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Amelioration of an open soilless cultivation system for microgardening spinach (*Spinacia oleracea* L.)

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Abstract

The objective of this study was to develop an open soilless culture system with high water and nutrient use efficiency, and low emission in the environs for microgardening high quality spinach. For this purpose, spinach (*Spinacia oleracea* L.) was grown in containers with soilless media supplemented with organic and inorganic nutritional sources. The experiment was laid out in a complete randomized design with four replications. Seven growing media were assessed: peat moss, peat moss combined with 150, 200 and 250 ppm ammonium nitrate (NH_4NO_3), and peat moss amended with compost having nitrogen equivalent to the mentioned NH_4NO_3 concentrations. Scheduled and quantified irrigation was provided with a sprinkler system to conserve water and minimize emission into the environment. Salt accumulation and pH of media was monitored throughout growing period. Spinach leaves were analyzed for total soluble solids, titratable acidity, ripening index, total nitrogen, total organic carbon, carbon to nitrogen ratio, fresh biomass, dry biomass, dry matter (mg g^{-1} fresh biomass), leaf moisture contents, nitrate content, colorimetric traits (lightness, chromacity and hue angle), ascorbic acid, total flavonols and anthocyanins and antioxidant capacity. Among all media, combinations of peat moss with NH_4NO_3 resulted in less nitrate, more organic carbon and dry matter (mg g^{-1} fresh biomass), higher total soluble solid contents and ripening index of the plants. A higher flavonoid content and higher antioxidant capacity were also observed in plants grown in these combinations. Further, these media accumulated less salt and maintained optimum pH level for spinach growth.

Key words: agro-pollutant, city farming, soilless culture, spinach, sphagnum peat moss.

Introduction

By 2050, the world's population is likely to reach nine billion that will result in an increased demand for food and considering the effects of climate change, the challenge to feed the population will be a chimera. During the past few decades, the request for proliferated food production to meet these demands has intensified the use of fertilizers that are contaminating the soil and underground water. Consequently, numerous health issues in humans and animals have surfaced especially due to the development of modern diagnostic techniques. Hence, regulations about reducing the emissions of nutrients and pesticides to soil and groundwater have been adopted in Europe and other developed countries (Van Os et al., 2012). Besides agro-pollutants, human health is at risk in areas where soil with poor texture, high pathogen infestation and unsuitable rhizosphere are constraints in good quality vegetable production.

On commercial scale, to counter these problems, soilless cultural techniques are the established alternative production systems. Soilless substrates have been shown to be beneficial in fruit, vegetable and ornamental crop production. Addition of compost to root media increases the antioxidant activity of spinach and Chinese cabbage (Ren et al., 2001). Compost enhances antioxidant activity, leaf nitrate reductase activity and chlorophyll content of well-fertilized strawberries. In addition, use of compost increases levels of organic acids (malic and citric acid), sugars (fructose, glucose and total sugars), soluble solids content and titratable acids content in strawberry fruit (Wang, Lin, 2002). Similarly, lettuce plants harvested from perlite or pumice culture had a higher titratable acidity, total nitrogen, phosphorus and potassium content than the plants grown on the soil culture (Siomos et al., 2001). Many researchers have observed higher sugar, soluble solids, vitamins and carotenoids content in tomatoes grown in soilless culture systems compared to soil (Gruda, 2009). However, most of the soilless techniques are not feasible for the microgarden system, where small areas such as balconies, backyards and small gardens can be utilized to grow herbs, vegetables and flowers for self-supplying to some extent that ensure access of nutritional diet to the people. Microgardens provide simple, low-budget and easy to manage soilless culture technology to urban or resources-poor rural families especially in developing countries (Orsini et al., 2013). Therefore, microgarden system based on soilless technology could increase the domestic availability of healthy food and may be practiced at sub-optimal climatic and soil conditions by efficiently managing the nutrients supply.

