# Comparative cultivation of *Spinacia oleracea* grown in Balcony hydroponics and traditional soil systems

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***Abstract:*** The majority of India's population relies on agriculture for food production. With the adverse environmental effects of agricultural practices, increasing levels of pollution and climate change, urbanization, natural disasters, and extensive use of chemicals and pesticides, leading to the depletion of soil nutrients, India's agriculture and food security are destabilized, resulting in loss of crop productivity. As a result, economically depressed farmers commit suicide. In Maharashtra (India), the news of farmers committing mass suicide has recently gained worldwide attention. With the rising world population, the demand for food production is increasing. Developing sustainable methods to increase food production is one of the major concerns of the world. To avoid food crises in the future, strategic planning and development of novel agricultural and planting system techniques are needed. We tested balcony hydroponics with a cost, time, and space-efficient human-centered design strategy. This study attempted to investigate the ability of *spinacia oleracea* in deep water culture (DWC) and Kratky systems compared to the conventional soil-based method with black cotton and red laterite soil. Various morphological characteristics, such as the shoot/root ratio, height, number of leaves, and survival rates of seedlings are compared. The data are analyzed using an unequal variance t-test. The test hypothesis is that the planting systems have a significant effect on the shoot/root ratio of the plant or not. The results indicated that the DWC planting system has a significant effect on plant growth. In addition, compared to the Kratky and conventional soil-based methods, other physiological parameter values are recorded highest in plants grown in the DWC system. The experiment aimed to achieve a planting system that can increase food productivity and practice sustainable farming with minimum cost and natural resources.

***Keywords* – hydroponics, deep water culture, *spinacia oleracea*, Kratky.**

## I. INTRODUCTION

India is home to approximately 640,000 villages that are spread over an area of 3.3 million square kilometers, serving 1.3 billion people, most of whom rely on agriculture for their livelihoods.[1] Agricultural help to India's GDP gradually declined from 38% in 1975 to 16% in 2014. Unsustainable land use, crop rotation patterns including intensive marginal land agriculture, deforestation due to changing cultivation, aggressive land growth caused by globalization, government subsidies for chemical fertilizers, decreasing farmland-to-manpower ratio, and excessive use of irrigation water have intensified land degradation.[2–4] In particular, farmers are the most financially affected by land degradation, as they are the poorest in Indian society. Several research studies have shown that poor farmers in many developed nations have also been the ultimate victims of land degradation.[5–6] Moreover, farmers are unaware about soil dynamics and seed planting techniques. The plants will compete for sunlight, water, and space if the seeds are not sown at a suitable distance, which will affect the growth and production of the plants, destroying the entire crop. Germination rates will be lower and farmers may try to compensate by investing in more seeds without any gain in the yield. Low-quality seeds result from poor seed to soil contact, seeds being covered too deep, bird predation, and overcrowding of plants. As a consequence, soil degradation and water scarcity frequently lead to crop failure, which accelerates the domino suicide effect.[7–8]

Soil-based agriculture faces several challenges, most notably a drop in per-capital land availability. Land under cultivation would further decrease due to rapid urbanization and industrialization as well as the melting of icebergs.[9] In arid and semi-arid regions, reducing agricultural water consumption while sustaining or improving the economic efficiency of the agricultural sector is a major challenge. Techniques such as hydroponics and aquaponics are designed to combat these issues.[10]

Hydroponics is a concept of growing plants using a nutrient solution instead of soil and is one of the most innovative agricultural methods to produce more from less.[11] The nutrient mix consists of major nutrients (nitrogen, potassium, and magnesium), secondary nutrients (calcium, sulfur, and phosphorus), and micronutrients (iron, copper, manganese, zinc, molybdenum, and boron). Hydroponics makes it possible for plants to grow up to 50% faster than in the soil. Fresh products can also be grown from a hydroponic garden, limiting the use of herbicides, pesticides, and a continuous supply of fresh water. Hydroponics saves the use of 80% of the irrigation water and provides crops throughout the year. This innovative technology complements the non-conventional cultivation setting of an urban balcony and is flexible enough to adapt to the preferences of individual users. Comparison between crops in hydroponic systems is not influenced by climate change; thus, it can be cultivated year-round and considered as off-season.[12]

