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Kale (*Brassica oleracea* L. var *acephala*) production in soilless systems in the Mediterranean region

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Abstract

The challenges faced by traditional agriculture led to the development of alternative agricultural systems such as soilless systems. This work aimed to assess the growth and yield components of kale under three soilless growing systems: Nutrient film technique set up vertically (T-vertical); Nutrient film technique set up horizontally (T-horizontal), and substrate coco bags (T-coco). The trials were conducted for two consecutive growing seasons (S1: Spring 2018 and S2: Fall 2019) in an unheated greenhouse. Irrigation supply, maximum plant uptake of water, and radiation use efficiency were evaluated for both seasons. The quantitative and qualitative parameters of the production were assessed in terms of yield (kg per plant and kg per m^2), number of leaves per plant, dry matter, protein content, nitrate level and leaf mineral composition. The main results showed that the maximum plant uptake was 0.30, 0.30 and 0.20 L m^{-2} day^{-1} respectively for T-vertical, T-horizontal and T-coco while the actual supply of water was 62.4, 32.28 and 3.27 L m^{-2} day^{-1}, respectively. A significant difference was recorded for the number of leaves, yield components, dry matter, protein level, Radiation Use Efficiency and mineral composition of kale leaves was higher during fall than in the spring season. However, the nitrates level was much higher in spring than in fall. The T-vertical soilless system showed better yield (6.83±2.27 kg per m^2), more proteins (2.53±0.31 g per100 g FW), and higher amounts of calcium (Ca), total nitrogen (N), manganese (Mn), and iron (Fe) than the other systems. The study demonstrated the potential of soilless production technologies in the coastal Mediterranean areas.

Key words: Kale, *Brassica oleracea* L. var *acephala*, soilless systems, yield, qualitative parameters, quantitative parameters.

Introduction

Traditional agriculture in different parts of the world is facing huge problems and challenges such as extreme drought (Putra and Yuliando, 2015), soil degradation, water scarcity (Fitton *et al.*, 2019; Gruda, 2019), increasing world population and rising urbanization (Guenther, 2019; Lal, 2013; Lehman *et al.*, 1993) affecting current agricultural systems. In the Mediterranean countries, poor agricultural practices adopted in greenhouse production are leading to lower crop yields, quality and economic return. Farmers are irrigating with low quality water (De Pascale *et al*., 2013) and mismanaging fertilizers applications which cause soil salinization and decreased crop yields (Atallah *et al*., 2000; Darwish *et al*., 2005; Solh *et al*., 1987). In addition, they are applying uncontrolled quantities of pesticides (Gruda *et al*., 2013) resulting in a lot of residues -in soils and in crops- which can pose serious danger to human health and also can affect adversely the environment. Repeated natural drought conditions have also amplified this phenomenon even though in this region, and in the last several decades the processes of greenhouse production have greatly expanded to reach the area of 3900 hectares (Ruijs, 2017). Considering such harsh environmental conditions and the lack of space due to increased urbanization that often translate into limited farming opportunities, the livelihood of farmers within the coastal region must be improved through the introduction of new crops and adopting new agricultural technologies that bring innovation to the sector. For this reason, crops such as kale (*Brassica oleracea* L., var *acephala*), recently introduced to the Lebanese market, is considered an excellent source of antioxidants and phytonutrients and a salt tolerant crop that can be adapted to the new agricultural technologies such as soilless systems.

The cultivation of Kale is traditionally known by the populations in North Turkey, the Pyrenean Peninsula, the south east of USA and coastal parts of Croatia (Ayaz *et al*., 2006; Velasco *et al*., 2007; Olson and Freeman, 2007; Batelja *et al*., 2009). It is one of the highest-quality brassicas in terms of chemical composition where young tender leaves are used for human consumption and older leaves as fodder crop (Cartea *et al*., 2002). In the remote and poor areas of Portugal, kale was to substitute milk (Monteiro and Rosa, 2008) because of its high protein and calcium content in the leaves.

