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Effects of Cultivation System and Fertilization on Seedling Production of *Ocimum basilicum* L. and *Mentha spicata* L.

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Abstract

The demand for aromatic plants as ornamentals and sources of essential oils has increased recently. A float system is a promising alternative method of seedling production. Two cropping systems, float and conventional (seed bed), and two nutrient solution formulations, one organic and one inorganic, were evaluated for *Ocimum basilicum* (basil) and *Mentha spicata* (spearmint) seedling production. Basil seedlings grown in float system had better or comparable growth of shoots and leaves with those grown in seedbeds, irrespective of the fertilization, whereas spearmint organic fertilization reduced the growth of the aboveground parts of the seedlings, regardless of the cropping system. By contrast, fertilization treatments on both species' seedling grown in float system showed better root length and higher root biomass accumulation. The survival percentage of seedlings after transplanting, as well as the subsequent growth of plants, were not seriously affected by the cropping system of the fertilization method during transplant production. Overall, we conclude that a float system can be used for the production of *Ocimum basilicum* and *Mentha spicata* seedlings under organic or inorganic fertilization.

Keywords: aromatic plant, basil, float system, organic fertilization, seedbed, spearmint

Introduction

The orientation towards organic products and the adoption of production methods that are friendly to the environment are a top priority nowadays and within this area, it is important to investigate environmentally friendly methods for the production of seedlings of these plants.

Float system technology is extensively used to produce tobacco seedlings in greenhouses, but is rarely used for the production of seedlings of horticultural crops (Biernbaum, 1992; Bilalis *et al*., 2009). The method was investigated for the production of seedlings of several vegetable species, such as tomato (Rideout and Overstreet, 2003), broccoli (Niedziela and Gumbi, 1993) and cabbage (Frantz *et al.*, 1998; Niedziela and Gumbi, 1993) and seedlings of various ornamental plants (Niedziela *et al*., 2005). However, they are currently used successfully for the production of leafy vegetables with a short cultivation period such as lettuce, spinach, rocket etc. (Nicola *et al.*, 2007) and are also promising for the cultivation of aromatic plants and herbs (Frantz and Welbaum, 1998; Miceli *et al.*, 2003). Potential advantages include lower production costs, more efficient use of water and nutrients, reduced foliar disease contaminations since the foliage stays dry, easier control of exposure to disease agents, as well as reduced risk of groundwater being contaminated by fertilizers and pesticides (Rideout and Overstreet, 2003).

The demand for medicinal and aromatic plants as ornamentals and as sources of essential oils for the food medicine and cosmetics industry has recently increased. The essential oils of *Mentha spicata* and *Mentha piperita* have been shown to possess insect-repellent properties and to inhibit the development of bacteria and fungi (Shylaja and Peter, 2004; Tassou *et al*., 2004).

Studies of aromatic plants (*Mentha* sp. and *Ocimum* sp.) in soil or hydroponic cultivation showed that the yield of essential oil and menthol in hydroponics were higher than that from plants grown in the soil (Fernandes *et al*., 2004; Paulus *et al*., 2002; Vimolmangkang *et al*., 2008). In general, herbs have the potential to grow up to 25% faster in a hydroponic solution, compared to soil (Skagg, 1996).

Hydroponics is considered as a particularly intensive cultivation system, based on the use of inorganic fertilizers;

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nevertheless, during the recent years it has been used extensively in combination with organic fertilizers for organic cultivation of several horticultural species. According to Treadwell *et al.* (2011) basil and spearmint plants grown in troughs with soilless media and fertilized with granular poultry litter yielded similarly as those that had received inorganic fertilization. EC, petiole NO_3-N and K values between inorganic and organic fertilization were also comparable, indicating a synchrony of nutrient availability and crop demand at the organic fertilization. On the other hand, Succop and Newman (2004) found a significant interaction between the media (rockwool, perlite and a mixture of peat, perlite and compost) and the type of fertilization (conventional or organic) used, on the yield and the taste of basil grown hydroponically in greenhouse. In general, the effect of organic fertilization on the quality of aromatic plants is highly variable, depending on the species, the fertilization applied and the characteristics measured (Aflatuni, 1993).

