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Research on microgreens farming in vertical hydroponic system

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Abstract Microgreens are species of vegetables and aromatic herbs in an early stage of growing, which are consumed after a vegetative cycle of 10-14 days. At first, they gained their popularity in luxury restaurants for the original flavour they gave to dishes. Over the years, their nutritional and therapeutic qualities have been recognised and today they are sold and consumed on a wide scale. The great majority of microgreens can be grown with no chemical fertilisers and pesticides, because they are consumed in their cotyledon-leaf stage, their development being provided by the spare substances of the seed. This paper presents the comparative study of two growing systems, i.e. ebb&flow benches compared to a vertical hydroponic system, as well as of two substrates frequently used in this culture, i.e. peat and perlite mix (70/30) compared to cellulose. For the four versions resulted, the documented parameters were the germination rate, the height of the microgreens and their weight at harvest. The results showed a slightly improved germination rate for the peat and perlite mix as compared to the cellulose substrate. The observed differences at harvest for the height and weight of the microgreens were small; the vertical hydroponic system yielded better results as compared to the growing benches for most of the species studied. The general conclusion following the analysis of the results is that a vertical hydroponic system alongside a peat and perlite substrate yields better results in microgreens farming in terms of germination rate and harvest, when compared to ebb&flow benches using a cellulose substrate. Furthermore, the vertical hydroponic system yields a slightly increased production on cultivated unit area, as compared to the ebb&flow bench system.

Key words

microgreens, vertical farming, organic agriculture

Microgreens, also known as shoots, are vegetables and aromatic plants consumed in their cotyledon-leaf stage or when they have developed their first pair of real leaves. They are a new type of exotic greens that were first popular in high-end restaurants and markets and have become a new culinary trend in the last years. Over the years, the demand for microgreens has been increasing and today there are over 80 species on the market [14].

Microgreens are generally three to ten centimetres in height, they are harvested at seven to 14 days after germination and sold as stems with cotyledons. They are appreciated for their wide range of intense flavours, colours, textures and shapes and, as such, they are used as ingredients in salads, soups, sandwiches etc., as well as for seasoning a great variety of main dishes [4, 6, 8, 12].

There are numerous studies showing that microgreens can contain health-beneficial vitamins, minerals and phytonutrients in much higher levels than their mature counterparts. A research conducted by Oh et al. [9] has proven that young leaves of lettuce (*Lactuca sativa* L.) had the highest total phenolic concentration and antioxidant action at seven days from germination, as compared to the leaves of more mature plants. Another research conducted by Lester et al. [5] has shown that, in general, younger spinach leaves (*Spinacia oleracea* L.) had a higher content of phytonutrients, such as: vitamins C, B_9 and K_1 and carotenoids (lutein, violaxanthin, zeaxanthin and beta-carotene) as compared to mature leaves. A high quantity of vitamin C is found in microgreens like broccoli, peas, sorrel, lentils, cress and chick-peas. A high level of vitamin D is found in sunflower microgreens, while a high quantity of calcium is found in red beet and green basil microgreens. Wheat grass and red beet have a strong antioxidant effect [7, 10, 11, 15].

Vertical farming or vertical agriculture is most of the time a hydroponic culture, whose practice requires arranging the growing benches stacked upon each other in columns (multilevel racks), while using artificial lighting and climate control. Applied vertical agriculture currently manages to obtain up to 10 times

the harvest of traditional agriculture on a given unit area [1, 2, 13].
This new concept in agriculture brings along a series of benefits: superior production (in quantity as well as in quality), ruling-out the damages caused by external environment factors and the possibility to produce fresh food in the proximity of or even within big cities [3].
This research is a comparative analysis of two systems appropriate for microgreens farming: ebb&flow benches and vertical hydroponic system. The paper also includes a comparative study of two of the most popular substrates used in microgreens farming: peat and perlite mix (70/30) and cellulose.

Material and Method

The research was conducted in the commune of Gorgota, Prahova County, approximately 40 km from Bucharest. The farm grows microgreens in a hydroponic flood benches system (Fig. 1), as well as in an experimental system of multilevel bench rack (Fig. 2).