Further, commercial hydroponic systems are automated and expected to cut labor and conventional agricultural practices such as weeding, spraying, watering, and tilling can be eliminated.[13] As the number of plants per unit is higher in hydroponics, higher yields can be achieved. According to Sardare, crops grown in soil-less culture are healthier and consistently more reliable than crops grown in soil.[9]

People can cultivate leafy vegetables, small herbs, and spices on their rooftops and balconies for fresh consumption. The future of hydroponics seems more promising now than any other time in the last 50 years. The start-up costs for the construction of a

hydroponic farm can be higher than the costs of soil-based farming. Therefore, it is important to adopt technologies that reduce human labor and lower overall start-up costs to promote the hydroponics industry.

Recently, NASA has carried out extensive hydroponic research for its controlled ecological life support system.[14] As hydroponics does not require soil for plant growth, it may be helpful for astronauts during their time in space to get their food. Globally, hydroponic yields tend to be at least 20% greater than that of conventional soil culture.[15]

Do-it-yourself systems are becoming popular, expanding the population of hydroponics enthusiasts. This is evident commercially as a large outlet store, IKEA, recently announced its in-home hydroponic system that can fit on a tabletop or a shelf.[16]

One of the simplest and most versatile forms of hydroponics is deep water culture (DWC) system. It consists of plant production by suspending the plant roots in a solution containing oxygenated water rich in nutrients.[17] This method uses a trough or tub filled with aerated nutrient solution to which a floating raft is added that holds the plants with their roots suspended vertically in the water column.[18] Plants are placed in net pots and roots are suspended in a nutrient solution where they grow quickly in a large mass and air is provided directly to the roots by an airstone. It is mandatory to monitor the oxygen and nutrient concentrations, salinity, and pH[19] as algae and molds can grow rapidly in the reservoir. This system works well for larger plants that produce fruits, especially cucumbers and tomatoes grow well in this system.

A suspended net pot, non-circulating hydroponic method, known as the Kratky system, is an innovative and effective technique for growing leafy, semi-head, and small romaine vegetables. It is a very easy and efficient approach to grow plants hydroponically. It requires no pumps, wicks, or electricity and is practically hands-free. The nutrient reservoir must be filled effectively to the brim with nutrients. The same reservoir is used once set up. It contains everything the plant needs throughout its lifecycle. Over time, the roots develop and drink down the reservoir, which effectively oxygenates by creating a pocket of moist air. The first half has air and roots and the second half has nutrients and roots. It effectively uses the plant's desire for water and nutrition to help oxygenate the air and roots. Through capillary action, plants are naturally watered and the entire growing medium in the net pot is moistened. The amount of nutrient solution decreases with plant growth, thereby creating an expanding moist air space that is retained because roots are prevented from drying by the tank cover. The DWC and Kratky methods can be set up at a low cost, using inexpensive and household materials, or even recycled items.

Baby spinach is an attractive choice for hydroponics because it is common as a fresh vegetable and has relatively high concentrations of bioactive compounds such as ascorbic acid, carotenoids, and flavonoids that contribute to its high nutritional value, despite its low caloric content.[20] This study attempted to investigate the potential of growing spinach using different hydroponic systems and compared them to the traditional farming systems.

## II. Materials

The materials required to design the hydroponic systems are as follows:

1) Ten coco peat coin pellets and a source of clean tap water.
2) A suitable germination tray.
3) Eight net pots (depth: 2 inches)
4) Pyrex volumetric container and a 10-liter drum to store solution.
5) Weighing balance, petri dish, spatula, and stirrer.
6) Clean sterile spraying bottle and grow light (18 W).
7) pH meter and calibration liquid.
8) Electrical conductivity meter and calibration liquid.
9) DWC reservoir (48 × 23 × 16 cm) and cover (54 × 25 cm).
10) Two Kratky reservoirs: diameter: 30 cm and depth: 4 cm.
11) Polystyrene sheet and adhesive tape.
12) A 4-watt airpump, 5 mm airtube, and a 4-inch silica airstone.
13) Extension cord and two electricity outlets (for grow light and airpump, respectively).
14) Plank set up and electrical connection for grow light.
15) Spinach seeds (Ugaoo website).