Research on lettuce and tomato in a float system supplied with organic or inorganic fertilizers, showed that organically fertilized seedlings had higher dry weight, root surface and length, but lower fresh weight and height than inorganically fertilized seedlings (Bilalis *et al.*, 2009).

In view of the lack of availability of organic seedlings for organic use and the advantages of hydroponic systems, a combination of those methods was attempted. Since hydroponics offer the possibility to produce seedlings in an organically fertilized way, while at the same time avoiding the disadvantages of soil based greenhouse cultivation, the present study was undertaken with the aim of recording seedling growth parameters of *Ocimum basilicum* and *Mentha spicata*, within a hydroponic float system employing organic and inorganic nutrient supplies, in comparison with soil-based cultivation.

Materials and methods

Experiments were conducted in a glasshouse of the Agricultural University of Athens (37° 58'55.83"N, 23° 42'16.69"E) in two consecutive years, from March to June. Two experiments were carried out for both species, *Ocimum basilicum* (sweet basil) and *Mentha spicata* (spearmint). For each species two cultivation systems were studied (floating and conventional-seedbed). Two fertilization treatments (inorganic and organic), with four replicates per treatment, were employed per species and cultivation system. Therefore, each experiment was carried out according to a complete randomized design with two factors (cultivation system and fertilization). Eight troughs of equal size were used for the float system: four for each fertilization treatment (2 fertilization treatments x 4 replicates). The same troughs were used both for basil and spearmint plants and the volume of each trough was 150 L. There was no aeration or recirculation of the nutrient solution in the troughs throughout the experimental period from sowing to transplanting of seedlings (60 days). Since no nutrient solution was added, evaporation of the nutrient solution in the troughs was minimized by placing seed trays one next to each other and by filling the gaps between trays and troughs with long polystyrene strips. The organic fertilization (C & C) consisted of 32 ml/50 L Codaphos (0-30-20) and 37 ml/50 L Codasting (7,2-0-0, plus 9% w/w free aminoacids) (C & C) (Sustainable Agro Solutions SA, Lleida, Spain), supplemented with 5 ml/50L Trichomic (*Trichoderma* sp.) (Trichodex Co, Sevilla, Spain) for root protection. The inorganic (conventional) fertilization treatment comprised a conventional (N-P-K) water-soluble fertilizer solution containing 21 g/ 50L N-P-K (11-11-23 plus Ca, Mg and minor elements B, Cu, Fe, Mn Zn) (Fytothreptiki Co., Athens, Greece) plus two fungicides: 30 ml Previcur 72.2 SL (propamocarb) and 30 ml Derosal 51.1 SC (carbedazim) (Bayer Crop Science, Athens, Greece). The concentrations used were determined in preliminary experiments. The pH and E.C. values of the nutrient solutions in the case of organic fertilization were 7.25 and 1.14 mS/cm and when inorganic fertilizers were used, 6.12 and 1.11 mS/cm, respectively.

Seeds of sweet basil and spearmint were sown in a mixture of peat (Klasmann TS2, Klasmann-Deilmann, Geeste, Germany) - perlite (Perloflor, Isocon SA, Athens, Greece) 1:1 v/v contained in polystyrene trays with 176 cells per tray (individual cell volume 11.5 cm^3). One seed per cell was placed on the surface of the substrate and covered with a thin layer of the mixture. In total, 704 seeds were used for each species, fertilization and cultivation system (176 seeds x 4 seed trays-replicates). The trays were then placed on the surface of the solutions within the troughs in the case of float system, whereas for conventional (seed bed) cultivation the polystyrene trays were placed on benches in the greenhouse, next to the float system troughs. The application of nutrient solution to the conventional system (seed bed) was carried out as required during the experimental period.