Fig. 1. Microgreens on growing benches

Fig. 2. Microgreens on multilevel bench rack (vertical farming)

Flood tables or benches (ebb and flow system) equipped with automatic irrigation systems are used in the hydroponic farming system
The vertical farming rack is 800 cm long, 160 cm wide and 420 cm tall. It has 4 levels of UV-resistant plastic benches, controlled temperature, artificial lighting and permanent ventilation. The rack is placed within an inflated double layer greenhouse with a heating system that provides the temperature necessary for the growth and development of the microgreens, especially during the cold season. Moreover, the module is also equipped with its own irrigation and fertilisation (fertirrigation) system, as well as with a pH and EC automatic adjustment system. The substances used for the conditioning of the irrigation water are certified for ecological agriculture: citric acid for pH correction and plant extract-based products and sugar beet molasses for EC regulation.
For both models of farming, the microgreens are sowed in small 9x7 cm plant pots, with a height of 5 cm, made of plastic. They are placed in support-trays containing 16 pots each, with the purpose to facilitate all the

operations of the technological flow, particularly the sowing and handling during harvest and delivery.

Microgreens have a vegetation cycle that varies in duration depending on the species. Thus, the duration may vary from 7-8 days (peas, red raddish, sunflower) to 12-14 days (red and green mizuna, pak choi, broccoli), or even 35-40 days (red/green basil, red sorrel etc.). This timeframe is calculated from the moment the seeds have germinated and are introduced into the system in order for them to develop.

The farm is currently growing 40-45 species, in a continuous dynamic dictated by the customers' needs and preferences. During our analysis four species of microgreens were studied: red radish (*Raphanus sativus*), red basil (*Ocimmum basilicum*), peas (*Pisum sativum*), and sunflower (*Helianthus annuus*). The growing substrate used in the experiment was peat (70%) and perlite (30%) mix and cellulose, depending on the studied culture. The seeds are certified and untreated, purchased from providers from Romania, Germany and USA. Some of them are normal vegetable seeds, while others are special microgreens seeds.

Microgreens growing technique: the plant pot is filled with a peat and perlite mix up to 75-80% of its volume, then the substrate is slightly pressed. After filling, the pot is placed in the support-tray and is sprayed with a small quantity of water on its surface. Thus, the seeds will have the humidity necessary to germination both at soil level (moisturised peat) and in the atmosphere (controlled relative air humidity).

Fig. 3. Pot, Tray, Trays filled with pots and substrate

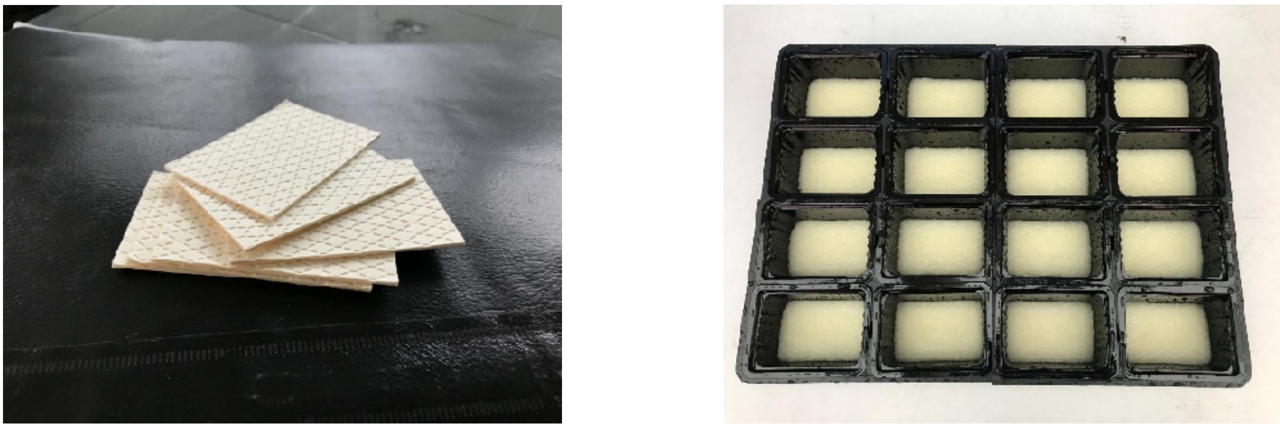

Fig. 4 (left to right): Dehydrated cellulose mat, Tray with pots and cellulose ready for seeding