Closed soilless system is zero emission cultural techniques but their high installation cost and sophisticated running and maintenance make them unsuitable for microgardening. On the other hand, open soilless systems are commonly used for vegetable and ornamental crops, as their management is simple but high emission of water and nutrients causes the contamination of soil and underground water and also increases the running costs. Moreover, the pollution due to microgardens near the living places could be unsafe for the residents in nearby areas. Therefore, a modified open soilless culture technique based on low emission system should be developed to cultivate green leafy vegetables. As nitrogen is the most important limiting nutrient especially for the production of green leafy vegetables and has to be applied generously, the emission of nitrogen containing compounds becomes a serious environmental problem. To solve these issues, soilless technologies such as bag, container or vertical cultures could be modified to cultivate green leafy vegetables. Containers such as pots have certain benefits for microgardeners that include low cost, easy availability, portability during adverse weather condition, easy storage when no crop is being grown and utilizing the water and nutrient resources efficiently, hence, preventing the soil and water contamination.

Nitrogen being the most important nutrient for the production of green leafy vegetables if excessively applied in microgardens, costs more and leads to the bioaccumulation of nitrate in spinach that may be hazardous. Therefore, an on-field trial was set to optimize the quantity and source of nitrogen and to develop a low emission open soilless system for the pot cultivation of hazard free good quality spinach at microgarden.

Material and methods

A low emission soilless pot technique was developed for the cultivation of spinach during the year 2011 at the University of Natural Resources and Life Sciences, Vienna, Austria. For this purpose, pots with 30 cm diameter and 7.5 litres volume were used. Sphagnum peat moss served as the basic growing medium, whereas either compost or ammonium nitrate (NH_4NO_3) was supplied as organic and inorganic sources of nitrogen, respectively. A slightly decomposed peat moss was supplied by Floragard Vertriebs GmbH (Germany) and had the following characteristics: pH 5.5 to 6.0, electrical conductivity (EC) 0.2 to 0.5 dS m^{-1}, redox potential 260 to 265 mV, NPK fertilizer (18-10-20) 0.8 kg m^{-3}. The compost had the following characteristics: pH 7.5 to 7.75, EC 0.5 to 0.6 dS m^{-1}, redox potential 190 to 195 mV, carbon to nitrogen ratio (C:N) of 17:1. Aqueous NH_4NO_3 (33% N) was used as an inorganic source of nitrogen. The experiment was laid out in a completely randomized design with seven treatments replicated four times. Sphagnum peat moss was used as the only growing medium for the pots where NH_4NO_3 had to be the primary source of nitrogen. Three concentrations of N (150, 200 and 250 ppm) were supplied as 500 ml of NH_4NO_3 solutions twice a week to check the nutrient leaching and maintain a steady nutrient concentration in the root zone. Amount of compost was adjusted to nitrogen equivalent of NH_4NO_3 concentrations. Control treatment was not supplied with either NH_4NO_3 or compost. The treatment combinations are presented in Table 1.

Table 1. Various combinations of the growing medium and nitrogen sources

Labels	Treatments
Peat	peat moss
AmN150	peat moss + NH_4NO_3 150 ppm
AmN200	peat moss + NH_4NO_3 200 ppm
AmN250	peat moss + NH_4NO_3 250 ppm
CompN150	peat moss + compost equivalent to 150 ppm N
CompN200	peat moss + compost equivalent to 200 ppm N
CompN250	peat moss + compost equivalent to 250 ppm N

Seeds of spinach (*Spinacia oleracea* L.) cv. ‘Metador’ were sown directly in pots. After one week of germination, plants were thinned to three per pot. To minimize the nutrient emission from the pots, sprinkler system was used to daily irrigate the plants till the media was wet. Moreover, three weeks after sowing, all pots were fertigated with P and K and at the same time, the fertigation with NH_4NO_3 to the selected pots started. Spinach leaves were harvested at physiological maturity when they were ready to be consumed as food and analyzed for their quality for human consumption.

Salinity and acidity of the media. Aqueous extracts of the media were obtained by 1:1.5 dilution method to monitor salt accumulation and pH of the media. EC and pH of the media were observed at sowing time, six weeks after sowing and at harvest time.