Measurements

Seedling emergence was recorded every two days after sowing (DAS), and final germination percentage was computed based on free seedling cells, at 20 DAS, for both *Ocimum basilicum* and *Mentha spicata*. T_{50} was calculated according to Coolbear *et al.* (1980). Two months after sowing, when the seedlings were at the stage of commercial marketing, 40 seedlings from each species (i.e. 20 per fertilization treatment), for each cultivation system (float and seedbed), were harvested and the following biometrical characteristics measured: plant height, leaf number and area per plant, fresh and dry weight of the plant aboveground parts (shoots + leaves), roots and root length. Throughout the duration of germination and seedlings development (60 days), mean daily temperature was 24.5 °C, whereas average daily minimum and maximum were 11.8 °C and 38.2 °C respectively. Temperatures inside the glasshouse were recorded in 10 min intervals, using a Hobo Weather Station.

Plant height, fresh and dry weight of shoots + leaves

Plant height was measured from the substrate surface to the apical bud in basil and spearmint. The plant aboveground parts were excised by cutting on the base of the plants and were weighted fresh (FW) and after oven-drying at 70 °C up to a constant dry weight (DW), using a Mettler PM 100 analytical balance.

Leaf number and area

In each plant the number of leaves was determined, as well as total leaf area using a Li-Cor 3100 area meter.

Root characteristics

The root samples were cleaned of the peat - perlite media by soaking in 30 ml of a 0.5% solution of sodium hexametaphosphate. Subsequently, the roots were transferred to a 0.1% trypan blue FAA staining solution (mixture of 10% formalin, 50% ethanol and 5% acetic acid). For determination of root length the stained root samples were placed on a high resolution scanner (Hewlett Packard 4C) using Delta-T software (Delta–T Scan 2.04, Delta–T Devices Ltd, Cambridge, UK) (Kokko *et al.*, 1993).

The root samples were weighed before (fresh weight, RFW) and after oven drying at 70 °C up to a constant weight (RDW), using a Mettler PM 100 analytical balance.

E.C., pH and dissolved O_2

For each trough, the EC (Crison CM35, Crison Instruments SA, Barcelona, Spain), the pH (Hanna pH212, Hanna Instruments Inc., Woonsocket, RI, USA) and the concentration of dissolved oxygen (Hanna HI 9142) were measured, at regular intervals, seven times throughout the experiment.

Seedlings transplanting and growth measurements

60 DAS, 40 seedlings from each combination of cultivation system and fertilization were transplanted into 1 L pots filled with a mixture of 1:1 (v/v) peat (Klasmann TS2, Klasmann-Deilmann, Geeste, Germany) and perlite (Perloflor, Isocon SA, Athens, Greece). Plants were grown in a net house located next to the glasshouse where the seedlings were produced and were regularly irrigated and fertilized once every two weeks using the same fertilization the plants received at the seedling stage before transplantation. Plants height was recorded at regular intervals, up to 37 days after transplantation.

Statistical analysis

On all parameters measured, a two-way analysis of variance (ANOVA) was used to test the significance of the effect of the factors (cultivation system and fertilization) and their interaction. Differences between treatments for both factors were evaluated using the *t*-test at $P \leq 0.05$. All statistical analyses were performed using the software Statgraphics plus 5.1 (Statpoint Technologies INC., Warrenton, VA, USA).

Results

Ocimum basilicum seedling production

Seed germination: *Ocimum basilicum* seeds germinated at a high rate (84.7-94.1%) in both cultivation systems with a T_{50} ranging from 5.40 to 7.18 days (Table 1). For both germination percentage and T_{50} no significant differences were detected between the fertilization treatments in either system. Accordingly, the effect of the cultivation system was not significant, except the germination rate under organic fertilization, which was higher in the float system compared to seedbed.

Plant height: Seedlings grown in the float system were significantly higher than those in the seed beds, irrespective of the fertilization. In the float system, seedlings fertilized organically (C & C) were taller (22.3 cm) than those produced with inorganic fertilizer (15.9 cm). In the seed bed however, inorganic fertilizer produced seedlings of a similar height (11.6 cm) to those fertilized with C & C (11.4 cm) (Table 2).

Leaf area (LA): Seedlings grown in the float system showed significantly higher leaf area per plant than those in the seed beds, only when supplied with organic fertilizers. In the float system, seedlings grown with C & C had significantly greater LA (48.9 cm^2) than those grown with N-P-K (32.7 cm^2), whereas in seedbeds LA was not significantly different between the fertilization treatments.