In the cellulose model, the cellulose was placed in each pot, then 16 pots were placed in each of the trays. After the preparation of the trays, the sowing is done by means of a special sowing machine using a drum. After sowing, the trays are labelled with the name of the species, the lot number and the date of sowing, then they are put in the germination room. Depending on the species, the trays will stay there for a period of 2 to 7-8 days, at a temperature of 18-20 degrees Celsius and an atmospheric humidity of 95-98% (dense mist). After coming out of the germination room, the trays are left for 2-3 hours in a room with a temperature of 20-22 degrees Celsius and diffuse light; during this period the acclimation (adaptation) of the plantules takes place. After this period, the trays are placed on the growing benches – either unfolded in the greenhouse or on vertical racks – where the entire process of growing takes place. Immediately after placing the trays on the benches, the first irrigation is carried out, which moisturises the whole substrate.

The administered water has a pH of 5.8-6 and an EC of 0.8. Then follows a period of two days with no water at all, in order to stimulate the development of the roots, as a consequence of the hydric stress. From the third

day onward the cultures are watered daily with a medium volume of water of approximately 270-280 l/bench, with a pH between 5.8 and 6.2 and an EC of 1.0-1.2. The exception to this rule is the basil culture, the EC of which is increased by 0.2 units every 7 days.
Analysed models:

1. 4-level vertical hydroponic system – peat + perlite (70/30) substrate
2. 4-level vertical hydroponic system – cellulose substrate
3. Ebb&flow growing benches system – peat + perlite (70/30) substrate
4. Ebb&flow growing benches system – cellulose substrate
5. Red radish microgreens in various stages of development.

After the germination, the radishes will have a period of adjustment to the new farming environment, which may last up to 24 hours. After this adjustment, they enter an accelerated growth stage that usually lasts until day 4, when the maximum threshold of growth intensity is reached; then follows a period of relatively constant growth, which lasts until day 7, when the harvesting takes place.

Fig. 5 Newly germinated microgreens, Microgreens at 4 days after germination, Microgreens at 7 days after germination

Red basil microgreeens in various stages of development.

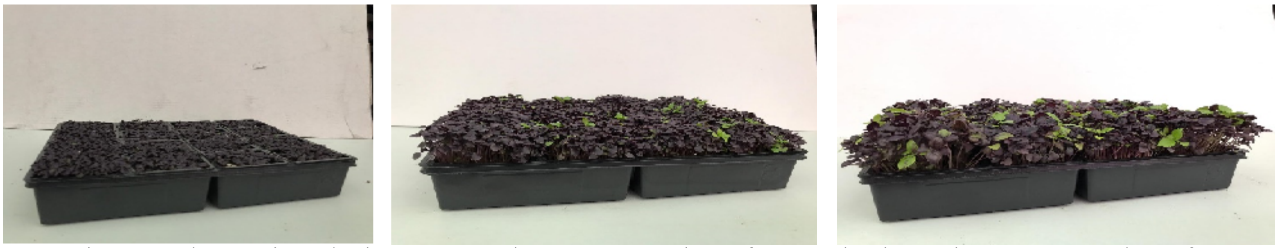

Fig. 6 Newly germinated microgreens, Microgreens at 4 days after germination, Microgreens at 7 days after germination

Basil is one of the species that are sold after a longer period of vegetation, which lasts between 27 and 31 days. This involves adding nutrients to the irrigation water. Without the nutrients necessary for their growth, the plants will not develop properly, the growths will be insignificant and non-uniform, the leaves will not get the proper pigment and after a while the death of the plants will occur. By using nutrients in various concentrations, taking into account the plants' development stage and providing sufficient light intensity, we manage to obtain healthy, developed, tantalizing microgreens.
Peas microgreens in various stages of development.

Fig.7 Newly germinated microgreens Fig.8 Microgreens at 4 days after germination Fig. 9. Microgreens at 7 days after germination germinație

The germination of the peas microgreens is relatively non-uniform, and this is why the trays are taken out of the germination room when around 40% of the seeds have a cracked tegument and their radicle is becoming visible, having a length of 1-2 mm. The complete germination usually takes place on the bench. Despite the relatively non-uniform germination of the seeds, at the end of the 7 days of growing the microgreens reach the same stage of development and the differences noticed in the germination stage are not visible anymore. Sunflower microgreens in various stages of development.

