawamura-Aoyama et al. (2014) and Shinohara et al. (2011), studied the utilization of organic nutrient solutions in the production of lettuce and observed lower values of root dry matter in lettuce plants cultivated in mineral solution, compared to the organic solutions. This fact can be associated with the components of the solutions, because these authors worked with 100% organic solutions, whereas in the present study the modified solutions were organo-mineral (biofertilizer + mineral fertilizer). According to Rosa et al. (2009), higher dry matter accumulation in the roots of plants cultivated with organic solutions may be related to the bioactivity of humic substances, which may have auxinic effect on the plants and with activation of H^+-ATPase of the plasmatic membrane. Activation of H^+-ATPase promotes electrochemical gradient of H^+, favoring the acidification of the apoplast, which leads to the rupture of bonds of the cell wall, promoting its elasticity and cell growth.

Shoot fresh and dry phytomass production

The highest values of shoot fresh phytomass were observed in plants that received the mineral solutions of Bernardes (T_1), Furlani (T_3) and Castellane and Araújo (T_5) (Fig. 2C), whose mean values corresponded to 223.50, 190.20 and 145.80 g plant^{-1}, respectively. With the corresponding organo-mineral solutions, in which organic substances were added, there was a decrease in shoot fresh phytomass. Since plant shoots are of greater interest in lettuce marketing, cut close to the soil, shoot fresh phytomass is the most important variable. Cultivation of plants under organo-mineral solution of Ueda (T_8) resulted in lettuce with lower weight (40.21 g plant^{-1}) (Fig. 2C).

Considering the hydroponic cultivation of lettuce with the solution of Furlani, the shoot fresh phytomass results of the present study do not corroborate with Alves et al. (2011) or Paulus et al. (2010), who found mean values of 339.55 and 359.60 g plant^{-1}, respectively. The inconsistency between the data of this research and above mentioned authors may be attributed to the temperature record during the experiment because, while these authors observed mean values lower than 34 ºC, the temperatures inside the greenhouse in the present study were higher than 36 ºC during 65% of the evaluation period, reachin maximum of 38 ºC. Blat et al. (2011), harvested 179.20 g lettuce plant^{-1}. They also pointed out that high temperature (maximum mean values of 37 ºC) is an important factor in the reduction of production.

Table 1. Analysis of variance for root fresh phytomass (RFP), root dry phytomass (RDP), shoot fresh phytomass (SFP) and shoot dry phytomass (SDP) as a function of different green-leaf lettuce cultivars and nutrient solutions.

Source of variation	DF	Mean square			
		RFP[1]	RDP[2]	SFP[3]	SDP[4]
Solution (S)	7	5.74**	0.308*	2.95**	7.15**
Block	2	2.05ns	0.072ns	0.04ns	0.44ns
Residual (a)	14	0.72	0.082	0.12	0.15
Cultivar (C)	2	0.48*	0.015ns	0.04ns	0.21ns
S x C	14	0.16ns	0.042ns	0.04ns	0.21ns
Residual (b)	32	0.14	0.027	0.03	0.29
CVa (%)		13.96	20.09	7.56	14.56
CVb (%)		6.23	11.51	3.90	20.03
Overall mean (g)		37.11	2.10	118.01	7.56

*Significant ($p < 0.05$); **Significant ($p < 0.01$); nsNot significant; CV = coefficient of variation; [1, 2, 3 and 4]Data transformed to $\frac{x^{0.28}-1}{0.28}$, √x, ln (x) and $\frac{x^{0.32}-1}{0.32}$, respectively.

Table 2. Chemical composition of the biofertilizers used to prepare the modified nutrient solutions.

Nutrients	Biofertilizer			
	BIO1	BIO2	BIO3	BIO4
	------------------------ mg L^{-1} ------------------------			
NH_4^+	14.144	34.787	12.800	7.284
NO_3^-	0.004	0.010	0.004	0.004
P	56.350	66.855	14.009	4.036
K	14.807	23.050	79.124	35.710
Ca	14.807	23.083	24.708	7.748
Mg	181.844	21.059	33.220	94.800
Zn	0.158	0.259	0.269	0.078
Fe	0.884	2.328	1.300	0.493
Mn	0.197	0.044	0.241	0.100
Cu	0.016	0.038	0.027	0.013

BIO1, BIO2, BIO3 and BIO4 - biofertilizers used, respectively, in the modified solutions of Ueda, Castellane and Araújo, Furlani, and Bernardes.