Compared with soil-based cultivation, soilless production offers numerous advantages (Gül, 2017) and can be more cost-effective (Grafiadellis *et al*., 2000) by increasing the productivity (Olle *et al*., 2012; Tüzel *et al*., 2019) and improving the product quality (Putra and Yuliando, 2015), even in areas with adverse growing conditions (Grillas *et al*., 2001). A number of authors reported that tuning over the soil to hydroponics led to a decrease in the application of pesticides (Savvas, 2003) and to better control the water and fertilizer use efficiencies (Putra and Yuliando, 2015; Tüzel *et al*., 2019). Recently, soilless cultivation is intensively used as a "major technological component in the modern greenhouse industry" (Savvas and Gruda, 2018) and many researches have mainly focused on the optimization of nutrient solution concentration comparing to yield and other quality components (Giuffrida and Leonardi, 2012; Kiani, 2020).

In Lebanon, there are no local studies and little is known about the potential of using soilless systems that are often developed using imported or locally available material. Therefore, the overall objective of this study resides in assessing soilless systems initiatives as a solution to the encountered environmental and urban problems in the coastal areas of Lebanon. The specific objectives are to assess the performance of three soilless systems on the production of kale in terms of yield components, dry matter and mineral composition.

Materials and methods

Study location and plant material: The greenhouse experiment on three soilless growing systems was conducted for 2 consecutive seasons: season 1 (S1- spring 2018) from January till July 2018 and season 2 (S2- fall 2019) from September 2018 till July 2019, in Tabarja, located on the coastal area of Lebanon (Latitude: 34° 1' 37" N, Longitude: 35° 37' 31" E and 10 m altitude). Kale (*Brassica oleracea* L. var. *acephala*) was chosen for the experiment where seeds of kale were obtained from "HARRIS SEEDS" – New York, USA and fresh plants (30 days old) were transplanted on 19 Jan, 2018 for S1 and 26 Sept, 2018 for S2 inside an unheated greenhouse.

Experimental design and growth conditions: For each season, plants were grown in three treatments corresponding to the different soilless systems. The treatments were following: i) T-vertical: Nutrient film technique set up in vertical system; ii) T-horizontal: Nutrient film technique set up in horizontal system; and iii) T-coco: Substrate coco bags. The experimental layout was a completely randomized design with 3 treatments (soilless systems) and three replicates per treatment. For the T-vertical and T-horizontal, the nutrient film technique (NFT) system consisted of rigid PVC pipe channels (4-inch diameter and 6 m long) with continuous recirculation of the nutrient solution (closed system). The pipe channels were placed 25 cm apart and were able to maintain 29 plants each. Therefore, in the horizontal treatment, the plant density was 10.4 seedlings m^{-2} while in the vertical one, it was 20.3 seedlings m^{-2}. Each treatment replicate consisted of 14 channels. Concerning irrigation supply for T-vertical and T-horizontal, each channel was watered through two emitters of 75 L h^{-1} each. Each irrigation cycle had a duration of 1 minute. In total, 36 watering cycles were necessary each day. For the T-coco treatment, the substrate bags contained a mixture of coco peat and coir fiber that supports the crop. The bags (1 m length x 0.25 m width x 0.1 m depth) were led on a steel structure and placed on telescopic legs following a slope of around 2 % and placed 40 cm above the ground. Each treatment replicate consisted of 2 rows of bags, each row occupying 9 m length, with plants placed at 25 cm distance. Consequently, the total number of plants per replicate was 72 and the planting density was 2.70 seedlings m^{-2}. Regarding the irrigation supply, each coco bag was watered with 4 drippers (one dripper per plant), each dripper has a capacity of 2 L h^{-1}. Each irrigation cycle consisted of applying water for a period of 3.5 minutes. In total, 7 irrigation cycles were completed each day.

All the parameters related to the estimation of irrigation supply rates for the three soilless systems are provided in Table 1.