Nutrient media preparation:

1. Add 3 g of micronutrient blend to 1 L of water. Add 3 g of calcium nitrate (amorphous) to 1 L of water. Add 1.5 g of magnesium sulfate to 1 L of water.
2. Stir well until completely dissolved.
3. Mix all of the above 1 L solutions in a 20-liter water container used for nutrient solution storage. The entire formulated solution is then diluted with 2 L of water.
4. The pH and EC of the overall nutrient solution were recorded using pH and EC meters respectively.

For the traditional soil-based systems, the following materials were used:

1) Two opaque pots with small holes at the bottom.
2) Planting soils: black cotton and red laterite soil.
3) Water for irrigation.

For all the systems, a meter tape was used to measure the length of the plant and pH meter was used to check the pH.

## III. Method

The study focused on comparing the growth of plants in soil and hydroponic systems in similar controlled conditions. For the cultivation of spinach, two different hydroponic systems were designed such as the DWC and Kratky systems. Two control setups were constructed with black cotton and red laterite soil.

For the germination stage, selected eight cocopeat pellet coins were hydrated with 25 ml of tap water and were placed in an opaque germination tray in the same line. A small hole was made in the center of each coin and 10 spinach seeds were placed in each hole, and then covered. A total of 40 seeds were placed in each of the hydroponic systems. The germination tray was placed directly under an 18-watt linear tube light such that each pellet coin was equidistant from the source of light. For the control setup, two opaque containers were filled with black cotton and red laterite soil. Forty seeds were placed about 1 cm deep in each system and covered with an additional layer of soil. The soil in both pots was then patted and watered with 100 ml of tap water. Both control setups were placed directly under growing light at the same distance as the pellet coins in the germination tray. No nutrient solution was provided to the control set ups as the nutrients are already present in the soil. During the first week, the coin pellets in the germination tray were watered with 25 ml of water on alternate days. The control set ups were watered with 100 ml of water every alternate day for the entire period of the experiment. In the second week, each pellet coin received 3 sprays of the prepared nutrient solution every alternate day. Upon removal from the germination chamber, coins were inspected for pests and abnormalities. Throughout the experiment, no pests were found in any seedlings. On removal from the chamber, visible seedlings were protruding from the medium and many more young roots were protruding from the bottoms of flats indicating that the germination was successful. Later, the flats were floated in the tubs, where they remained until removal for harvest.

The DWC system consisted of 5400 ml of nutrient solution for four net pots. An airstone was placed centrally in the DWC system and connected to a 4-watt airpump through a 5-mm airtube, which was further connected to an electrical extension. The DWC system was covered using an opaque plastic lid. Four holes were made in the system for the placement of net pots. The Kratky system was divided into two reservoirs, holding two net pots each. Each reservoir contained 2700 ml of nutrient solution. The two Kratky systems were covered using a polystyrene sheet each, held in place using an adhesive tape. Two holes were cut in each system for the placement of net pots. The cocopeat coin pellets were extracted from the germination tray and transplanted into their respective setups. Four coin pellets were placed in four net pots for the DWC system whereas two coin pellets were placed in two net pots for each of the two Kratky systems. The pH and EC of the respective nutrient solution were observed at an interval of 3 days within the 2-week transplanting stage. In the Kratky systems, the roots of the plant were partially submerged within the nutrient solution whereas in the DWC system the roots of the plant were completely submerged within the nutrient solution.

All phases and set ups of the experiment were conducted in the same location having an average low temperature of 25 °C. A spade net was created to generate constant regulation of fresh air and regulate the impact of wind power to distribute wind evenly across all set ups. Each plant was kept at a distance of 8 inches from the grow light for 10 hours per day, recording 8,000 lumens. pH between 6.0 to 7.0 and EC of 1390 µS/cm were maintained throughout the growing period of spinach.