Table 3. Quantities of fertilizers used to prepare 1000 L of the nutrient solutions.

Fertilizers	Unit	Nutrient solutions (treatments)							
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Biofertilizer	L	0.0	998.1	0.0	498.6	0.0	920.7	636.7	0.0
$(NH_4)_2SO_4$	g	76.1	10.6	50.0	0.0	45.2	0.0	0.8	22.0
$Ca(NO_3)_2.6H_2O$	g	1185.9	1098.9	1200.0	1132.3	938.8	884.5	94.5	123.5
KNO_3	g	71.7	145.1	420.3	433.9	751.6	783.4	222.8	198.4
KCl	g	481.4	296.3	235.7	154.6	147.2	52.9	0.0	0.0
$CuSO_4.5H_2O$	g	0.1	0.0	0.2	0.1	0.3	0.2	0.0	0.0
$ZnSO_4.7H_2O$	g	0.1	0.1	0.6	0.2	0.7	0.4	0.0	0.0
$MnSO_4.H_2O$	g	1.3	0.8	2.4	2.4	1.5	1.2	1.6	1.8
$MgSO_4.7H_2O$	g	370.2	179.6	116.0	28.1	163.3	44.3	0.0	44.3
Tank water	L	997.7	0.0	997.8	499.4	997.8	77.2	362.8	999.6
$(NH_4)_6Mo_7O_{24}.4H2O$	g	0.0	0.0	0.3	0.3	0.1	0.1	0.1	0.1
H_3BO_3	g	2.91	2.81	2.1	2.0	2.9	2.8	3.0	3.1
MAP	g	118.9	107.3	52.3	39.1	102.1	93.4	9.2	13.4

$(NH_4)_2SO_4$- ammonium sulfate; $Ca(NO_3)_2.6H_2O$- calcium nitrate; KNO_3- potassium nitrate; KCl- potassium chloride; $CuSO_4.5H_2O$- copper sulfate; $ZnSO_4.7H_2O$- zinc sulfate; $MnSO_4.H_2O$- manganese sulfate; $MgSO_4.7H_2O$- magnesium sulfate; $(NH_4)_6Mo_7O_{24}.4H_2O$- ammonium molybdate; H_3BO_3- boric acid; MAP- monoammonium phosphate; T1, T3, T5 and T7 are the mineral solutions of Bernardes, Furlani, Castellane and Araújo, and Ueda, respectively; T2, T4, T6 and T8 are the organo-mineral solutions of Bernardes, Furlani, Castellane and Araújo, and Ueda, respectively

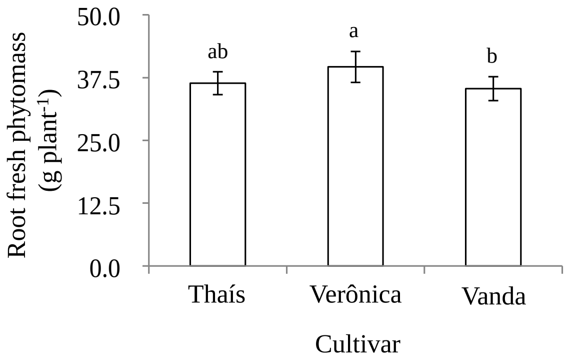

Fig 1. Root fresh phytomass as a function of the isolated effect of the different cultivars. Vertical bars represent the standard error of the mean.