Table 1. Parameters on irrigation supply rates for the different systems

Parameter	Unit	T-vertical	T-horizontal	T-coco
Irrigation duration	min $cycle^{-1}$	1	1	3.5
number of cycles/day	cycles day^{-1}	36	36	7
Emitter capacity	L h^{-1} (per plant)	5.18	5.18	2
Emitters per m^2	m^{-2}	-	-	4
Capacity per m^2	L m^{-2} h^{-1}	104	53.8	8
Irrigation rate	L m^{-2} min^{-1}	1.73	0.90	0.13
Irrigation supply	L m^{-2} $cycle^{-1}$	1.73	0.90	0.47
Irrigation supply	L m^{-2} day^{-1}	62.40	32.28	3.27

Nutrient solution: All the treatments were covered with the same nutrient solution (NS) prepared according to the plant's growth stage with a constant value of pH=5.5 and an electrical conductivity EC=1.1 dS cm^{-1}. The nutrient solution (NS) concentration used for both growing seasons was obtained as a product of different chemicals mixed with water in a way to provide all the plant needs (Table 2). The concentration of each element is presented in Table 2.

Maximum uptake rates: Maximum plant uptake of water was used as criteria to evaluate the irrigation supply of the growing systems. The maximum plant uptakes expressed per hour were based on general plant physics and literature studies. Using general plant physics it was found that plant water uptake at maximum will equal the amount of incident radiation energy (Janka *et al*., 2016; Steppe *et al*., 2008). The maximum inside radiation level during seasons S1 and S2 were 328 and 314 W m^{-2}, respectively, which corresponded to 1.18 and 1.13 M Jm^{-2} h^{-1}, respectively. Transpiration of 25 ^{o}C water requires a heat of evaporation of 2.4 MJ L^{-1}. Dividing the maximum inside radiation by 2.4 MJ L^{-1} renders a maximum water uptake of 0.49 and 0.47 L m^{-2} h^{-1}, for S1 and S2, respectively. Using findings from literature studies, it was found that plant water uptake was reported to be 0.5 L h^{-1} m^{-2}

Table 2. Composition of the nutrient solution (NS) during both growing seasons

	EC, pH and major elements									
Recipe	EC	pH	NH_4	K	Ca	Mg	NO_3	SO_4	HCO_3	HPO_4
Units (mmole L^{-1})	1.1	5.5	0.27	1.2	1.1	0.4	3.5	0.4	-	0.27
	Trace elements									
Recipe	Fe	Mn	Zn	B	Cu	Mo				
Units (µmole L^{-1})	18.7	3.7	3.6	7.5	0.6	0.031				

around noon in early April for tomato (Kläring and Zude, 2009; Nederhoff and De Graaf, 1993). Combining both approaches in our study, maximum water uptake was set at 0.5 L m^{-2} h^{-1}.

Data collection and measurements

Climatic parameters and nutrient solution: The daily means of air temperature (°C), relative humidity (%) and indoor solar radiation (MJ m^{-2} day^{-1}), inside the greenhouse during the consecutive growing seasons were collected at the plant level, recorded on a data logger system and connected to a personal laptop.

Quantitative parameters: The quantitative aspects of kale (*Brassica oleracea* L.var. *acephala*) were evaluated for the spring and the fall seasons under three growing soilless systems. Fresh Kale leaves collected at maturity stage were put in plastic bags, and transported to the Soil, Plant, and Water Laboratory of the Holy Spirit University of Kaslik (USEK) for analyses. Representative and evenly distributed leaves with a stem width at the widest point were sampled from five plants per replicate. Different measurements were conducted on harvested kale leaves such as total yield (kg per plant and kg per square meter), number of leaves per plant and dry weight. Fresh leaves from each replicate (500 g approximately) were washed with clean water to remove dirt, chopped finely and dried in an oven at 65 °C, for 24 h. for further analyses. Moisture were calculated while expressing the data on fresh weight basis.

