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A Comparative Study on The Growth Performance of *Spinacia oleracea* L. (Spinach) in Hydroponic and Soil-Based Systems

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ABSTRACT

In order to cultivate spinach, this study compared soil and hydroponic growing methods. A soilless method known as hydroponic farming offers fresh veggies in harsh environmental conditions on a limited amount of arable land. An open, naturally ventilated region served as the experimental site. The hydroponic structures included a nutrient film technique (NFT) system, EBB and flow systems, and a soil-based system optimized for green crop growing. The results indicated that compared to EBB and flow systems, as well as soil systems, spinach produced in the NFT system had significantly improved plant growth characteristics, including plant height, number of leaves, leaf area, fresh weight, and yield, when compared to other systems under study, the NFT system had higher levels of nutrients (Ca, Mg, K, Na, B, Fe, Zn, Co, and Ni) in water as well as N, P, K, Ca, Mg, Na, B, S, Fe, Zn, Cu, Mn, Cd, Co, and Ni elements and this study showed that spinach grown in NFT systems yielded noticeably larger yields with improved nutritional quality compared to soil-grown systems. When growing veggies that are high in nutrients but need little water and arable land, hydroponic systems are a good option.

Keywords: *Hydroponics, Nutrient film technique, EBB & flow system, Soil based system, Spinach*

1. Introduction

Significant environmental harm is caused by the global food production system, which also uses an enormous number of resources. Agriculture constitutes 60-70% of the total global water consumption, as reported by FAO in 2019. The practice of cultivating soil is currently encountering challenges due to various human activities, including industrialization and urbanization, soil fertility and quality depletion are caused by sudden natural disasters, climate change, and uncontrolled exploitation of chemicals for agricultural reasons [1-2]. Soil is not essential for the growth and survival of plants. Any substance with sufficient nutrients to sustain plant growth can function as soil or a ground surface. Hydroponics is cultivating plants in a water-based environment devoid of soil by providing them with a mineral solution. The practice of cultivating soil is currently encountering challenges as a result of various human activities, including industrialization and urbanization. In addition, abrupt natural calamities, climate change, and unregulated use of chemicals for agricultural purposes contribute to soil fertility and condition. Researchers have devised a new method for agriculture called soil-less agriculture or hydroponics. Hydroponics is a farming technique that involves cultivating plants in water and nutrients [3]. More research needs to be conducted to compare the output or growth rates of plants in aquaponics to those in soil-based or hydroponic systems. Aquaponics is a hydroponic production system that relies on water to deliver nutrients. Hydroponic plant cultivation techniques are highly efficient for horticulture [4], making them an ideal benchmark for comparing with aquaponics, hydroponics is a well-established and commercially successful horticultural production method widely utilized worldwide. It has comparable capital expenditure and production expenses to aquaponics, particularly plant cultivation. Hence, determining the plant production rates in aquaponics compared to hydroponics can provide insights into the economic and financial feasibility of aquaponic plant production systems and techniques [4].

In the Chenopodiaceae family, spinach (*Spinach oleracea* L.) is an annual cool-season crop commercially produced using seeds in dry soil either in hills or disseminated. It is among Egypt's most important vegetable crops with shallow roots and leaves. Fresh, steamed, quickly cooked, frozen, and canned spinach leaves are exceptionally high in nutrients. Furthermore, according to [5-6] it is regarded as a good source of dietary fibers, minerals (potassium, calcium, magnesium, iron, manganese, and selenium), and numerous vitamins (A, B2, B6, B9, C, E, K, and folate), it is abundant in flavonoids, p-coumaric acid derivatives, and uridine [7]. These compounds have been shown to have anti-oxidative [8-9] qualities crucial for maintaining human health. Due to its effective use of natural resources, particularly in regions where soil and water constrain plant development, hydroponic agriculture is gaining popularity globally. It also contributes to the fight against climate change and yields high-quality food [10].

The study aimed to evaluate and contrast traditional soil-based farming with hydroponic cultivation systems—specifically, NFT and EBB & flow—to produce spinach. With an emphasis on plant height, number of leaves, leaf width, and mineral nutrient concentrations between NFT, EBB, and flow hydroponic systems and soil-based systems for growing spinach crops, the study attempts to assess and compare plant growth characteristics and nutritional quality.