Growth and physiological measurements. At harvest stage, leaves of the spinach plants were analyzed for their colorimetric properties using tristimulus colorimeter Chroma Meter CR-400 (“Minolta”, Japan). The CIELab scale uses the coordinates L*, a*, b* and determine chromacity (C*) and hue angle (H°) that has been successfully used for the colorimetric evaluation of leaf (León et al., 2007), fruit peel and pulp (Crisosto et al., 2007; Liang et al., 2011), vegetable peel (Gajewski et al., 2008) and flower (Osmani et al., 2009). The L* value indicates the colour appearance parameter of lightness or luminance and ranges from 100 = the perfect white colour to 0 = black. Hue angle (H°) like SPAD reading, gives a rapid and non-destructive estimate of leaf chlorophyll content (León et al., 2007). C* and H° values were derived as suggested by Liang et al. (2011). After harvest, fresh biomass (F_b), dry biomass (D_b), dry matter (D_m) mg g^{-1} fresh biomass and leaf moisture content (LMC) were evaluated.

For the determination of total soluble solids (TSS), titratable acidity (TA), ripening index, ascorbic acid (AA) and nitrate (NO_3) content of the leaves, leaf extract was prepared by blending fresh leaves and differentially centrifuging the slurry for five minutes at 1000 rpm. The supernatant was clarified with 10–20 µm cellulose filter papers (VWR, France) and the filtrate was used for the determinations. TSS content was analyzed with a refractometer and presented as °Brix value (Wang et al., 2007; Tabatabaei et al., 2008). Potentiometric titration of the leaf extract was carried out against 0.1 N NaOH up to pH 8.2 for determining the TA as % oxalic acid per 100 ml of spinach leaf extract (Ergun, Jezik, 2011; Mahmood et al., 2012). Ripening index was calculated by the ratio between TSS and TA. Ascorbic acid content was determined as described by Ruck (1961). Extraction was carried out with 0.4% oxalic acid and the aliquot was titrated against 2,6-dichlorophenolindophenol dye until a faint pink colour appeared. Ascorbic acid was used as standard and the results were expressed as mg ascorbic acid per 100 ml of leaf extract. Analysis of NO_3 was performed by remission photometry method as described by Schmidhalter (2005). A digital reflectometer Reflectoquant RQflex plus ("Merck", Germany) was utilized for this purpose and content were expressed as mg NO_3 per litre of leaf extract.

Total nitrogen (TN) and total organic carbon (TOC) were evaluated with an elemental analyzer CNS ("Elementar", Germany). Leaves were dried at 80°C for 72 hours and then ground to powder using a ball mill. TN (mg g^{-1} D_b) and TOC (mg g^{-1} D_b) were determined and C:N ratio was calculated. Trolox equivalent antioxidant capacity (TEAC) of methanolic plant extracts was determined according to the DPPH method (Brand-Williams et al., 1995) with slight modifications. TEAC values were derived from the standard regression curve and EC_{50} values of Trolox and plant samples were calculated. EC_{50} values of plant samples were compared with reference to Trolox and the results were expressed in µM TE g^{-1} F_b.

Total flanonols and anthocyanins were extracted from the homogenized plant material with 2% (v/v) HCl/methanol solution. Subsequently, the HCl/methanol solution was separated from tissue debris and centrifuged at 14.000 rpm for three minutes. Duplicate determination was carried out by adding 140 µl of the supernatant to 860 µl HCl/methanol solution. Using HCl/methanol as a blank, absorbance of the acidified dilute extract was measured at 360 nm for flavonols and at 520 nm for anthocyanins. Results were expressed as quercetin-equivalents for flavonols and pelargonidin-equivalents for anthocyanins.

Statistical analysis. Using the software *IBM SPSS* (version 19), analysis of variance (ANOVA) was carried out and the main effects were tested using general linear model (GLM) procedure. The treatment means were separated by Duncan's multiple range test at α = 5% and the correlations between the variables were explored using Pearson's correlation coefficient.

Results

Accumulation of salts and pH in the growing medium at harvest indicates nutrient uptake by a plant, salt retention capacity of the medium and therefore the reusability of the medium. Although at sowing time, higher EC values (≈1.7 mS cm^{-2}) were observed for compost amended media compared to EC 1.15 mS cm^{-2} for other media, this gap between EC values almost diminished at harvest (Fig. 1).