After conducting the experiment, the results of the two hydroponic systems were analyzed and compared using a statistical approach to support the hypothesis of the study. The experiment levels and variables were identified and then analyzed by unequal variance t-test software to test the hypothesis, whether the hydroponic system is better than the traditional system or not.

Other main parameters recorded in this study were the height of the plant, survival rate of seedlings (%), germination time, and the number of leaves. Survival percentage was calculated using the formulae:

$$\text{Survival percentage} = \frac{\text{Total number of surviving seedlings}}{\text{Total number of transplanted seedlings}} \times 100$$

Comparisons were then made between plants grown in the control systems to a) plants grown in the DWC and b) Kratky system.

## IV. RESULTS AND DISCUSSION

The whole experiment took 30 days to complete. The growth of the plants was measured for 28 days starting 19 August, 2020 till 15 September, 2020. The height of the plants and the shoot/root ratio indicate any difference in growth.

Table 1: Average shoot/root ratio, height, number of leaves, and germination rate.

| Planting system | Shoot/root ratio | Number of leaves | Germination rate (%) | Height (cm) |
|---|---|---|---|---|
| DWC | 3.47 | 36 | 95 | 12.83 |
| Kratky | 2.67 | 30 | 82.5 | 13.60 |
| Black cotton soil | 2.04 | 3 | 15 | 10.5 |
| Red laterite soil | 1.97 | 3 | 7.5 | 13.26 |

