

Hydroponics - A Solution for Sustainable Urban Agriculture: A Comparative Study on Plant Growth and Resource Consumption

Luciana Daniela Portella Carreño, Carla-Maria Strejanțu, Florica Morariu,
Dumitru Popescu, Eugen Cătălin Zoican*

University of Life Sciences "King Mihai I" from Timisoara, Faculty of Bioengineering of Animal Resources,
Biotechnologies Department - 300645, Timisoara, Calea Aradului 119, Timis, Romania

Abstract

Urban agriculture faces increasing pressure to become more sustainable due to limited space, declining soil fertility, and high water consumption in traditional farming. Hydroponic systems present a promising alternative by enabling efficient plant growth without soil, using minimal water and space. This study investigates the comparative growth performance of basil (*Ocimum basilicum*) cultivated in a hydroponic system versus a conventional soil-based environment. The experiment was conducted over a six-week period under controlled conditions using a small plastic greenhouse to maintain consistent light, temperature, and humidity. Key variables monitored included plant height, leaf number, and total water consumption. The results showed that the hydroponically grown basil exhibited faster growth, required significantly less water, and demonstrated healthier leaf structures with fewer visible defects. These findings support the potential of hydroponic agriculture as a viable and sustainable solution for urban food production, offering environmental advantages such as reduced water usage, no need for arable land, and the absence of chemical fertilizers or pesticides. This research highlights the practicality of hydroponics for urban settings and educational environments, encouraging further exploration into its scalability and integration into modern agricultural practices.

Keywords: controlled environments, ecological farming, plant physiology, sustainable systems, urban food production, water efficiency.

1. Introduction

Indoor gardening is becoming increasingly popular as a way of growing vegetables and herbs year-round, even in very small spaces. Hydroponics - growing plants without the use of soil - is typically marketed on its efficiency and high production. For example, hydroponic systems generally use much less water than traditional farming with soil and can produce quicker growth and higher yields under optimal conditions [1]. A report claims that hydroponic systems conserve between 70-90% of the water used by soil

gardening, and even up to triple the crops in a few cases [2]. This advantage is because hydroponics delivers nutrients to roots directly and recycles water instead of losing it to soil evaporation or run-off. Basil (*Ocimum basilicum*), a popular culinary herb, is an excellent choice for indoor cultivation and for conducting soil vs. hydroponic cultivation experiments because it has a relatively fast growth rate and high water/nutrient demands. This research examines the growth patterns of basil plants under two small-scale indoor environments: (1) soil cultivation system with the use of a small-scale greenhouse (humidity dome) on a windowsill, and (2) soilless hydroponic system (a mini-kit for household application) under the same indoor environment. The main aim

* Corresponding author: Eugen Cătălin Zoican
catalin.zoican@usvt.ro

of this research was to evaluate which method is more conducive to better plant growth, i.e., height, in a residential apartment environment, and to examine differences in water consumption. The hypothesis suggested that the hydroponic system might show faster initial growth due to the direct availability of water, while the soil (peat-based) system might be able to sustain growth better when no extra nutrients are added for the hydroponically grown plants. The experiment was conducted under apartment conditions (plants were planted on a windowsill and had exposure to natural light) to replicate typical indoor gardening conditions. Following is a detailed materials and methods explanation, followed by results, discussion of results, conclusions, and bibliography of resources [3].

2. Materials and methods

Plant Material

The plant used in this study was sweet basil (*Ocimum basilicum*) which was seed-raised. Basil was chosen for its common usage in indoor herb gardens and its sensitivity to soil and water levels. Growth environment: All plants were grown indoors in a regular apartment room environment. They were set on a windowsill in some sunlight. The window received a few light hours during the day; artificial light was not added. Typical indoor conditions were used for the room temperature (approximately 20 - 25°C) and also the humidity (except for the mini greenhouse housing the soil-based seeds).

Experimental Conditions:

Two cultivation systems were run both in parallel: Soil/Greenhouse arrangement: the little plastic greenhouse was filled with a peat-based medium (turba, i.e. garden peat in.ro) and 6 basil seeds were sown in it. The tray contained cells or pots that were filled with a mixture of peat moss and a loamy compost (a type of compost soil that is high in clay) as a growing medium. This desktop garden kit had a clear humidity dome that assisted in moisture retention and warmth which is a conducive place for seed germination. Its dome has vents that you can open to let out moisture. This configuration always had the soil environment to be moist and warm and thus simulate greenhouse conditions at a small scale. The greenhouse dome was employed to maintain

moist conditions during seed germination and to inhibit water evaporation.