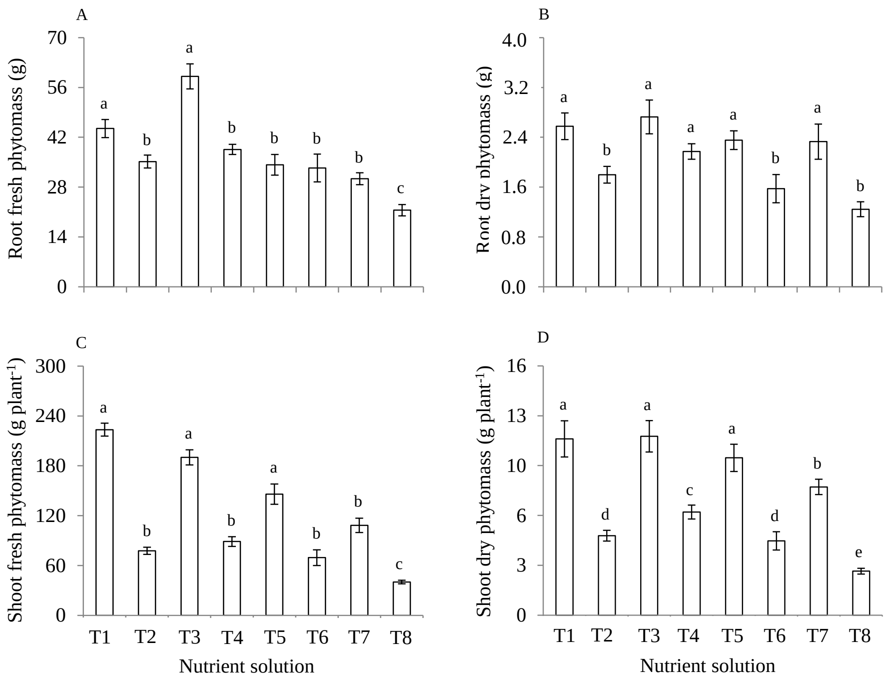

Fig 2. Fresh (A and C) and dry (B and D) phytomasses of lettuce roots and shoots, respectively, as a function of the different mineral nutrient solutions of Bernardes (T1), Furlani (T3), Castellane and Araújo (T5) and Ueda (T7), and of the organo-mineral nutrient solutions of Bernardes (T2), Furlani (T4), Castellane and Araújo (T6), and Ueda (T8). Vertical bars represent the standard error of the mean.

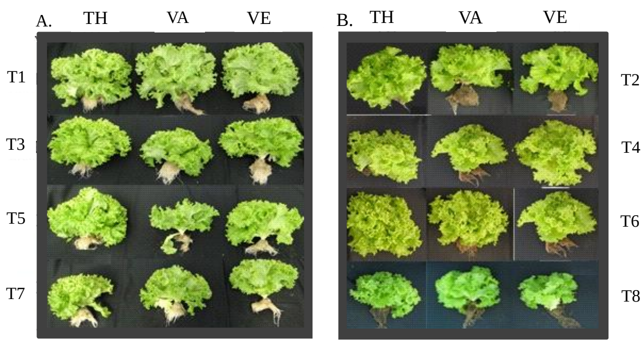

Fig 3. Photographs of plants of the cultivars Thaís (TH), Vanda (VA) and Verônica (VE) subjected to different mineral nutrient solutions (A): Bernardes (T1BM), Furlani (T3FM), Castellane and Araújo (T5CM), and Ueda (T7UM), and to different modified nutrient solutions (organo-mineral) (B): Bernardes (T2), Furlani (T4), Castellane and Araújo (T6), and Ueda (T8).

According to Feltrim et al. (2009), lettuce plants accumulate less fresh matter in the shoots, when there is thermal stress by high temperatures, because the plant transpires too much, causing a large reduction in the production of organic compounds (Sousa Neto et al., 2010).

Although the organo-mineral solutions promote lower shoot fresh phytomass, the mean value per plant was obtained in Furlani organo-mineral solution (T_4) (88.84 g), similar to that 98.69 g was found by Dias et al. (2009), using the mineral solution of Furlani. A similar result was also observed for the Castellane and Araújo organo-mineral solution (T_6), whose production of 73.27 g surpassed the 56.12 g plant^{-1} obtained by Testolin et al. (2014), using fish farming water complemented with 100% of the recommendation of micronutrients proposed by the solution of Castellane and Araújo (1994).

There were lower values of shoot fresh phytomass with the use of the organo-mineral nutrient solutions, comparing solutions with similar chemical composition, i.e., Bernardes mineral (T_1) with Bernardes organo-mineral (T_2), Furlani mineral (T_3) with Furlani organo-mineral (T_4) and so on.