Leaf number (LN): Leaf number per plant was not significantly affected by the cultivation system, in both organic and inorganic fertilization. The seedlings grown in the float system under organic fertilization had more leaves per plant compared to those grown with N-P-K, whereas in the seedbeds fertilization had no effect on LN.

Fresh weight of shoots + leaves (FWSL): The fresh weight of the seedlings was significantly higher in the float system than in the seed bed in both fertilizations (Table 2). The FW of seedlings grown in the float system with C & C (3.56 g per plant) was significantly higher than those grown with N-P-K (2.35 g per plant), whereas in the seedbed seedling FWSL was similar between inorganic and organic fertilization (Table 2).

Dry weight of shoots+leaves (DWSL): Accordingly, aboveground parts dry weight was significantly higher in the float system irrespective of fertilization treatment. However, there was no effect of fertilization on the accumulation of dry mass in both cultivation systems (Table 2).

Shoots+leaves dry/fresh weight ratio (DWSL%): In both cultivation systems, DWSL% was higher in seedlings fed with inorganic fertilizers (N-P-K), than those grown with C & C. Seedlings grown in float system with inorganic fertilization also showed higher dry mass percentage than those grown in seedbeds, although no such difference appeared with organic fertilization (Table 2).

Fresh weight of roots (FWR): Plants grown in float system showed higher FWR compared to those in seedbeds, whereas no difference was observed between the fertilization treatments in either cultivation system (Table 2).

Dry weight of roots (DWR): Similarly, the accumulation of biomass in the roots of plants grown in float system was 2-3 times higher than those grown in seedbeds. Although the effect of fertilization on DWR of plants grown in float system was negligible, plants grown in seedbeds and fed with inorganic fertilizers showed higher DWR compared to those received organic fertilization (Table 2).

Root dry/fresh weight ratio (DWR%): Plants grown in float system had higher DWR% than those grown in seedbeds only when received organic fertilization. Again, the effect of fertilization was significant only in seedbeds, where N-P-K resulted in plants with higher DWR% compared to C & C.

Root length (RL): Root length of the plants grown in float system was at least twice as much compared to those in the seedbeds in both fertilizations. Although RL was not affected by fertilization in float system, was higher in plants received N-P-K than those fed with C & C in seedbeds (Table 2).

Mentha spicata seedlings production

Seed germination: In general, spearmint seeds germinated slower (higher T_{50} values) and at lower rate than those of basil. However, maximum germinability (89.4%) was observed in float system with inorganic fertilization and was significantly higher than germination under organic fertilization, or under the same fertilization in seedbeds. Inorganic fertilization positively affected % seed germination in both systems, as well as the speed of germination in the float system (lower T_{50} value) (Table 1).

Table 1. Effect of fertilization and cultivation system (float system and seedbed) on seed germination and T_{50} values of *Ocimum basilicum* and *Mentha spicata*

Fertilization	*Ocimum basilicum*		*Mentha spicata*	
	Germination (%)	T_{50} (days)	Germination (%)	T_{50} (days)
		Float system		
C & C	91.9 a °	6.36 a	48.9 b	12.85 a
N-P-K	94.1 a	5.40 a	89.4 a °	10.74 b
		Seed bed		
C & C	84.7 a °	7.18 a	44.3 b	13.05 a
N-P-K	89.8 a	6.48 a	64.2 a °	11.79 a

Mean values within each column in each cultivation system, followed by different letters, differ significantly according the *t*-test, at $P<0.05$; (°) Mean values within each column between cropping systems differ significantly according the *t*-test at $P<0.05$

Table 2. Effect of fertilization (inorganic and organic) and culture system (float system and seedbed) on the growth characteristics of basil (*Ocimum basilicum*) seedlings, 2 months after sowing