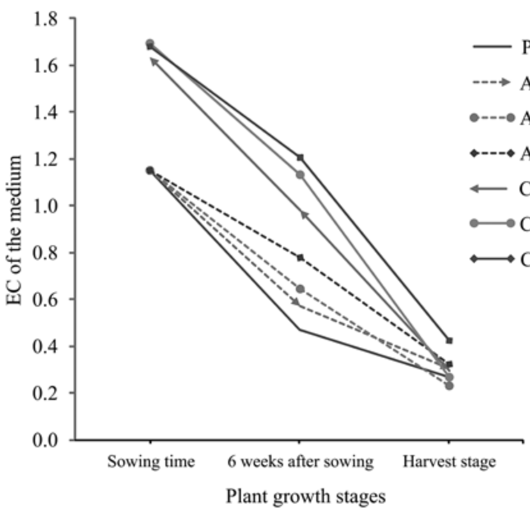

Figure 1. Electrical conductivity (EC) of the media monitored at different stages of spinach cultivation as affected by peat moss and its combination with compost and ammonium nitrate (NH_4NO_3) fertigation

Compost amended media had higher pH (≈7) than the rest of the media (pH = 5.6) but unlike EC, this difference lasted till the harvest (Fig. 2).

Plants grown in peat moss showed the lowest NO_3 content in their leaves, whereas adding compost in peat also increased the NO_3, reaching at the highest level in CompN250 (Table 2). On the contrary, NH_4NO_3 fertigated plants assimilated the highest TN and peat treated plants the lowest. TOC was highest in plants grown with AmN150 and peat. The addition of NH_4NO_3 led to a decrease in TOC, whereas addition of compost led to the lowest TOC. Spinach growing in organic media without NH_4NO_3 showed a significantly higher C:N ratio. Spinach cultivated in peat, AmN150 and AmN250 produced the highest TSS content. The compost amended media led to

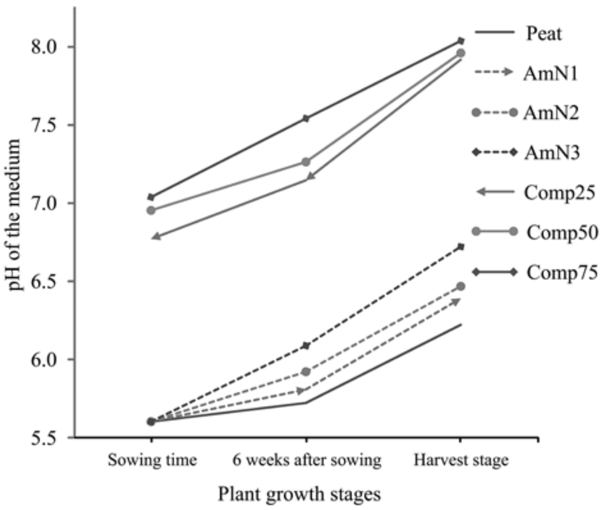

Figure 2. pH of the media monitored at different stages of spinach cultivation as affected by peat moss and its combination with compost and ammonium nitrate (NH_4NO_3) fertigation

a relatively lower TSS. As for titratable acidity, no effect of the treatments was observed. However, AmN150 and peat resulted in the highest ripening indices and CompN150 the lowest. In general, the compost amended media produced lower ripening indices.

Plants grown in compost amended media had significantly higher L* and C* values. No effect of various levels of either compost or NH_4NO_3 was observed. On the contrary, media amended with peat and NH_4NO_3 showed higher H° values than compost. Levels of compost and NH_4NO_3 had no effect on L*, C* and H° tristimulus values (Table 3). Ascorbic acid content was not affected by any of the treatments. The plants grown in peat accumulated 100% or higher flavonols than composted plants and similarly, the plants gown in NH_4NO_3 supplemented media accumulated 77% or higher flavonols than those grown in compost. Increasing the level of NH_4NO_3 reduced the flavonols. Anthocyanins content was not detected in spinach grown in any of the media (data not shown). Plants grown in peat medium

Table 2. Nitrate (NO_3) content, total nitrogen (TN), total organic carbon (TOC), carbon to nitrogen ratio (C:N), total soluble solids (TSS), titratable acidity (TA) and ripening index as affected by different media