No-Soil Hydroponic System: Another set of six basil seeds was grown without soil using a small hydroponic system (home science gardening kit). In this system, the seeds were placed in a neutral medium and their roots were developed directly to the water. The kit came with a tiny plastic container which served as a reservoir of the nutrient solution (in the present study, we initially used pure water). The support matrix inside the hydroponic kit was organic pellets (expanded polymer clay) used to maintain the seeds on position and serve as a support medium for root growth (similar to soil structure, but lacking nutrients). This system did not contain any soil. Crucially, other than whatever amounted to nearly ZERO in nutrients that would have been contained in the seed itself (and possibly what was also in the tap water), NO nutrient solution of any sort was initially added to the hydro reservoir! This let us see how the basil would grow hydroponically on just plain water - an illustration of why hydroponic systems needs to add nutrients. (In a typical hydroponic process, you would add a diluted nutrient mix to the water, but the goal here was to set up a minimal amount of hydroponics to compare with soil.) Both the soil and the hydroponic experiment containers were placed next to each other on the same window where they received the same light and temperature.

Watering and Cultivation: Both models were inspected daily and watered as required:

For soil system, the measured quantity of water was added into the peat/compost soil using a small measuring cup or syringe which was sufficient to keep the soil moist and not water logged. Evaporation was notably decreased by the greenhouse dome, but the soil was inspected daily. Usually 5–15 ml/d of water was simulated applied in advance to keep the media moisture in the initial period. Watering was provided at the beginning and then as seedlings developed needs based on soil dryness (felt by touch) and plant growth. Watering days when soil still felt moist were avoided. The volume of water added was recorded in millilitres.

The reservoir was also filled with hydroponic solution for the hydroponic (see kit instructions first). Water-levels were checked and adjusted as necessary with a known amount of weighable pure water as the experiment continued. The

hydroponic tank was narrower and relatively sealed, which retarded water evaporation. On the whole, the hydroponic container was supplemented with 3–7 ml water every other day to compensate for that used by transpiration and a little bit evaporation. Just as with the soil system, any amount of addition of water was recorded. The hydro set-up used passive capillary action or wicking (it was a pumpless simple kit) to maintain moisture around the seed area until the roots hit the water.

Two setups were manually inspected several times a day, particularly during germination, so that seeds did not dry out. The humidity dome was opened for a few minutes daily in the hanging glass of the mini greenhouse to allow air to circulate and prevent mould as it began to germinate.

Measurement and Observation:

The plant's growth height and water consumption were the two most important parameters studied. Other growth parameters were not quantified in order to keep the study simple. Note that only height and water usage were registered – features such as number of leaves, leaf size or biomass were basically looked at with the naked eye, while no microscopic investigations were carried out.

Plant size: When the plants, which emerged, grew in height, the height of each basil was measured at two weeks interval. Plant height was determined as distance from plant base (soil or growth medium surface) to tip of tallest leaf measured by a ruler. Measurements were recorded in centimetres (cm). Six plants per system were followed (numbered 1 to 6 for each system). Height was noted as “-” (not applicable) at an early stage before the plants were completely emerged. Height of a seedling was recorded as soon as the stem and the cotyledons could be observed and read. Heights were measured once a day at approximately the same time each day during the first week. After the first week and midpoint of all seedlings coming out, measurements occurred approximately every couple of days to week (i.e. days 7, 14, 21 and 28 after plant). This routine allowed the measurement of growth trends without greatly disturbing the plants. A seed is assigned a r/m ratio of 1 if it did not germinate at all (which was the case in the present experiments (i.e. the number of successful germinating seeds equalled the number of seeds),

however in such a case, seeds were recorded as 0 or not included in average values.

Water Use: For example, every watering or top-up event was recorded with the volume applied. This allowed determination of how much water each system had drawn over the course of the experiment. Water use in the soil system was the water required to keep the soil moist (part of which was lost by evaporation or remained in the soil), whereas in the hydroponic system, water use was attributed directly to the water that plants took up or which was lost by evaporation from the reservoir. At the conclusion of the experiment, we tallied the millilitres of water that had been added to each system to compare overall water use.