Fertilization	Height (cm)	Leaf area /plant (cm^2)	Leaf number /plant	Shoots+leaves fresh weight (g)	Shoots+ leaves dry weight (g)	Shoots+ leaves dry/fresh weight (%)	Root fresh weight (g)	Root dry weight (g)	Root dry/fresh weight (%)	Root length /plant (cm)
					Float System					
C & C	22.3 a°	48.9 a°	8.2 a	3.56 a°	0.509 a°	14.2 b	1.06 a°	0.137 a°	12.9 a°	73.6 a°
N-P-K	15.9 b°	32.7 b	6.8 b	2.35 b°	0.421 a°	17.7 a°	1.02 a°	0.133 a°	13.0 a	75.9 a°
					Seedbed					
C & C	11.4 a°	25.1 a°	7.0 a	1.30 a°	0.172 a°	13.3 b	0.50 a°	0.052 b°	10.8 b°	29.3 b°
N-P-K	11.6 a°	28.2 a	8.0 a	1.27 a°	0.194 a°	15.3 a°	0.54 a°	0.068 a°	13.9 a	38.0 a°
System	*	*	ns	*	*	*	*	*	ns	*
Fertilization	*	ns	ns	*	ns	*	ns	ns	*	ns
System x Fertilization	*	ns	ns	ns	ns	ns	ns	ns	*	ns

Mean values within each column in each cropping system followed by different letters, differ significantly according the *t*-test at $P<0.05$; (°) Mean values within each column between cropping systems differ significantly according the *t*-test at $P<0.05$; *: significant effect of factor or interaction, ns: non significant effect at $P<0.05$

Table 3. Effect of fertilization (inorganic and organic) and culture system (float system and seedbed) on the growth characteristics of spearmint (*Mentha spicata*) seedlings, 2 months after sowing

Fertilization	Height (cm)	Leaf area /plant (cm^2)	Leaf number/ plant	Shoots+ leaves fresh weight (g)	Shoots+ leaves dry weight (g)	Shoots+ leaves dry/fresh weight (%)	Root fresh weight (g)	Root dry weight (g)	Root dry/fresh weight (%)	Root length/ plant (cm)
					Float System					
C & C	9.2 a	7.2 b°	7.7 a	0.42 a	0.064 b	15.6 b	0.35 a°	0.041 a°	11.6 b°	27.8 a°
N-P-K	9.4 a	11.2 a°	7.9 a°	0.39 a °	0.082 a	19.9 a°	0.32 a°	0.051 a°	17.0 a	24.8 a°
					Seedbed					
C & C	10.5 a	9.5 b°	8.7 b	0.49 a	0.072 a	14.7 a	0.28 a°	0.031 a°	13.3 b°	16.4 a°
N-P-K	9.4 a	14.3 a°	11.7 a°	0.51 a °	0.076 a	15.6 a°	0.14 b°	0.025 a°	17.8 a	12.4 a°
System	ns	*	*	*	ns	*	*	*	ns	*
Fertilization	ns	*	*	ns	ns	*	*	ns	*	ns
System x Fertilization	ns	ns	*	ns	ns	*	ns	ns	ns	ns

Mean values within each column in each cropping system followed by different letters, differ significantly according the *t*-test at $P<0.05$; (°) Mean values within each column between cropping systems differ significantly according the *t*-test at $P<0.05$; *: significant effect of factor or interaction, ns: non significant effect at $P<0.05$

Plant height: By contrast, there was no significant effect of either cultivation system or fertilization on the height of spearmint plants (Table 3).

Leaf Area (LA): In both systems, inorganic fertilization resulted in higher LA compared to organic, whereas the LA of plants grown in seedbeds was higher than those in float system, regardless of the fertilization (Table 3).

Leaf number (LN): LN of plants grown in float system was not affected by fertilization, whereas in seedbeds N-P-K resulted in higher LN than C & C. Plants fed with N-P-K had more leaves when grown in seedbeds than in float system (Table 3).

Fresh weight of shoots+leaves (FWSL): The FWSL was not affected by fertilization in both systems. Although there was also no effect of the cultivation system on the FWSL of plants grown with organic fertilization, inorganic fertilization favoured the FWSL of plants grown in seedbeds (Table 3).

Dry weight of shoots + leaves (DWSL): There was no effect of the cultivation system on the accumulation of dry mass in spearmint plants in both fertilization treatments. In the float system though, plants fed with N-P-K had higher DWSL than those receiving C & C (Table 3).