Growth comparison: To account for differences in plant density, growth comparisons were based on growth per unit radiation received using Radiation Use Efficiency (RUE). RUE, was defined as plant dry weight at the end of the cultivation in gram per plant divided by the incident radiation sum in MJ PAR per plant. Solar light sums per day were calculated using the nearby weather station 5-min data. The solar radiation was taken to include 45 % PAR of which 70 % was transmitted into the greenhouse as incident PAR. The incident PAR was expressed per plant and then summed over the growing period.

Qualitative parameters

Mineral leave analysis: The sampled leaves from both seasons were analyzed for macro nutrients including total nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca) and micro nutrients including, iron (Fe), zinc (Zn), manganese (Mn), cupper (Cu) and sodium (Na) as well as total proteins. Total nitrogen and protein content were determined after mineralization of kale leaves with sulfuric acid by "Regular Kjeldahl method" (Bremner, 1965) using AOAC "Official methods of analysis", method 976.06 (calculation coefficient Nx6.25). Phosphorus was evaluated by the method of absorption spectrophotometry (Pinta, 1968), potassium concentration were determined with Sherwood Model 410 flame photometer following the method F-008A (Sherwood Scientific Ltd, 1 The Paddocks, Cherry Hinton Road, Cambridge - CB1 8DH, UK) while other the concentrations of different minerals (Mg, Ca, Fe, Zn, Mn Cu and Na) were determined using an inductively coupled plasma emission spectrometer (Liberty 200 ICP AES, Varian, Australia).

Nitrate content: For the determination of nitrate, Cataldo method was used where complex formed by nitration of salicylic acid under highly acidic conditions absorbs maximally at 410 nm in basic solutions (Cataldo *et al*., 1975).

Statistical analysis: Each dependent variable was preliminarily evaluated for normal distribution and homogeneity of variance according to Kolmogorov–Smirnov test and Bartlett's test, respectively. Two-way ANOVA was used to evaluate the effect of different treatments (Season and soilless systems) and their interactions for all other parameters. Due to the non-normal distribution of RUE, a non-parametric analysis was carried out for this parameter by applying Scheirer–Ray–Hare Test. This analysis was carried out using the software package rcompanion in R studio software [R Core Team,2013]. The package is available *via.* the Comprehensive R Archive Network (CRAN, https://cran.r-project.org).

The Tukey's Test at 0.05 probability level was calculated to test the significance of the difference between means. Parametric statistical analyses were performed through the GLM procedure of SAS University Edition (Cary, NC, USA).

Results and discussion

Irrigation supply: For the three considered soilless systems, the actual supply of water surpassed the maximum plant uptake with an actual supply of 62.4 L m^{-2} day^{-1}, 32.28 L m^{-2} day^{-1} and 3.27 L m^{-2} day^{-1}, respectively for T-vertical, T-horizontal and T-coco, while the maximum plant uptakes, calculated on the basis of estimated value of 0.5 L m^{-2} hr^{-1} as previously described, were 0.30 L m^{-2} day^{-1}, 0.30 L m^{-2} day^{-1} and 0.20 L m^{-2} day^{-1}, respectively for T-vertical, T-horizontal and T-coco (Table 3). At some point, such result was expected because it is well known that soilless systems require considerable overcapacity in water supply to ensure that all plant positions receive enough water to meet the maximum plant uptake, especially that root growth may prevent the water movement from one plant to another. Furthermore, the considered uptake rate of 0.5 L m^{-2} hr^{-1}, is valid only for a defined radiation level, as taken from literature studies. In reality, this level depends highly on greenhouse light supply (more natural light and or extreme artificial light supply may show a higher transpiration level as will greenhouses with more transparent decks). In addition, water uptake increases in the greenhouse when transpiration rise due to high flow of hot dry air (Janka *et al*., 2016; Steppe *et al*., 2008; Vermeulen *et al*., 2012).