**Fig. 1 Germination chamber**

**Fig. 2 Control setups- a) Red laterite soil b) Black cotton soil**

**Fig. 3 DWC system**

**Fig. 4 Kratky system**

**Fig. 5 Soil-based and hydroponic systems (Whole setup)**

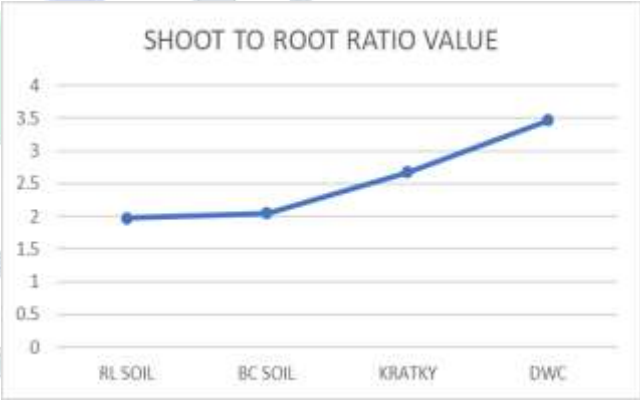


**Fig. 6 Plants shoot/root ratio after 28 days**

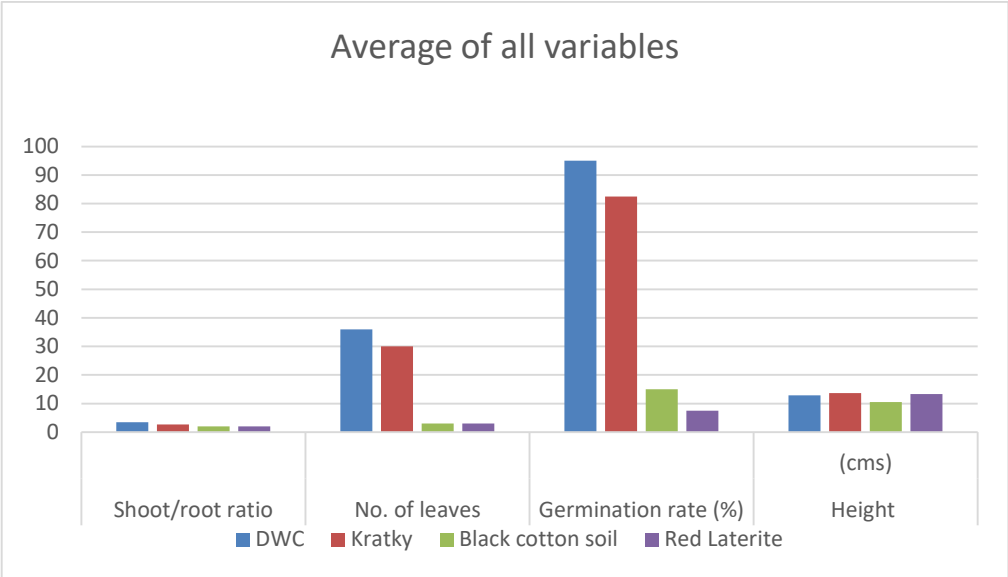


**Fig. 7 Average of all variables**

Statistically, values of $p \leq 0.0500$ indicate model terms are significant whereas values greater than 0.500 indicate the model terms are not significant. According to the results from the t-test of unequal variance software, the *p* value of the DWC system compared with the black cotton soil was less than 0.05, whereas the *p* value of the Kratky system was not statistically significant. This indicates that the cultivation system did have a significant effect on the shoot/root ratio of the plants. The shoot/root ratio in the DWC system was significantly higher than that of the control setups. (Fig. 5)

Hydroponic system: The average height of plants in the DWC system was 12.83 cm and that in the Kratky system was 13.60 cm. The average number of leaves was 36 in the DWC system and 30 in the Kratky system. The highest survival percentage of seedlings was observed in the DWC system (95%) followed by the Kratky system (82.5%).

Soil-based system: The average height of plants was 10.05 cm in the black cotton soil system and 13.36 cm in the red laterite soil. The average number of leaves in black cotton and red laterite soil was 3. The lowest germination rate was observed in red laterite (7.5%) and black cotton soil (15%).

The data shows treatments that are planted using a hydroponic system did germinate and grew faster than traditional soil systems. The difference in the speed of growth was evident in the height of the plants. As for the length of the leaves, the differences were negligible. The results showed that the highest values of all physiological parameters were obtained from plants grown in the hydroponic system. Survival and growth are usually increased because of intensive contact between the roots with growing media and the nutrients and water holding capacity of the container media.[21] The hypothesis of the experiment is accepted for changing the planting system will influence the plants' shoot/root ratio. In this case, the hydroponic system has a better effect as it makes the plant grow faster and more efficiently.

The experiment can be conducted on a larger scale for future work to study whether the hydroponic system will satisfy present and future consumer needs. Various factors such as soil type and solution type should be considered while experimenting on a larger scale. Also, the period of the experiment should be extended as new changes may appear after a certain period. Another aspect is the type of plants. In this experiment, only one plant type was considered. However, the experiment can be performed with different types of seeds to test if the results can be applied to more plants.

## IV. CONCLUSION

The goal of this study was to discover an efficient lab to land transfer technique for an alternative agri-farming method, the hydroponic system, towards a sustainable agriculture farming approach. This experiment tested two farming systems to compare and find the best system that covers current and future demand with the lowest cost and use of natural resources. It is about time to comprehend the importance of man's two most precious commodities: land and water, to safeguard millions of farmers whose livelihoods depend on them. A large section of the farming community outside the loop is still unaware of technological developments in the field of agriculture. The farmers need to be informed on the importance of soil health and the distance between the seeds to avoid overcrowding of plants. A more holistic approach should be implemented at the farm level, to create awareness on the soil health, interactions among the new products and microflora, and soil dynamics. This may increase awareness among land and water resource managers, policy-makers, and politicians to undertake measures to become more proactive and creative in connecting with the rural population and mitigate the issue of mass farmer suicides. Furthermore, it is necessary to develop low-cost techniques that are easy to operate and maintain, require less labor, and lower overall set-up and operating costs to build a successful commercial hydroponic technology.

In addition to the technical benefits of hydroponics, there are psychological and environmental benefits as well. High water content and high plant density lead to an increase in the levels of oxygen produced by hydroponic gardens versus soil gardens. In a city with a high level of pollution, hydroponics could help clean air through photosynthesis which consumes the greenhouse gas carbon dioxide and releases oxygen. Psychologically, hydroponics can provide people a deeper connection to growing because they can see the roots of plants and can be creative in the design. It has less maintenance than a typical soil system and can also serve as a stress reliever. Hydroponics provides an opportunity for an overall economic, social, and environmental improvement in society.

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