The use of mineral and organo-mineral nutrient solutions resulted in the highest and lowest mean values of shoot dry phytomass, respectively (Fig. 2D). In decreasing order, the values corresponded to 11.48, 11.31, 10.09, 8.23, 6.62, 5.10, 4.77 and 2.82 g plant^{-1} with the use of the treatments T_3, T_1, T_5, T_7, T_4, T_2, T_6 and T_8, respectively. Similar behavior was observed by Gallo et al. (2016), studying the hydroponic production of lettuce using mineral and organo-mineral nutrient solutions, the latter composed of phytoplankton extract. The mean values obtained using modified nutrient solutions were higher than those reported by Sikawa and Yakupiyiyage (2010), who found 0.9, 2.76 and 1.6 g plant^{-1}, cultivating lettuce with nutrient solution composed of water from catfish farming, in three types of substrate: polystyrene sheets, crushed stone and sand, respectively. Brum et al. (2011), using the solution of Castellane and Araújo, found mean value of 5.11 g plant^{-1}, while Paulus et al. (2010) obtained shoot dry phytomass of 12.16 g plant^{-1} of lettuce cultivar Verônica in the Furlani solution. On the other hand, Luz et al. (2010), using nutrient solution with 50, 75, 100 and 125% of the concentration proposed by Furlani, obtained values of 11.33, 13.66, 14.70 and 11.37 g plant^{-1}, respectively. The reason for the lower productions of shoot fresh phytomass and shoot dry phytomass using the organo-mineral solutions may be associated with the adsorption of nutrients by organic compounds, reducing the supply of the respective ions to the plants, at a level not equivalent to that of mineral solutions. Such information corroborates with Monteiro Filho et al. (2014). Dias et al. (2009) observed reductions of 95.59% and 92.25% in shoot fresh and shoot dry phytomasses of lettuce, respectively, with the treatment of 100% biofertilizer instead of 100% mineral using nutrient solution of Furlani. According to the authors, such behavior is related to the slow release of ions from the exchange complex, which comes from organic substances still undergoing mineralization and the low nutritional content of the biofertilizers. In addition, the nutrients coming from organic fertilizers typically contain complex molecules, such as proteins, which need to be decomposed into its constituent elements before being absorbed by the plants. Besides bovine manure, the modified solutions used in the present study contained poultry blood and milk, ingredients that are rich in proteins and probably were not totally decomposed during the biodegradation process, which also contributed to the lower shoot fresh phytomass and shoot dry phytomass, compared to the mineral solutions. It should be highlighted that the predominant form of N in liquid organic fertilizers is the ammonium ion (NH_4^+); thus, before being injected in the hydroponic system, it must undergo oxidation to nitrite and then to nitrate (Treadwell et al., 2007). The absence of nitrification of the biofertilizers observed in the present study is evidenced by the high NH_4^+ concentration (Table 2), which can be an explanation for the lower results obtained with the organo-mineral solutions. The lower production observed using organo-mineral solutions, compared to the mineral, can also be related to the supply of nutrients that are essential to the crop, because the solutions had the same electrical conductivity (1.5 dS m^{-1}). Therefore, it is not possible to evaluate the actual contribution of the organic fraction to the electrical conductivity.

In general, plants were in good external state, with no signs of nutritional deficiency, regardless of the utilized solution (Fig. 3).

Materials and methods

Experiment location and conduction

The experiment consisted of cultivation of 3 green-leaf lettuce cultivars in 8 nutrient solutions in hydroponic system. We adopted the nutrient-film technique (NFT), carried out in a protected environment (greenhouse) at the Center of Agricultural and Environmental Sciences of the State University of Paraíba, located in the city of Lagoa Seca, Paraíba, Brazil, at the following geographic coordinates: 7° 10′ 15″ S, 35° 51′ 14″ W. The mean temperature in the greenhouse was 35.2 ºC.