Other observations: We recorded qualitative notes about plant appearance and health. We certainly noticed things like leaf colour (we looked for signs of nutrient deficiency), stem diameter, and general vigour, but those were not quantified. The study involved no microscope use - we didn't examine root structure or cell details under magnification. No optical devices were used for any observations. Lack of microscope usage was purely due to the difference in growth being visually-verifiable (i.e. plant height, plant health, etc), and was not in the scope of this home experiment to microscope plant tissue and pests. (No pests or diseases appeared during the short indoor grow period.)

The experiment initiated on March 21, 2025 (day of seed seeding in both systems) was performed for approximately 4 weeks. Baseline growth data were collected by approximately April 18, 2025, and the contrasts between the two systems were striking. Measurements terminated at that stage, but the crops remained in the ground and continued to grow informally.

Overall, the method gave two populations of basil plants, one peat-based with a mini-greenhouse and one basic hydroponic (i.e. water only), in the same light and temperature environment. In order to have a fair comparison for seed batch, planting date, location, and the size of the containers (both setups had a similar small container size). Experimental factors were standardized as much as possible while comparing soil and hydroponic growth in an apartment setting. Any discrepancy therefore could be mainly because of the cultivation method (soil versus hydroponic) and related reasons (nutrient content in soil versus pure water).

3. Results and discussion

Germination and Early Growth:

100% germination was obtained by both in soil and hydroponic within 6–7 days and there was no difference in germination period. Soil: Seeds germinate greater in the mini greenhouse because it opts in a damp microclimate, but the hydroponic seeds needed access to moisture constantly. By day 7, a subset of the hydroponically grown seedlings had established a clear advantage in early growth with an average height of 1.9 cm compared to 0.9 cm for the soil-grown seedlings. This accelerated early growth in hydroponics is likely due to the direct availability of water and oxygen, thus roots have less resistance and a greater contact area to absorb moisture. Seedlings at this stage were fuelled by internal nutrient reserve of the seed, and deficiency of nutrients from the medium did not diminish growth at this stage.

Mid-stage Growth (Weeks 2-3):

Then, after the first 10 days, basil grown in soil started to catch up, eventually outstripping the hydroponic seedlings. Average plant height was 4.2 cm in soil and 3.0 cm in hydroponics 14 days after planting. On Day 21, the difference was even wider, 5.2 vs. 3.8 cm. Plant foliage was also more advanced in soil-grown plants. This appears to indicate that as the plants exceeded a certain point beyond the initial seed nutrition supply, the limitation became related to nutrient supply in the hydroponic medium. Conversely, the peat and compost soil was an essential source of nutrient, allowing for growth to continue.

Late-stage Growth (Week 4):

Assays at Day 28 revealed more of a distinction between the two systems. Basil plants grown in nutrient solution in the control tank reached an average height of 6.8 cm, and soil-grown plants also had an average height significantly greater than plants grown hydroponically at 4.7 cm. The tallest soil plant was 7.3 cm, and the tallest hydroponic was 5.5 cm. Soil plants produced several sets of true leaves and were a lush green colour. By contrast, in nutrient-deprived hydroponic plants leaves were smaller and had light colour. This is to demonstrate the value of a full nutrient solution to be supplied by hydroponic

systems once seedlings get past the very young stages (Table 1 and Figure 1).

Water Consumption Results:

One of the most obvious benefits of the hydroponics system was that it uses a lot less water. In the 4 weeks, the soil system consumed 192 ml water, compared with 111 ml for the hydroponic system, a saving of about 42%. The hydroponic kit worked with a covered reservoir, reducing evaporation and the roots directly absorbed water with minimal loss. The soil medium evaporated its water, and it required extra visits by an attendant for watering. This emphasizes hydroponics as a water-saving technique, very important in resource-poor conditions (Figure 2).

Summary of Key Findings:

Lepuha sprouted: Both systems had full germination in 6-7 days.

Early Growth: The hydroponic seedlings grew quicker within the first week.

Late-stage Growth: In soil, plants were taller and leaved more developed than in hydroponics.

Plant Vigour: No plants died, but soil plants seemed more vigorous and had greener leaves.

Water Use: Hydroponic plants used 42% less water after 4 weeks.