Shoots + leaves dry/fresh weight ratio (DWSL%): Accordingly, the DWSL% of plants grown in float system with inorganic fertilization was higher from those in float with C & C and those in seedbeds fed with N-P-K (Table 3).

Root fresh weight (FWR): Float system had a positive effect on plants FWR in both fertilizations. Although fertilization did not affect the FWR of plants grown in float system, in seedbeds feeding with inorganic fertilizers resulted in lower FWR (Table 3).

Root dry weight (DWR): Similarly, float system favoured the accumulation of dry mass in the roots of spearmint plants in both fertilizations, but the effect of fertilization on DWR was not significant (Table 3).

Root dry/fresh weight ratio (DWR%): In both systems, inorganic fertilization resulted in higher DWR% compared to organic. There was also no effect of the cultivation system on the DWR% of N-P-K - fed plants, whereas C & C - fed plants grown in float system had less DWR% than those grown in seedbeds.

Root length (RL): There is a clear positive effect of the float system on plants RL, irrespective of the fertilization, whereas fertilization did not affect plants RL in both cultivation systems (Table 3).

Dissolved O_2, pH and E.C. of nutrient solution in float system

Dissolved O_2 gradually decreased during the course of seedling growth, as no recirculation or aeration of the nutrient solution within the float system troughs was employed. However, throughout the experiment, O_2 levels were sufficient to sustain root growth and function, as roots of plants grown in float system did not show symptoms of anoxia, even at the later stages of seedling growth, when O_2 concentration fell below 3 mg/l (Fig. 1). The presence of *Trichoderma* when organic fertilization was applied did not result in higher O_2 consumption, as O_2 levels between inorganic and organic fertilization were comparable at each sampling date.

The initial pH of the nutrient solution when inorganic fertilizers were used was higher than the organic one and did not present remarkable changes throughout plant growth, whereas under organic fertilization after a significant increase the first 20 days, pH values gradually decreased and were stabilized during the last month of the experiment (Fig. 1B).

The E.C. of the nutrient solution showed an initial significant increase, in particular when organic fertilizers were used (up to 1.8 mS/cm), and after 20 DAS gradually decreased. In all sampling dates the E.C. of the organic nutrient solution was higher compared to inorganic one, although after 50 DAS they both reached at the same low level of dissolved nutrients, which is reflected at low E.C. values, near 0.4 mS/cm (Fig. 1C).

Survival and growth of plants after transplantation

In all cases, float system and seedbed, inorganic and organic fertilization, all the seedlings of both basil and spearmint that were transplanted, survived the transplantation and continued growing; however, different rates were noted, depending on transplantation and the treatment combination of cultivation system and fertilization used during seedling growth.

In basil, although the plants derived from the combination float system + C & C were taller during transplanting, their growth rate was slow and comparable to those derived from seedbed + C & C, which remained short throughout their growth. Plants from both, seedbed + N-P-K and float system + N-P-K although increased their height slowly soon after transplanting, developed vigorously 20 days after transplanting (DAT) and thereafter, outgrowing the plants from float system + C & C (Fig. 2A).

By contrast, spearmint plants had comparable height at the stage of transplanting irrespective of the experimental treatment during seedling growth, but those derived from the seedbed + N-P-K treatment developed better and were taller at the end of experimentation, 37 DAT. Spearmint plants derived from all the other system + fertilization treatments showed a similar growth trend after transplanting and had comparable height at 37 DAT (Fig. 2B).