Table 3. Supply rates and maximum plant uptakes

Parameter	Unit	T-vertical	T-horizontal	T-coco
Water supply	$L.m^{-2}.day^{-1}$	62.40	32.28	3.27
Water uptake	$L.m^{-2}.day^{-1}$	0.30	0.30	0.20

Finally, the obtained result shows that more research is needed for further optimization of the irrigation supply rate by adjusting the duration of watering per cycle or by reducing the number of irrigation cycles per day.

Quantitative parameters: The results related to the analysis of variance and mean comparisons for number of leaves per plant, marketable yield, dry matter percentage and radiation use efficiency (RUE) of kale grown under different soilless systems for both seasons are presented in Table 4.

Considering the season as the source of variance, there was a significant difference, at $P \leq 0.05$, for all the considered parameters with higher mean values for the fall than for the spring

Table 4. Effect of different soilless systems on yield, yield components, dry matter and Radiation Use Efficiency (RUE) on Kale grown in spring and fall seasons

Source of variation	Number of leaves/plant ± SD	Yield kg/plant ± SD	Yield kg/m^2±SD	Dry matter (%)± SD	RUE g/MJ* ± SD
Season (S)	***	****	****	****	****
Spring	46.87±11.37 b	0.56±0.28 b	3.26±1.53 b	7.46±0.41 b	2.58±1.22 b
Fall	60.96±17.00 a	0.91±0.56 a	4.97±2.75 a	10.52±0.75 a	8.62±5.77 a
Treatments (T)	****	****	****	ns	****
T-vertical	41.80±6.42 c	0.39±0.10 c	6.83±2.27 a	9.04±1.43	2.81±1.49 c
T-horizontal	48.37±9.35 b	0.54±0.13 b	3.28±1.05 b	8.73±1.48	3.83±2.04 ab
T-coco	71.57±11.51 a	1.28±0.41 a	2.54±0.65 c	9.21±2.28	10.16±6.64 a
S x T	ns	ns	ns	ns	ns

ns: Not significant, *: significant at $P \leq 0.05$. Means followed by different letter in each column are significantly different according to the Tukey multiple comparisons test (P=0.05).

season. In fact, the mean values of the number of leaves per plant, the marketable yield (as kg per plant and kg m^{-2}), the dry matter and RUE were 60.96±17.00 leaves per plant, 0.91±0.56 kg per plant, 4.97±2.75 kg m^{-2}, 10.52±0.75 % and 8.62±5.77 g MJ^{-1}, respectively for the fall season compared to the mean values of 46.87±11.37 leaves per plant, 0.56±0.28 kg per plant, 3.26±1.53 kg m^{-2}, 7.46±0.41 % and 2.58±1.22 g MJ^{-1}, respectively for the spring season.

Considering the treatment as the source of variance, the treatment T-coco was significantly higher than the other treatments in terms of number of leaves per plant, the marketable yield per plant and the RUE with values of 71.57±11.51 leaves per plant, 1.28±0.41 kg per plant and 10.16±6.64 g MJ^{-1}, respectively. Particularly, the number of leaves per plant in T-coco was 48 % and 71 % significantly higher than in T-horizontal and T-vertical. The yield per plant in T-coco was 137 % and 228 % significantly higher than in T-horizontal and T-vertical. The RUE was 165 % and 261 % significantly higher than in T-horizontal and T-vertical. Such differences in growth comparisons are directly related to the plant density in different soilless system.

However, the yield (kg m^{-2}) was 108 and 169 % significantly higher in T-vertical than T-horizontal and T-coco. According to Barrett *et al*. (2016), coco peat tends to have a higher water holding capacity comparing to NFT systems. The obtained results are in agreement with the findings of Wortman (2015), who recorded a total yield corresponding to an average of 0.826 kg per plant of kale in NFT. Moreover, Chandra *et al*. (2014) obtained an average yield of field grown red kale equivalent to 0.272 kg per plant and a yield of 0.450 kg per plant in aeroponic grown kale.