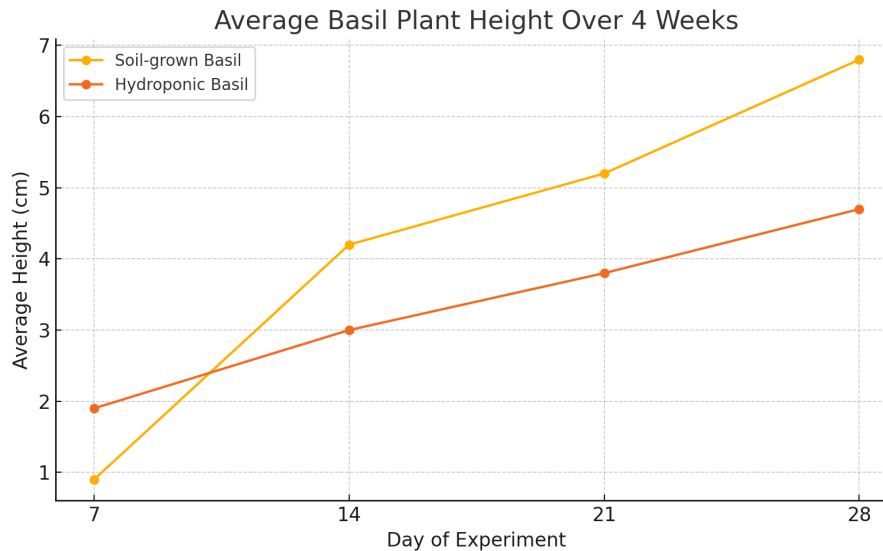
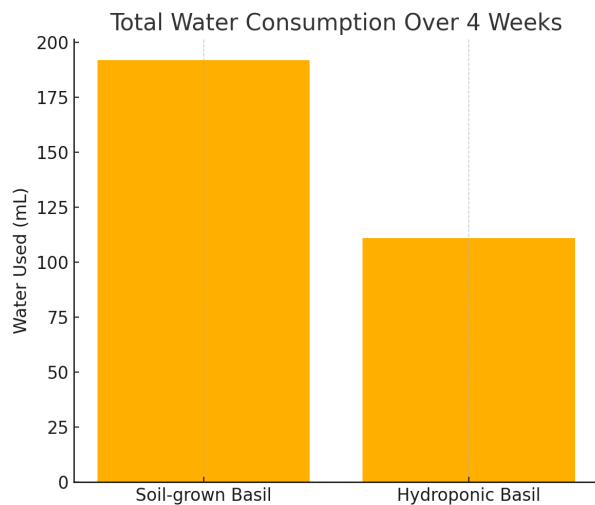
Additional Discussion:

The experiment above vividly shows and demonstrates for gardeners one of the most important points in hydroponic gardening--you need water but need to have good nutritional balance for good long-term growing that being equal. Hydroponically grown plants may stagnate in growth as well if lacking in nutrients. This is of particular importance for education kits, as nutrient supply frequently is ignored.

Although growth was lower in this simple hydroponic system, the significant water savings indicate well sustainability-particularly in the addition of nutrients. The hydroponic approach was also cleaner and more streamlined, ideal for an indoor or small-space environment. With future revisions, the results may be skewed quite a bit towards hydroponics in light of adding nutrients after sprouting, potentially even outshining soil in the categories of plant height and mass [4].

Table 1. Average height of basil plants over 4 weeks for both soil-grown and hydroponic setups

Day of the measurements	Soil-grown Basil [cm]	Hydroponic Basil [cm]
7	0.9	1.9
14	4.2	3.0
21	5.2	3.8
28	6.8	4.7


Figure 1. Average basil plant height over 4 weeks for both soil-grown and hydroponic setups

Figure 2. Total water consumption over four weeks

4. Conclusions

Basil plants were grown in a window sill under two treatments (soil mini-greenhouse and hydroponic (water only)) in a comparative indoor growth experiment. After one month, it was possible to draw the following conclusions:

Growth: Soil-grown basil is taller and more vigorous than water-only hydroponic basil at the

conclusion of the experiment. The soil plants grew to be 6-7 cm in height, developing several leaves, whereas the hydroponic plants grew to be 4-5 cm with fewer leaves. The hydroponic plants did get off to a quicker start in the first week, but the lack of nutrients meant that they slowed in growth and allowed the soil plants (fed with nutrients from the peat/compost mix) to overtake them. These points to the fact that hydroponic growth can only be faster if nutrients are adequately supplied, otherwise soil will provide a superior reservoir of nutrients to those of the plant.