The experiment tested four mineral nutrient solutions formulated with chemical fertilizers according to the methodology of Bernardes (1997), Furlani (1995), Castellane and Araújo (1994), and Ueda (1990), referred to as T_1, T_3, T_5 and T_7, respectively. The other four solutions were organo-mineral, formulated from the mixture of biofertilizers and chemical fertilizers with chemical compositions similar to those of the previously mentioned, resulting in the organo-mineral nutrient solutions of Bernardes (T_2), Furlani (T_4), Castellane and Araújo (T_6), and Ueda (T_8). The quantities of chemical fertilizers and biofertilizers used in the formulation of the nutrient solutions are described in Table 3. The experiment was set up in randomized blocks in split plots, with three replicates. Plots contained the eight nutrient solutions (T_1-T_8) and subplots contained the green-leaf lettuce cultivars: Thaís, Verônica and Vanda. Plants were cultivated in gutters spaced by 0.30 m, with spacing of 0.30 m also between plants. The subplot had 6 plants of each cultivar.

Preparation of organo-mineral nutrient solutions

The organo-mineral nutrient solutions were prepared by formulating four biofertilizers, according to the methodology proposed by Fernandes et al. (2011), obtaining mixtures of organic ingredients with chemical compositions similar to those suggested by Bernardes (1997), Furlani (1995), Castellane and Araújo (1994), and Ueda (1990) in their mineral solutions. These biofertilizers were referred to as BIO1, BIO2, BIO3 and BIO4, respectively. The ingredients were bovine manure, bovine milk, blood of poultry raised in the Center of Agricultural and Environmental Sciences of the State University of Paraíba state, and molasses, purchased in the market of Campina Grande city, Paraíba state.

After formulation, the ingredients were mixed and diluted in 30 L of rainwater. To promote the action of aerobic microorganisms, compressed air was injected in the biofertilizers using an air compressor for 30 days, which ensured a dissolved oxygen concentration close to 2.0 mg L^{-1}. The water in the tank was analyzed and the following results were obtained: electrical conductivity = 0.239 dS m^{-1}; pH = 7.3; in mg L^{-1}: Ca^{++} = 48.4; Mg^{++} = 6.4; ($CaCO_3$) = 147.5; K^+ = 21.7; Cl^- = 33.4; Na^+ = 4.7; Total Fe = 0.01; SO_4^- = 3.3; P = 0.0; NO_3^- = 0.75 and NH_4^+ = 0.15.

The results of the chemical analyses of the biofertilizers based on dry matter was conducted at the Laboratory of Soil, Water and Plant, of the Agricultural Research Company of Rio Grande do Norte-EMPARN (Table 2).

Since the results of the chemical characterization of the biofertilizers were inferior to the nutritional concentrations recommended by Bernardes (1997), Furlani (1995), Castellane and Araújo (1994), and Ueda (1990), mineral fertilizers were used in complementation, constituting the organo-mineral nutrient solutions.

Planting, nutrient solution calibration and analyzed production parameters

Green-leaf lettuce seedlings were produced in phenolic foam, according to the methodology described by Monteiro Filho et al. (2014).

The nutrient solutions were supplied into the gutters after daily calibration with water and stock nutrient solutions according to the treatments, to maintain a volume of 17 L in the tank, electrical conductivity of 1.5 dS m^{-1} and pH close to neutrality, with the use of a solution of NaOH or H_2SO_4 (1 mol L^{-1}).

Lettuce production was evaluated 25 days after transplanting, through the determination of shoot fresh phytomass (SFP), root fresh phytomass (RFP), shoot dry phytomass (SDP) and root dry phytomass (RDP), after drying the samples in forced-air oven at 60 ºC, until constant weight.

Statistical analysis

The data of production parameters were subjected to analysis of variance by F-test at 0.01 and 0.05 probability levels. When significant effect was observed in the analysis of variance, the means obtained in the different treatments were compared by the tests of Scott-Knott (nutrient solutions) and Tukey (cultivars), both at 0.05 probability level. For normality purposes, the data of RFP, RDP, SFP and SDP were transformed to: $\frac{x^{0.28}-1}{0.28}$, $\sqrt{x}$, ln (x) and $\frac{x^{0.32}-1}{0.32}$, respectively. The statistical software used was Sisvar (Ferreira, 2014).