Fig. 10 Newly germinated microgreens Fig. 11 Microgreens at 14 days after germination Fig. 12 Microgreens at 27 days after germination

Unlike the other species studied in this experiment, the sunflower microgreens need an additional manual operation. After approximately 2 days on the bench it is mandatory to clean the teguments of the former seeds in order to ensure the normal development of the cotyledons. If this operation is omitted, the tegument will come off the plantlet's cotyledons much too late, causing the excessive lengthening of the little stems and the injury of the tender tissues still growing and developing. This is undesirable, because it affects the visual quality of the produce, which therefore cannot be sold.

Results and Discussions

The quantity of seeds used for sowing a pot is the same for both substrates. As we can see from Table 1, microgreens are sowed with a very high density of plants per plant pot. This way we can even reach several hundred plants in order to obtain a well garnished pot, with a pleasant commercial look.

Table 1. Seed quantity for sowing

Species	Mean quantity of seeds per pot in alveolar tray (g)		Mean quantity of seeds for a m^2 (g)	
	peat 70%+ perlite 30%	Cellulose	peat 70%+ Perlite 30%	Cellulose
Red radish	2.3	2.3	557.52	557.52
Red basil	2.3	2.3	557.52	557.52
Peas	12	12	2,908.80	2,908.80
Sunflower	7	7	1,696.80	1,696.80

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Table 2. Germination percent of microgrees depending on species and growing substrate

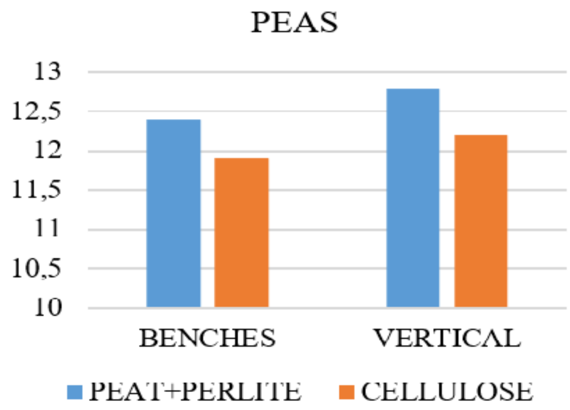
Species	Growing substrate	Germination percent (%)
Red radish	peat 70% + perlite 30%	85%
	cellulose	80%
Red basil	peat 70% + perlite 30%	90%
	cellulose	80%
Peas	peat 70% + perlite 30%	70%
	cellulose	65%
Sunflower	peat 70% + perlite 30%	70%
	cellulose	80%

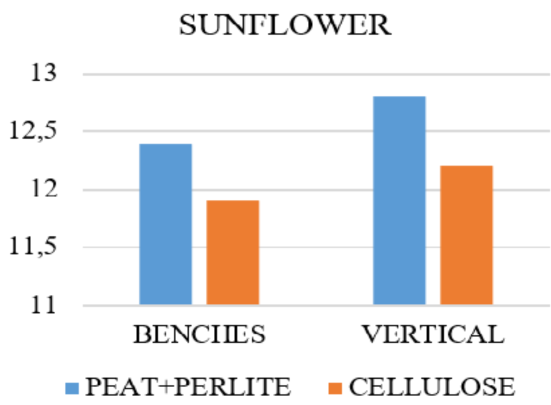
Although the germination of all the seeds took place under the same conditions, we can notice differences in their germination percent. Thus, in the peat model we notice a difference of up to 10% for basil and 5% for radish and peas. However, the sunflower had a 10% better germination for the cellulose substrate, unlike the other models.

Table 3. Average height of microgreens depending on species and growing substrate