The dry matter content of kale leaves analyzed in the present study ranged between 7.46±0.41 % for the spring season and 10.52±0.75 % for the fall season. However, no significant difference was found between the considered treatments. Comparing to existing studies in literature for kale cultivated in soil, Sikora and Bodziarczyk (2012) found dry matter percentage ranging from 16.75 to 17.39 %. Similarly, Lisiewska *et al*. (2008) obtained, for different varieties of kale cultivated in soil, values between 17.7 and 18.08 %. Furthermore, Emebu and Anyika (2011) found that kale has a moisture content of 81.38 %. Although in soilless systems, the dry matter content is expected to be higher; however, in our study the dry matter content was lower and this may be due to the nutrition solution and EC levels (Asaduzzaman *et al.*, 2015).

Mineral composition of kale leaves

Macro elements: Total N, K, Ca and Mg had higher mean values in the fall season than the spring season while the P content was found 62 % higher in spring than in fall season. However, no significant difference was found between the two seasons. The mean values of the N content (g in 100g Fresh weight (FW)), K and Ca (mg in 100 g FW) and Mg (µg in 100 g FW) were 0.39±0.05, 20.58±3.14, 0.31±0.04 and 24.23±3.27, respectively for the fall season compared to the mean values of 0.35±0.03,

Table 5. Macro elements Composition of kale under different treatments

Source of variation	Total N g/100g FW± SD	P mg/100g FW± SD	K mg/100g FW±SD	Ca mg/100g FW± SD	Mg microg/100g FW± SD
Season (S)	**	***	****	****	****
Spring	0.35±0.03 b	3.33±0.63 a	14.04±1.18 b	0.21±0.02 b	16.65±2.50 b
Fall	0.39±0.05 a	2.05±0.67 b	20.58±3.14 a	0.31±0.04 a	24.23±3.27 a
Treatments (T)	*	ns	ns	**	ns
T-vertical	0.40±0.05 a	2.72±1.34	17.46±3.60	0.27±0.05 a	20.58±4.47
T-horizontal	0.38±0.04 a	2.49±0.55	16.26±4.05	0.24±0.03 b	19.11±3.00
T-coco	0.33±0.04 b	2.85±0.81	17.73±5.19	0.28±0.08 a	21.63±6.79
S x T	ns	ns	ns	***	ns

ns: Not significant, *: significant at $P \leq 0.05$. Means followed by different letter in each column are significantly different according to the Tukey multiple comparisons test (P=0.05).

14.04±1.18, 0.21±0.02 and 16.65±2.50, respectively for the spring season (Table 5).

T-vertical showed a significant higher value for total N with an average of 0.40±0.05 g in 100 g of fresh weight compared to 0.38±0.04 for T-horizontal and 0.33±0.04 for T-coco systems. These values are higher than those given by Fallovo *et al.* (2009) who found a mean concentration of N in lettuce grown in floating raft culture equivalent to 0.0051 g in 100 g. The T-coco treatment was significantly higher than the other treatments in terms of Ca content with 17 % and 4 % more than in T-horizontal and T-vertical. However, there was no significant difference between the three considered treatments for the P, K and Mg content which showed an average of 2.68±0.9 mg, 17.15±4.28 mg, and 20.44±4.75 mg/100g FW respectively. Our findings in terms of P content are lower than those reported by USDA (2018), with 55 mg in 100g of fresh raw leaves of kale, and those found in the study of (Miller-Cebert *et al*., 2009) that revealed 320 mg of phosphorus in 100 g of edible parts. However, Fallovo *et al*. (2009) showed an average value of phosphorus equivalent to 0.54 mg in 100g of Fresh Weight (FW) in lettuce leaves. Regarding the calcium (Ca) content, our values are much lower than those reported by Miller-Cebert *et al*. (2009) and the USDA Food Composition Database (2018) who found an average of 470 mg and 254 mg in 100 gram of fresh weight respectively. In addition a study done by Fadigas *et al*. (2010), revealed that the average Ca contents in Kale in winter were 551 mg in 100 g of fresh weight compared to 535 mg in the summer. Concerning the potassium (K) and the magnesium (Mg) contents, the values were 46 % and 45 % respectively higher in fall season than spring season which are in accordance with Fadigas *et al*. (2010), who showed an average of 117 mg of Mg for the winter comparing to 106 mg in 100 g fresh weight for summer. Although Emebu and Anyika (2011), stated a mean value equivalent to 7.03 mg for K and 6.69 for Mg in 100 g of FW while the USDA (2018) values are equivalent to 348 mg/100 g of fresh weight (K) and 0.92 mg/100 g of fresh kale (Mg). Moreover, Fallovo *et al.* (2009), showed a mean concentration of K and Mg in lettuce leaves grown in floating raft culture equivalent to 6.67 and 0.58 mg respectively in 100 g of FW during summer season while others revealed a higher values equivalent to an average of 1840 mg of K and 190 mg of Mg in 100 g of fresh weight (Miller-Cebert *et al*., 2009).