Conclusion

Higher commercial production of lettuce was obtained with the mineral solutions of Bernardes, Furlani and Castellane and Araújo. Regardless of the nutrient solution, no visual signs of lack or toxicity were observed in the lettuce plants. Lettuce production using modified solutions with electrical conductivity above 1.5 dS m^{-1} should be evaluated. The biofertilizer used to prepare the solutions must be maintained under adequate time and condition for decomposition of composition and also for the nitrification process to occur.

Acknowledgments

The authors thank the State University of Paraíba, for its contribution through the PROPESQ program to conduct this research.

References

Alves MS, Soares TM, Silva LT, Fernandes JP, Oliveira, MLA, Paz VPS (2011) Estratégias de uso de água salobra na produção de alface em hidroponia NFT. Rev Bras Eng Agríc Ambient. 15: 491–498.

Araújo JS, Andrade AP, Ramalho CI, Azevedo CAV (2009) Características de frutos de pimentão cultivado em ambiente protegido sob doses de nitrogênio via fertirrigação. Rev Bras Eng Agríc Ambient. 13: 152-157.

Bernardes LJH (1997) Hidroponia da alface: uma história de sucesso. São Paulo,Estação Experimental de Hidroponia "Alface e Cia".

Blat SF, Sanchez SV, Araújo JAC, Bolonhezi D (2011) Desempenho de cultivares de alface crespa em dois ambientes de cultivo em sistema hidropônico. Hortc Bras. 29: 135-138.

Brum B, Lopes SJ, Torck LS, Silveira TR, Toebe M, Santos PM (2011) Tamanho da semente e acúmulo de fitomassa seca de folhas de alface hidropônica em duas épocas de cultivo. Rev Ciênc Agra. 39: 64–68.

Castellane PD, Araújo JAC (1994) Cultivo sem solo: hidroponia. Jaboticabal, FUNEP.

Charoenpakdee S (2014) Using animal manure to grow lettuce (*Lactuca sativa* L.) in a Homemade Hydroponics System. KKU Res. J. 19: 256-261.

Cometti NN, Matias GCS, Zonta E, Mary W, Fernandes MS (2004) Compostos nitrogenados e açúcares solúveis em tecidos de alface orgânica, hidropônica e convencional. Hortic Bras. 22: 748-753.

Dias NS, Brito AF, Sousa Neto ON, Lira RB, Brito RF (2009) Produção de alface hidropônica utilizando biofertilizante como solução nutritiva. Rev Caatinga. 22:1 58-162.

Feltrim AL, Cecilio Filho AB, Rezende BLA, Branco, RBF (2009) Produção de alface-crespa em solo e em hidroponia, no inverno e verão, em Jaboticabal-SP. Rev Ciênc Agra. 37:9-15.

Fernandes AA, Martinez HEP, Pereira PRG, Fonseca MSM (2002) Produtividade, acúmulo de nitrato e estado nutricional de cultivares de alface, em hidroponia, em função de fontes de nutrientes. Hortic Bras. 20:195-200.

Fernandes JD, Monteiro Filho AF, Chaves LHG, Gonçalves CP, Cruz MP (2011) Formulação de biofertilizante utilizando a ferramenta Solver do Microsoft Office. Rev Verde Agroecol Desenv Sustenta. 6: 101-105.

Ferreira DF Sisvar: (2014) A Guide for its Bootstrap procedures in multiple comparisons. Ciênc Agrotec. 38:109-112.

Furlani PR (1995) Cultivo de alface pela técnica de hidroponia – NFT Campinas, IAC,18p. (IAC, Documentos 55).

Gallo F, Rodrigues C, Borba A, Ramos JB, Azevedo EB, Madruga J (2016) Growth and chemical composition of hydroponically cultivated Lactuca sativa using phytoplankton extract. Int J Agron Agric Res. 8: 125-134.

Helbel Junior, C.; Rezende R, Frizzone JA, Santos HS, Dallacort R (2007) Produção hidropônica da cultura da alface com soluções nutritivas e vazões distintas. Acta Sci Agron. 29: 391-395.

Kawamura-Aoyama C, Fujiwara K, Shinohara M, Takano M (2014) Study on the hydroponic culture of lettuce with solid food waste as a nitrate source. Jap Agric Res Quart. 48:71-76.