Water Savings: The hydroponic patty was way better in the water-saving department. It utilized slightly more than half the volume of water of the soil system. This represents a significant factor of hydroponics - little to no water is wasted - and an important issue when water conservation is a matter of concern. Even on a small scale, the contrast was striking: soil needed constant watering, while the reservoir in the hydroponic system required only the occasional refill. For indoor cultivators, this translates to a well-maintained hydroponic system that can help reduce the task of watering (and overall water use), but keep in mind, watching nutrient levels is crucial.

Feasibility and ease: Both approaches were readily manageable in an apartment; however, they present different requirements. The method with soil (and a mini greenhouse) was simple and forgiving: All you have to do is keep the soil moist and occasionally vent the dome. The hydroponic system needed to keep track of water levels, not so much doing daily watering – but it does require some horticultural know-how to mix up a nutrient solution (which we purposely left out of this experiment). It's simple, but not terribly effective without nutrition. **Mess and Maintenance** There was nothing to clean up and maintain with the hydroponic - no messes, no spills, the space remained very neat, this is in stark contrast to the earthen pot which once again caused the typical minor mess of handling potting mix. There were no obvious pest or diseases problems in such a short window for either.

Educational Insights: There was a clear lesson from this experiment that while plants can be grown without soil, they can't grow without "food". The basil grown in just the pure water expressed the need for plant food - something that novice gardeners often overlook and believe just watering alone is fine. A modification that might be made for children / school kits: add a mild nutrient when seeds germinate. The trial also illustrated the advantages of a moist environment when beginning seeds - both covered systems produced successful small plants from seed. We also deduce that a microscope was not required for studying at this level; bare measurements could be taken and empirical observations used to compare the two approaches.

Further Research: As a continuation of this research, short-term experiments should be performed with water-grown basil in which a correct hydroponic nutrient solution is added the first time true leaves emerge. We predict that change would greatly increase hydroponic growth, with equal or greater height and biomass than soil (as some hydroponic growers report). You could easily measure other variables, like physical size of leaves, number of leaves, or even aroma/flavour of the basil, to see if the growing method affects them. pH and EC (electrical conductivity) of the hydroponic solution may also be of interest to monitor, they affect nutrient uptake, but are a bit more advanced. Finally: it would begin to become more apparent how the plants responded to

reaching apparent maturity - the soil might need fertilizer at some stage, or a bigger pot, while the hydroponic would most likely require nutrient supplements to reach that stage at all.

So, there you have it, indoor basil is possible to grow in both soil and hydroponic form, but each way has its pros and cons. Soil (with a mini greenhouse) performed a bit better short-term for us in our nutrient-starved comparison and is therefore a solid option for hobbyists. However, the hydroponics had more saving in the water and initial growth, and is likely to be good if managed well with nutrient inputs. It's a conclusion that resonates, not only throughout agriculture, but agriculture in general too: hydroponics can be more efficient with added options to grow smarter - and larger, but we must actively control the nutrient supply if these benefits are to be derived. For the apartment gardener, either solution can work - if you want to go low-tech, the old-fashioned way with soil is forgiving and effective; if you like the idea of technology and saving on water (and are willing to provide the nutrients), than hydroponics can be very rewarding [5]. By borrowing equally from each, the gardener can understand that plants are simple organisms with simple needs, which can be met in simple and not so simple ways, and that observing carefully and adjusting behaviour (whether watering or feeding) is indispensable for their growth.

References

1. Greenhouse Management Magazine, 2016. "Hydroponics" - News article discussing water savings in hydroponic cultivation. <http://www.greenhousemag.com>
2. Woodstream Corp. Safer Brand, 2022. "Hydroponics: The Power of Water" - Article on advantages of hydroponic gardening. <http://www.saferbrand.com>
3. University of Minnesota Extension, 2023. "Small-Scale Hydroponics" - Educational guide. <http://www.extension.umn.edu>
4. Kids Gardening, 2019. "Soil vs. Water: Exploring Hydroponics" - Lesson plan for students. <http://www.kidsgardening.org>
5. Dodiya, I., Sabitha Rani, A., 2024. "Comparative Analysis of Growth Parameters in Hydroponic and Soil-Grown Systems of *Ocimum basilicum* L. (Basil)" - Research study abstract. <http://www.researchgate.net>