Citation: D. Indira and A. Sabitha Rani (2024). A Comparative Study on The Growth Performance of *Spinacia oleracea* L. (Spinach) in Hydroponic and Soil-Based Systems. *Agriculture Archives: an International Journal.*
DOI: https://doi.org/10.51470/AGRI.2024.3.2.19

Received on: April 19, 2024
Revised on: May 20, 2024
Accepted on: June 19, 2024

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2. Materials and Methods

2.1 Nutrient Film Technique

Like the floating root system, this NFT technique involves partially submerging the plant roots in the nourishing solution, but rather in a liquid stream that travels through a pipe system. NFT uses less nutrient solution than the floating root system, but it still needs more energy and parts to function. The flow of nutritional solution can be either periodic or continuous, with the excess solution gravitationally returning to the storage tank [11].

2.2 Ebb and Flow system

This hydroponic system is the first to utilize the flood and drain technique. To give plants moisture and nutrients, nutrient solution and water from the reservoir are pumped through a water pump to the grow bed until they reach a specific level and remain there for a set amount of time. Furthermore, while it is possible to cultivate various crops, root rot, algae, and mold are common issues. Consequently, a modified system with a filtration unit is necessary. Plants are set up in a tray that is frequently topped off with water pumped from a reservoir below and rich with nutrients. [12] state that the system uses gravity to return the water to the reservoir for further use.

2.3 Soil preparation

Digging into the soil assisted in loosening it in preparation for planting. This process can improve aeration and raise nutrients to the top. Raiding a flat piece of metal or wood over the surface levelled it. Doing this may prevent loose soil from washing or blowing away. It can also aid in more uniform irrigation watering of the field. It's time to plant after the soil has been ready and remove any debris from the soil. Make a furrow, which is a long, thin trench. At uniform intervals, drop the seed into the furrow. Cover the seed with dirt. With every crop they plant, planters are fine-tuned. They plant seeds at precise intervals and dig them down to the proper depth for the state of the soil at that time. In natural soil, we applied the general forming approach in this study. Digging into the soil revealed a suitable spot to sow the seeds. They inserted the seeds about 1 centimetre into the ground. Periodically assessed the moisture content of the soil and applied water as needed [13].

2.4 Standardization of hydroponic protocol for *Spanacia olerecia* (NFT, EBB and soil)

a) Selection of Spinach Variety: selected spinach (savoury variety) for hydroponic cultivation.

b) Preparation of Hydroponic System: We chose a hydroponic system such as the nutrient film technique (NFT) appropriate for growing spinach, and we carefully cleaned and disinfected it using EBB and flow to stop the growth of infections.

c) Nutrient Solution Preparation: We measured and combined the necessary amounts of macro and micronutrients by published formulations or manufacturer guidelines for hydroponically grown spinach. To get the best results for spinach, adjust the pH of the nutritional solution to between 6.0 and 6.5.

d) Seed Selection and Germination: The seeds were germination-treated either directly in a germination tray containing organic soil or with a preferred approach, like germination on paper towels.

e) Transplantation: Carefully transfer the seedlings into the hydroponic system after they have sprouted true leaves and the seeds have germinated.

f) Environmental Control: Maintained the ideal growing environment for spinach, concerning temperature (18–24°C), humidity (60–70%), and light intensity (12–16 hours each day).

g) Harvesting: Harvested spinach leaves, usually 4-6 weeks post-transplantation, when they reach the required size. Trim the leaves slightly above the plant's base with clean, sharp scissors to encourage regrowth and more harvests.

2.5 Comparative analysis of growth parameters of hydroponic and soil-grown systems

a) Experimental Design: Implemented measures to maintain consistent environmental conditions, including temperature, humidity, and light, to reduce the impact of confounding variables on both systems.

b) Selection of Planting Medium: For the soil-based system, select a conventional potting mix or soil typically used for vegetable production. A hydroponic media and standardized nutrient solution for the hydroponic system will be used.

c) Preparation of Experimental Setup: Establish equivalent containers or plots for hydroponically and soil-cultivated spinach. Ensure that each treatment group consistently receives equal quantities of water, light, and nutrients throughout the experiment.

d) Planting and Maintenance: Concurrently sow spinach seeds or seedlings in soil-grown and hydroponic systems. Continue to provide both treatment groups with regular upkeep and care, such as fertilizer, pest control, and watering.

e) Data Collection: We have systematically measured and documented growth parameters consistently throughout the trial.