Treatments	NO_3 mg L^{-1}	TN mg g^{-1} D_b	TOC mg g^{-1} D_b	C:N	TSS °Brix	TA % oxalic acid	Ripening index
Peat	946 f	34.65 c	403.0 ab	11.65 a	7.25 a	0.128	58.69 a
AmN150	2097 d	56.85 a	412.8 a	7.26 c	7.23 a	0.120	60.70 a
AmN200	1799 e	55.23 a	390.3 c	7.07 c	6.10 b	0.113	54.21 ab
AmN250	2031 d	55.10 a	397.5 bc	7.21 c	6.83 ab	0.127	54.98 ab
CompN150	3263 c	35.78 c	375.3 d	10.50 b	6.23 b	0.140	44.95 c
CompN200	3984 b	47.35 b	376.4 d	7.96 c	6.10 b	0.114	54.32 ab
CompN250	4203 a	36.20 c	376.9 d	10.44 b	5.95 b	0.122	48.78 bc
Probability	***	***	***	***	*	ns	**

Note. Values connected by the same letter within a column are not significantly different at $\alpha = 0.05$; * – $p < 0.05$, ** – $p < 0.01$, *** – $p < 0.001$; ns – non-significant; D_b – dry biomass.

Table 3. Colorimetric traits: lightness (L*), chromacity (C*), hue angle (H°), ascorbic acid (AA), total flavonols and Trolox equivalent antioxidant capacity (TEAC) as affected by different media

Treatments	L*	C*	H°	AA mg 100 mL^{-1}	Flavonols µg mL^{-1}	TEAC µM TE g^{-1} F_b
Peat	33.68 b	14.66 b	179.12 a	137.4	40.22 a	16.36 a
AmN150	34.19 b	15.82 b	179.12 a	147.6	39.59 a	15.88 a
AmN200	32.94 b	14.62 b	179.12 a	126.1	34.58 b	15.23 a
AmN250	33.67 b	14.78 b	179.11 a	117.8	34.89 b	13.30 b
CompN150	37.37 a	18.74 a	179.06 b	123.1	19.53 c	10.08 c
CompN200	37.79 a	20.15 a	179.05 b	120.7	16.74 d	8.86 c
CompN250	37.76 a	19.11 a	179.07 b	129.0	19.02 c	8.42 c
Probability	***	***	**	ns	***	***

Note. Values connected by the same letter within a column are not significantly different at $\alpha = 0.05$; ** – $p < 0.01$, *** – $p < 0.001$; ns – non-significant; F_b – fresh biomass.

showed higher TEAC than those in NH_4NO_3 or compost amended media. Thus, spinach cultivation in peat resulted in a 62% to 94% higher TEAC than in compost. Similarly, the addition of NH_4NO_3 in the media resulted in a 32% to 89% higher TEAC than that of compost.

As presented in Table 4, spinach grown in compost amended media produced the maximum F_b, D_b and LMC, whereas peat treated plants produced the minimum. However, peat medium resulted in the highest D_m (mg g^{-1} fresh biomass), whereas compost in the least D_m.

The statistical correlations between physical, morphological and biochemical quality attributes revealed the linkage between various quality attributes. NO_3 was found to be negatively correlated with TOC, TSS, H°, flavonols, TEAC and D_m, although the relation with TSS was weak. Further, positive correlations of NO_3 with C*, F_b and D_b were evident (Table 5).

Moreover, TOC was found to be positively linked with TSS, and H°, whereas negatively linked with C*, flavonols, TEAC, F_b and D_b. H° was positively related with flavonols, TEAC and D_m, and negatively with F_b and D_b. A positive correlation between flavonols, TEAC and D_m was also evident, whereas both flavonols and TEAC were found to be negatively correlated with C*, F_b and D_b (Table 5).

Table 4. Comparison of means for fresh biomass (F_b), dry biomass (D_b), dry matter (D_m) and leaf moisture content (LMC) affected by different media

Treatments	F_b g	D_b g	D_m mg g^{-1} F_b	LMC %
Peat	91.45 b	11.89 d	131.90 a	86.81 d
AmN150	111.36 b	13.44 cd	124.10 ab	87.59 cd
AmN200	129.78 b	15.21 abcd	116.70 abc	88.33 bcd
AmN250	126.63 b	13.56 bcd	109.90 bcd	89.01 abc
CompN150	176.67 a	18.52 a	104.20 cd	89.58 ab
CompN200	178.92 a	17.34 abc	97.38 d	90.26 a
CompN250	189.64 a	17.46 ab	92.81 d	90.72 a
Probability	***	**	**	**

Note. Values connected by the same letter within a column are not significantly different at $\alpha = 0.05$; ** – $p < 0.01$, *** – $p < 0.001$.