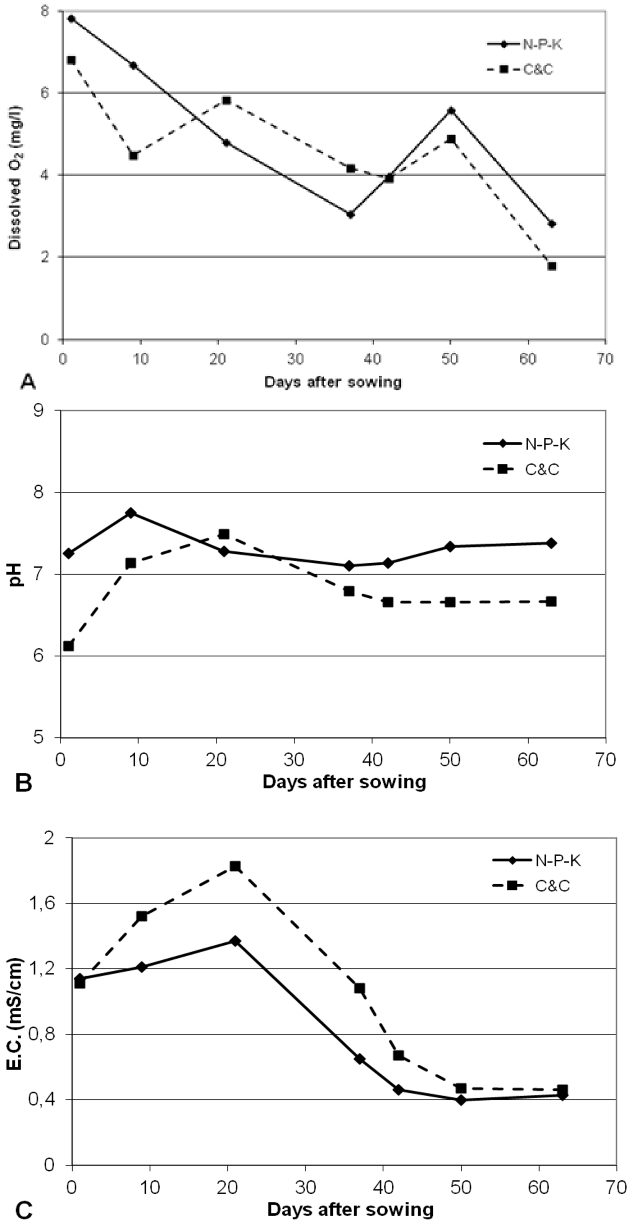

Fig. 1. Dissolved O_2 (A), pH (B) and Electrical Conductivity (C) of the nutrient solution in float system during the course of cultivation of both species, under organic (C & C) and inorganic (N-P-K) fertilization

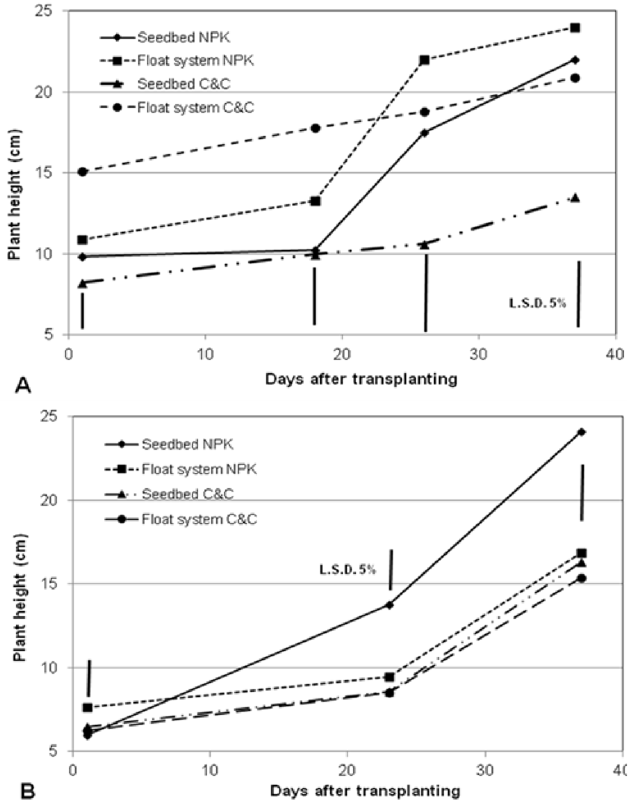

Fig. 2. The growth of basil (A) and spearmint (B) plants after transplanting, as affected by the cultural system (float and seedbed) and the fertilization (inorganic and organic) during seedling growth; (Vertical bars in each date indicate L.S.D. values at $P<0.05$)

Discussion

Although seed germinability and the rate of germination were not seriously affected by either cultivation system or fertilization in basil, in spearmint there was a clear positive effect of float system on seed germinability and T_{50} value, when the nutrient solution contained inorganic fertilizers (Table 1). It is possible that the constant hydration of the substrate immediately after sowing into the float system favoured the germination of the less vigorous spearmint seeds, compared to the periodic irrigation of the substrate in seedbeds. In addition, although in basil the effect is not significant, inorganic fertilization showed a tendency to improve seed germination in both cultivation systems, compared to organic one.