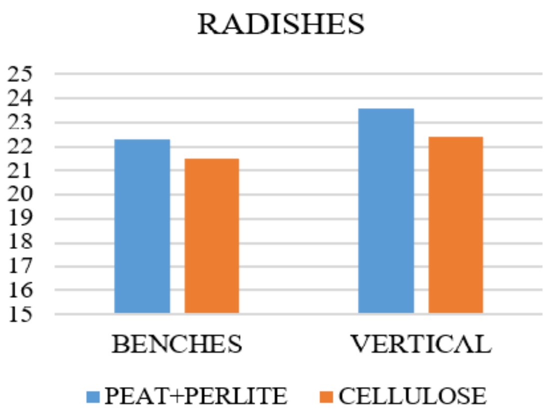
Species	Growing substrate	Growing model	Average height of the plants (cm)	Average weight of the plants when sold (g/pot)
Red radish	peat 70% + perlite 30%	Growing benches	11.2	22.3
	Cellulose		10	21.5
	peat 70% + perlite 30%	Vertical system	12.9	23.6
	Cellulose		12.1	22.4
Red basil	peat 70% + perlite 30%	Growing benches	10.5	20.1
	Cellulose		9.6	19.6
	peat 70% + perlite 30%	Vertical system	12	21.5
	Cellulose		10.9	20.6
Peas	peat 70% + perlite 30%	Growing benches	11.7	12.4
	Cellulose		10.4	11.9
	peat 70% + perlite 30%	Vertical system	12.7	12.8
	Cellulose		11.8	12.2
Sunflower	peat 70% + perlite 30%	Growing benches	11	28, 2
	Cellulose		10.4	27.4
	peat 70% + perlite 30%	Vertical system	13.3	28.9
	Cellulose		12.6	27.5

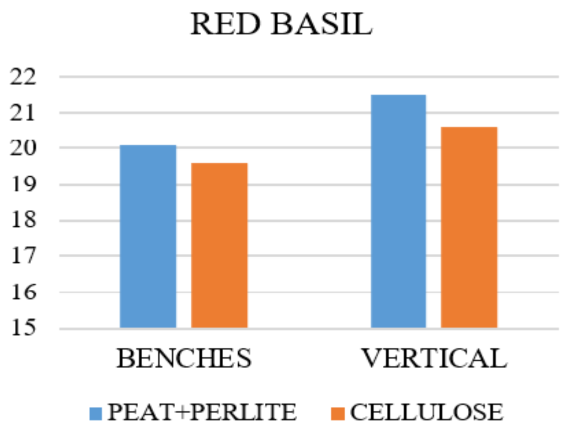
When analysing the information in Table 3, we notice a similar growth rate in terms of height, as all the 4 microgreens species fell within the margin of 9.3-13.3 cm at the moment of harvest. In terms of vegetative mass harvested at the end of the experiment, the 4 species recorded different growth rates, and the maximum was reached by the sunflower microgreens in peat grown in vertical system, with 28.9 g/harvested pot. At the oposite extreme there are the peas microgreens grown on benches, whose average weight was 11.9 g/harvested pot (cellulose substrate).





Graphs 1, 2 Average weights for a pot (grams)





Graphs 3, 4 Average weights for a pot (grams)

The graphs above show the average weight in grams of the harvest corresponding to a pot, but, when calculating the productive potential of a full bench the differences become much more obvious. Thus, we can notice that the most important differences between the two growing systems are found in red basil microgreens, where the vertical system with peat and perlite substrate recorded an additional growth of 2.52 kg, as compared to the same species grown in the normal, ebb&flow system (result calculated for the area of a bench – 12.8 sq. m). A notable difference is also recorded for the radish microgreens, in both substrates: 2.34 kg for peat and 1.62 kg for cellulose. When calculating these differences for a whole year, we reach values of 30.24 kg for basil, 121.68 kg for radish microgreens in peat + perlite and 84.24 kg for red radish microgreens in cellulose substrate. These values correspond to the capacity of a single growing bench

Conclusions

1. Microgreens are a produce that can be obtained in an ecological system, in a very short time. They are easily adaptable to the conditions of a greenhouse or growing room with artificial lighting. They can also be purchased or grown in a household system and they offer a wide range of health-beneficial substances in any season; this is why they are a good source of nutrients, worthy of being included in our daily diet.
2. Microgreens are appropriate for intensive vertical agriculture, particularly due to the reduced height they reach at harvest and their short life cycle. Vertical agriculture is a new model of performant, technologised agriculture, able to produce significant quantities of fresh food in controlled climate spaces, even within or in the proximity of cities, all year round.
3. In the case of all the four species, the analysis of the results shows that the peat and perlite substrate generated an additional growth in weight and height, as compared to the cellulose substrate, both for the vertical and the horizontal (ebb&flow) system.
4. In the case of all the four species, the analysis of the results shows that the vertical growing system had a slightly improved production on the same farming area as compared to the horizontal (ebb&flow) system. This production improvement completes the production improvement via raising the number of levels of the rack.

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