Table 5. Pearson's coefficient of correlations between nitrate (NO_3) content, total nitrogen (TN), total organic carbon (TOC), total soluble solids (TSS), hue angle (H°), total flavonols, Trolox equivalent antioxidant capacity (TEAC), fresh biomass (F_b), dry biomass (D_b), dry matter mg g^{-1} F_b (D_m)

	NO_3	TN	TOC	TSS	H°	Flavonols	TEAC	F_b	D_b
NO_3	–								
TN	ns	–							
TOC	−0.74**	0.42*	–						
TSS	−0.49**	ns	0.49**	–					
H°	−0.67**	ns	0.70**	ns	–				
Flavonols	−0.92**	0.41*	−0.76**	0.49**	0.73**	–			
TEAC	−0.78**	0.66**	−0.79**	0.53**	0.72**	0.83**	–		
F_b	0.77**	ns	−0.67**	−0.78**	−0.70**	−0.77**	−0.73**	–	
D_b	0.63**	ns	−0.55**	−0.45*	−0.46*	−0.68**	−0.57**	0.63**	–
D_m	−0.73**	ns	0.57**	0.65**	0.60**	0.67**	0.58**	−0.78**	−0.55**

* – $p < 0.05$, ** – $p < 0.01$; ns – non-significant at $\alpha = 0.05$

Discussion

Salt accumulation in the media was monitored during the growth of spinach. Low electrical conductivity (EC) of all the media (0.22 to 0.42 mS cm^{-2}) at harvest stage suggests less salt accumulation and efficient nutrients uptake by the plants. The pH of compost amended media reached at 8.0 at harvest, whereas a good pH range for plant growth (6.2 to 6.7) was maintained by peat and NH_4NO_3 fertigated media. Therefore, these media may be reused due to less salt accumulation and optimum pH value. In the present study, TN in plants grown in peat or compost additions was lower than in NH_4NO_3 fertigated plants, mainly due to the fact that N content per leaf area increases with the N availability (Noguchi, Terashima, 2006), and low N nutrition levels decrease N content of plant shoot and root (Watanabe et al., 2010).

Compost additions resulted in a higher NO_3 accumulation in spinach. In general, organically grown crops accumulate less nitrate content but active mineralization of organic matter could lead to excessive NO_3 accumulation in plants (Anjana et al., 2007). Moreover, the combination of NO_3 and NH_4^+ in a fertilizer reduces the nitrate content in vegetables (Wang et al., 2009). TOC and TSS were higher in plants grown in peat and NH_4NO_3 additions. In general, soluble organic compounds such as soluble sugars and organic acids serve as osmoticums to maintain osmotic potential and generate turgor pressure but at specific conditions, NO_3 in cell vacuoles could also serve as an alternative to organic osmoticums (Burns et al., 2011).

NO_3 was positively linked to fresh and dry biomass which indicates that NO_3 was reduced to ammonium that was assimilated into amino acids (Masclaux-Daubresse et al., 2010), producing more protein and thus resulting in more biomass. Crop demand for N is also dependent on dry matter accumulation and therefore vegetables such as lettuce shows increase in fresh and dry biomass with the increase in NO_3 application and its accumulation in the leaves (Cometti et al., 2011). A correlation between TOC, TSS and D_m suggests an increase in carbon assimilation which then boosts the production of carbohydrates and plant biomass. Leaf chlorophyll is directly related to TN in a leaf as nitrogen is one of the basic components of chlorophyll structure. In the present study, significantly higher H° affirmed the higher content of chlorophyll in peat and NH_4NO_3 treatments that led to increased CO_2 fixation and thus resulting in higher TOC in these treatments (Table 2). Spinach grown in compost additions had higher leaf clarity or lightness (see L* value in Table 4) and higher C* values indicating vividness in leaf colour. This was also obvious from relatively lower H° (more yellow aspect), as yellowish hue has more lightness and is more vivid compared to greener hue (H° close to 180°). Besides, positive relation of H° with TOC and D_m was present, owing to the increase in carbohydrates and proteins in high chlorophyll containing plants, consequently adding to the solid contents of the cells.