Micro elements: Considering the season as the source of variance, there was a significant difference, at $P \leq 0.05$, for micro elements (Fe, Mn and Na) with higher mean values for the fall in comparison with the spring season. The mean values of the Fe, Mn and Na content (µg per 100 g Fresh weight (FW)) were 1.18±0.13, 0.77±0.10 and 39.66±5.73, respectively for the fall season compared to 0.95±0.20, 0.58±0.06 and 36.52±21.01, respectively for the spring season (Table 6). No significant difference was observed for the Zn and Cu content in both seasons. The Fe, Mn and Na contents were approximately 24 %, 33 % and 9 % significantly higher in the fall than in the spring season.

Considering the treatment as the source of variance, the treatment T-vertical was significantly higher than the other treatments in terms of Fe, Zn and Mn content with values of 1.20±0.20, 0.31±0.09 and 0.77±0.14 µg per 100 g FW, respectively (Table 6). Particularly, the Fe content in kale in T-vertical was 24 % and 19 % significantly higher than in T-horizontal and T-coco. The Zn content in T-vertical was 7 % and 15 % significantly higher than in T-horizontal and T-coco and the Mn content was 22 % significantly higher than in both T-horizontal and T-coco. However the T-coco treatment had a higher value in Na content (55.44±14.34 µg per 100 g FW) compared to T-horizontal and T-vertical with 29.97±6.54 and 32.02±6.86 µg per 100 g FW respectively which are much lower than those found in USDA (2018) with an average of 53000 µg per 100 g FW in kale leaves (Table 6). According to the USDA Food Data Central, kale showed a mean value of 1600 µg for Fe, 390 µg for Zn and 920 µg for Mg per 100 g of fresh kale leaves. However Hall (2009), obtained a Fe value equivalent to 1700 µg and 440 µg for Zn per 100 g of fresh kale leaves while Emebu and Anyika (2011) reported a value of 8940 µg for Fe and 2160 µg per 100 g for Zn in 100 g of FW. Finally, 7650 µg of Fe, 1450 µg of Zn and 2470 µg of Mn in 100 g of FW was found in fresh kale leaves in other study (Miller-Cebert *et al*., 2009).

Our results are in agreement with those obtained with Fadigas *et al*. (2010) who declared that kale leaves collected during winter time have a higher concentration of macro and micro nutrients (Zn, Mn) compared to those cultivated during summer. No significant difference between treatments was observed for Cu content with a mean value of 0.04 µg per 100 g FW in all treatments while the USDA (2018) value showed 0.053 mg per 100 g fresh weight in kale leaves.

Total proteins and nitrate: There was a significant difference in the proteins level between the two seasons with more proteins recorded in the fall season (2.48±0.35 g in 100 g FW kale leaves) than the spring season (2.16±0.17 g in 100 g FW kale leaves) (Table 7). Our results concur with the USDA Food Composition

Table 6. Micro elements composition (µg in 100g FW) of kale under different treatments during both seasons.