Float system, in comparison to seedbed, resulted in better development of the aboveground parts of basil (taller plants, with larger leaves and higher fresh weight of shoots and leaves, as well as higher biomass production), particularly when it was combined with organic fertilization (Table 2). In addition, basil seedlings grown in both systems accumulated less water when fertilized with C & C compared to N-P-K; hence were less succulent and less prone to transplant shock (Frantz *et al.,* 1998). On the other hand, several attributes of spearmint seedling growth (e.g. leaf area, biomass of plant aerial parts) were negatively affected from the combination of float system and organic fertilization (Table 3). Instead, the combination of seedbed and inorganic fertilization proved to be beneficial for spearmint seedling growth. However, in all cases spearmint growth was limited and significant differences among experimental treatments do not necessarily result in considerable differences in plant growth (Table 3). The results of the present study and those of Treadwell *et al.* (2011) on basil and spearmint plants grown in soilless culture using organic and inorganic fertilization, indicate that organic fertilization in soilless systems may adequately cover the needs of basil and spearmint plants for nutrients, both for the production of transplants and for growth after transplanting.

In addition, basil and spearmint seedlings grown in the float system developed a rich root system with higher length, fresh and dry weight, under both organic and inorganic fertilization, compared to those grown in seedbeds (Tables 2 and 3). Therefore, irrespective of the development of the aboveground part of the plant, seedlings produced in the float system are expected to be better established after transplanting, since they already have an extensive root system. Our results agree with Bilalis *et al.* (2009), where the combination of float system and organic fertilization led to the production of well developed transplants of lettuce and tomato. However, they observed better development of the root system under organic fertilization, whereas in our study both C & C and inorganic fertilization had equal effect on root development in both cultivation systems.

A number of studies have clearly demonstrated that several herbs, including basil and spearmint, provide high yields and good product quality when cultivated in soilless systems and in particular in floating systems (Miceli *et al.*, 2003; Treadwell *et al.,* 2011). However, there are no experimental data so far on the potential of using the tobacco seedling production system in greenhouses to produce transplants of herbs, particularly in combination with organic fertilization.

From the present study it is also evident that for the production of herbs transplants, as in the case of basil and spearmint, the employment of a simple float system without recirculation and/or aeration of the solution may be adequate. Throughout the period of growth in the troughs, O_2 levels did not fall below 2.0 mg/l (Fig. 1A), a level which is reported as sufficient to sustain lettuce growth in floating hydroponics (Goto *et al.*, 1996). Accordingly, despite the significant reduction of the E.C. values at the later stages of development (after 35 DAS), due to consumption of nutrients by growing seedlings, no nutrient deficiency symptoms were observed at the stage of transplanting (70 DAS) (Fig. 1C). The increase of the E.C. values up to 20 DAS, particularly in the organic fertilization, could be ascribed to both the mineralization of the organic fertilizers and the loss of water due to evaporation from the troughs and water uptake by plants, at a stage where the minerals uptake by seedlings is minimal.

All transplants of both basil and spearmint were successfully transplanted, survived and developed well after transplanting, irrespective of the system or the fertilization employed during their development (Fig. 2 A, B). As a result, despite the data of Frantz *et al.* (1998) who reported that the survival after transplanting of cabbage seedlings grown under several production systems including floating system, depended on their water content, in the current study all transplants survived irrespective of their water content, since organically produced transplants were less succulent than those fed with N-P-K.

Conclusions

The present study showed that floating hydroponics, especially in combination with organic fertilization, is a promising cultivation system for transplants production of basil and spearmint, as it allows the production of vigorous seedlings with rich root system and good establishment after transplanting, at low labour cost and in an environmentally friendly way. This technique of transplants production could successfully be adopted in the case of other herb species; however, further studies must be carried out on this aspect.

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