In fruits and vegetables, the concentration and type of sugars and organic acids, and the balance between them decisively contribute to the product flavour (Bayyari, Costell, 2010). Ripening index of plants grown in peat and NH_4NO_3 media was highest and moreover, these media produced the highest vitamin C, TOC, TSS, total flavonols and TEAC in spinach, all adding to the nutritional value of spinach. In spinach, flavonols and their derivatives are found to be the main flavonoids (Cho et al., 2008). The carbon nutrient balance predicts that the availability of excess carbon at a certain nutrient level leads to the increased production of carbon based secondary metabolites and their precursors (Ibrahim et al. 2011). However, contrary to high flavonols concentrations, plants grown in peat and NH_4NO_3 additions produced less F_b and D_b because biomass production is negatively correlated to phenolic components due to the competition between protein synthesis and secondary metabolite production (Anjana et al., 2007; Ibrahim et al., 2012).

Conclusion

Modification in the open soilless culture technique proved efficient in utilizing the resources. First, use of soilless media, controlled NH_4NO_3 fertigation, scheduled and quantified sprinkler irrigation not only led to negligible emission but also sustained the salts and pH in media to almost optimum levels during growth period. Consequently, contamination in the soil was less, spinach yield was higher and the media remained reusable for growing the crop in next season.

As to spinach quality, the peat moss and NH_4NO_3 fertigation resulted in the accumulation of lower amounts of NO_3 and more organic carbon that resulted in more dry matter. Higher total soluble solids contents and higher ripening indices were also observed. This was accompanied by higher chlorophyll contents (H° close to 180), higher flavonoids and higher antioxidant activity, which are attributes of a high quality food product. So, for producing good quality spinach, growing media consisting of sphagnum peat moss in combination with NH_4NO_3 application could be used according to the suggested modified open soilless culture technique.

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Špinatų smulkioji daržininkystė: auginimas atviroje, be dirvožemio sistemoje

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Santrauka

Tyrimo tikslas – sukurti atvirą, be dirvožemio, augalų auginimo sistemą, pasižyminčią dideliu vandens ir maisto medžiagų naudojimo efektyvumu ir maža emisija į aplinką, geros kokybės špinatams auginti smulkiosios daržininkystės būdu. Daržiniai špinatai buvo auginami talpyklose terpėje be dirvožemio, papildyta organiniais ir neorganiniais mitybos šaltiniais. Bandymai buvo išdėstyti randomizuotai, keturi pakartojimai. Vertintos septynios auginimo terpės: baltosios durpinės samanos, baltosios durpinės samanos su 150, 200 ir 250 ppm amonio nitrato (NH_4NO_3) ir baltosios durpinės samanos, papildytos kompostu, turinčiu šioms NH_4NO_3 koncentracijoms ekvivalentišką kiekį azoto. Siekiant sumažinti vandens emisiją į aplinką, drėkinta pagal schemą ir joje numatytas dozes, naudojant purkštuvus. Visą auginimo laikotarpį matuota druskos kaupimasis ir terpių pH. Špinatų lapuose analizuotas bendras tirpių kietųjų medžiagų kiekis, titruojamasis rūgštumas, subrendimo indeksas, bendras azoto kiekis, bendras organinės anglies kiekis, anglies ir azoto santykis, žalios biomasės kiekis, sausos biomasės kiekis, sausųjų medžiagų kiekis (mg g^{-1} žalios masės), lapų drėgmės kiekis, nitratų kiekis, kolorimetrinės savybės (šviesumas, spalvingumas ir atspalvio kampas), askorbo rūgšties kiekis, bendras flavonolių bei antocianinų kiekis ir antioksidacinis aktyvumas. Iš visų terpių baltųjų durpių samanų su NH_4NO_3 variante augalai turėjo mažiau nitratų, daugiau organinės anglies ir sausųjų medžiagų (mg g^{-1} žalios masės), didesnį bendrą tirpių kietųjų medžiagų kiekį ir subrendimo indeksą. Didesnis flavonoidų kiekis ir antioksidacinis aktyvumas taip pat nustatytas augaluose, augintuose šiose terpėse. Be to, šios terpės sukaupė mažiau druskų ir išlaikė optimalų špinatams auginti pH lygį.

Reikšminiai žodžiai: agroteršalai, augalų auginimas be dirvožemio, durpinės samanos, *Spinacia oleracea*, ūkininkavimas mieste.