Source of variation	Fe	Zn	Mn	Cu	Na
Season (S)	**	ns	****	ns	*
Spring	0.95±0.20 b	0.30±0.10	0.58±0.06 b	0.04±0.01	36.52±21.01 b
Fall	1.18±0.13 a	0.28±0.04	0.77±0.10 a	0.05±0.01	39.66±5.73 a
Treatments (T)	*	ns	***	ns	****
T-vertical	1.20±0.20 a	0.31±0.09	0.77±0.14 a	0.04±0.01	32.02±6.86 b
T-horizontal	0.97±0.11 b	0.29±0.04	0.63±0.10 b	0.04±0.00	29.97±6.54 b
T-coco	1.01±0.22 ab	0.27±0.08	0.63±0.08 b	0.04±0.01	55.44±14.34 a
S x T	ns	ns	ns	ns	****

ns: Not significant, *: significant at $P \leq 0.05$. Means followed by different letter in each column are significantly different according to the Tukey multiple comparisons test (P=0.05).

Databases (2018) where fresh kale showed a level of 2.92 g of proteins per 100 g fresh weight. Considering the treatment as the source of variance, the T-vertical treatment showed a mean value of proteins equal to 2.53±0.31 g in 100 g of FW compared to 2.36±0.24 g for the T-horizontal and the lowest value was obtained with T-coco treatment and equal to 2.08±0.22 g in 100 g of fresh weight. The proteins level in T-vertical coco was 7 % and 22 % significantly higher than in T-horizontal and T-coco (Table 7).

Regarding the nitrates level, the value in the spring season is 341 % higher than the fall season (172.82±49.66 mg in the spring compared to 39.21±26.00 mg in 100 g FW in the fall season). Considering the treatment as source of variance, no significant difference was observed between the different systems (Table 7). In general, nitrate levels in all treatments and seasons were under the maximum level in foodstuffs as provided by the European Commission regulations (No 1258/2011) of 2500-3500 mg/ kg. Comparing to a study done in Iran on 11 types of vegetables, the average of nitrate concentration of 2 seasons varied between 16.1 mg in 100g for cabbage, 78.1 mg in 100 g for lettuce and 170.2 mg NO_3 in 100 g for fumitory (Nowrouz *et al*., 2012). Another study done in Republic of Macedonia reported an average value of nitrate content in cabbage of 14.15 mg in 100 g (Kirovska-Cigulevska, 2016). The lower nitrate levels observed in the fall cultivation might have resulted from the low average temperature and light intensity which affected negatively the activity of nitrate reductase (Kojima *et al*., 1995).

Table 7. Total proteins (g in 100 g FW) ± SD and nitrate content (mg in 100 g FW) ± SD in kale leaves under different soilless treatments during 2 consecutive seasons

Source of variation		Total Proteins (g in 100 g FW) ± SD	Nitrates (mg in 100 g FW) ± SD
Season (S)		**	****
	Spring	2.16±0.17 b	172.88±49.66 a
	Fall	2.48±0.35 a	39.21±26.00 b
Treatments (T)		**	Ns
	T-vertical	2.53±0.31 a	104.53±51.95
	T-horizontal	2.36±0.24 a	114.22±87.45
	T-coco	2.08±0.22 b	99.38±103.09
S x T		ns	ns

ns: Not significant, *: significant at $P \leq 0.05$. Means followed by different letter in each column are significantly different according to the Tukey multiple comparisons test (P=0.05).

This study revealed that kale planted during fall season has a higher product yield, dry matter, proteins level and leaf mineral composition compared to the spring season however the T-vertical showed better yield, more proteins and higher amounts of minerals among other treatments. Further studies on the quantity parameters as well as the quality parameters are needed for the coming growing season to evaluate and present more conclusive results. It is essential also to develop more studies regarding the efficiency of water-usage.

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