Lovatto PB, Watthier M, Schiedeck G, Schwengber JE (2011) Efeito da urina de vaca como biofertilizante líquido na produção orgânica de mudas de couve (*Brassica oleracea* var. *acephala*). Hortic Bras. 29: 4571- 4577.

Luz JMQ, Fagundes NS, Silva MAD (2010) Produção hidropônica de alface dos tipos mimosa e romana em diferentes concentrações de solução nutritiva. Biosci J. 26: 195-201.

Monteiro Filho AF, Pereira GL, Azevedo MRQA, Fernandes JD, Azevedo CAV (2014) Cultivo hidropônico de cultivares de alface em soluções nutritivas organo-minerais otimizadas com a ferramenta SOLVER. Rev Bras Eng Agríc Ambient. 18: 417–424.

Ohse S, Dourado Neto D, Manfron PA, Santos OS (2001) Qualidade de cultivares de alface produzidos em hidroponia. Sci Agric. 58: 181-185.

Paulus D, Dourado Neto D, Frizzone JA, Soares TM (2010) Produção e indicadores fisiológicos de alface sob hidroponia com água salina. Hortc Bras. 28: 29-35.

Paulus D, Paulus E, Nava GA, Moura CA (2012) Crescimento, consumo hídrico e composição mineral de alface cultivada em hidroponia com águas salinas. Rev Ceres. 59: 110-117.

Ribeiro K, Ferreira E, Costa MSSM, Gazolla D, Szimanski C. (2007) Uso de biofertilizante no cultivo de alface hidropônica. Rev Bras Agroec. 2: 1600-1603.

Rosa CM, Castilhos RMV, Vahl LC, Castilhos DD, Pinto FS, Oliveira ES, Leal OA (2009) Efeito de substâncias húmicas na cinética de absorção de potássio, crescimento de plantas e concentração de nutrientes em *Phaseolus vulgaris* L. Rev Bras Ciênc Solo. 33: 959-967.

Santos D, Mendonça RMN, Silva SM, Espínola JEF, Souza AP (2011) Produção comercial de cultivares de alface em Bananeiras. Hortc Bras. 2: 609-612.

Sarmento JDA, Morais PLD, Almeida MLB, Sousa Neto ON, Dias NS (2014) Qualidade e conservação da alface cultivada com rejeito da dessalinização, Rev Caatinga. 27: 90 – 97.

Shinohara M, Aoyama C, Fujiwara K, Watanabe A, Ohmori H, Uehara Y, Takano M (2011) Microbial mineralization of organic nitrogen into nitrate to allow the use of organic fertilizer in hydroponics. J Soil Sci Plant Nutr. 57: 190-203.

Sikawa DC, Yakupitiyage A (2010) The hydroponic production of lettuce (*Lactuca sativa* L) by using hybrid catfish (Clarias macrocephalus×C. gariepinus) pond water: Potentials and constraints. Agr water manage. 97: 1317-1325.

Silva VPR, Pereira ERR, Azevedo PV, Sousa FAZ, Sousa IF (2011) Análise da pluviometria e dias chuvosos na região Nordeste do Brasil. Rev Bras Eng Agríc Ambient. 15: 131-138.

Sousa Neto ON, Dia NS, Terumi AR, Rebouças JRL, Oliveira AM (2010) Produção de alface hidropônica e microclima de ambiente protegido sob Malhas termo-refletoras. Rev Caatinga. 23: 84-90.

Testolin G, Manfron PA, Alves VC, Marques TA, Rampazo ÉM, (2014) Avaliação da alface hidropônica usando água de piscicultura misturada com diferentes porcentagens de soluções nutritivas. Bioener Rev: Diálogos. 4: 23-34.

Treadwell D, Hochmuth GJ, Hochmuth RC, Simonne EH, Davis LL, Laughlin WL, Li Y, Olczyk T, Sprenkel RK, Osborne LS (2007) Nutrient management in organic greenhouse herb production: Where are we now? Hort Technol. 17: 461-466

Ueda S. (1990) Hidroponia: guia prático. São Paulo, Agroestufa.