2.6 Methodology for plant growth parameters to monitor the growth in hydroponics and soil-based system plants:

a) Germination Percentage The germination percentage (GP) is frequently used to assess the potential for success of a seed population. The equation to calculate GP is
GP = seeds germinated/total seeds x 100.

b) Plant height: Determine the vertical distance in centimeters (cm) between the base of the stem (at the soil surface) and the highest point of the plant, which could be either the top of the canopy or the highest section of the plant.

c) Breadth of leaf: The leaf width (W) is the maximum distance between any two points on the blade edge parallel to the leaf length axis, which connects the leaf apex and base.

d) Length of leaf: Determine the length of the leaf by measuring from the top of the leaf to the point where the lowest leaflets meet the leaf stem.

e) Stem diameter: To determine the distance between the center of the handlebar clamp and the center of the steerer tube clamp, utilize a measuring tool such as a ruler, tape measure, or digital calliper.

Ensure you measure the distance between the center of one clamp and the center of the second clamp.

f) Leaf number per plant: Enumerate and quantify the quantity of leaves on every individual plant. Enumerate all discernible foliage on the plant, encompassing the apex of budding leaves in the early stages of emergence.

g) Preparation of Nutrient Solution:
Hydroponics uses dissolved plant nutrients, typically in the form of inorganic and ionic forms, in water. We used different chemical combinations to provide 17 essential components for plant growth. We used a modified Hoagland nutrient solution for leafy crop hydroponic cultivation. To prepare the nutrient solution for spinach, basil, and strawberries, combine one liter of nutrient solution in a tube well with one litre of water.

h) Modified Hoagland Nutrient solution component: Composition: $Ca (No^3)_2\ 4H_2O$ – 202g/L; Iron EDDHA- 5.6 g/L; KH_2PO_4- 136 g/L; KNO_3 – 133 g/L; $MgSo_4\ 7H_2O$ – 58.1 g/L; H_3BO_3 – 2.83 g/L; $ZnSo_4\ 7H_2O$ – 0.22 g/L; $MnCl_2\ 4H_2O$ – 0.20 g/L; $CuSO_4\ 5H_2O$ – 0.08 g/L; $NaMoO_4\ 2H_2O$ – 0.12 g/L.

2.7 Nutrient analysis in water for Hydroponics
Physiochemical parameters like pH, EC, Dissolved oxygen, Nitrates, Ammoniacal nitrogen, sulphate, phosphate, calcium, magnesium, Sodium and potassium and macro and micronutrients like Ca, Mg, K, Na, B, Fe, Zn, Co and Ni were analysed by using the standard protocols mentioned in APHA 23rd edition.

2.8 Nutrient analysis in soil
The physiochemical parameters like pH, Ec, organic carbon and nutrient contents (N, P, K, Ca, Mg, Na, B, S, Fe, Zn, Cu, Mn, Cd, Co and Ni elements) in spinach grown soil sample by using standard protocols mentioned in ASTM 2006.

3. Results and Discussion

3.1 Plant growth comparison of Spinach in NFT, EBB & Flow and Soil based system:
This study investigates the plant growth, morphology, and yield features of spinach grown in two distinct hydroponic systems: Nutrient Film Technique (NFT) and EBB& Flow hydroponics systems and traditional soil systems. Figure 1 compares spinach's growth, morphology, and yield-related characteristics cultivated in hydroponic NFT, EBB & Flow, and Soil-based systems. The study examines several environmental growing circumstances, such as plant height, length of leaf, leaf number per plant, width of leaf, stem diameter, and root length. The spinach showed notable variations in the characteristics when cultivated in the NFT system under diverse environmental circumstances.
The NFT system yielded the highest plant height of spinach (7.02±0.59cm), while the EBB & Flow system followed with the lowest plant height (10.82±0.64cm). Soil-based methods yielded the lowest plant height (7.02±0.60cm).
The NFT system had the most significant number of leaves per plant (26.5±5.48), whereas soil-based systems had the lowest number of leaves per plant (10.7±1.5 b). Compared to crops grown in soil-based systems (1.12±0.11cm2) and EBB & Flow systems (1.21±0.15cm2), the leaf area of spinach grown in the NFT system (2.69±0.29cm2) was significantly greater (P<0.05). It might be possible because more leaves provide more photosynthetic products and a higher photosynthetic reaction. In the spinach crop, the NFT system (3.55±0.28cm and 13.1±1.15cm) showed the highest values for stem diameter and root length, followed by the EBB & Flow system (2.89±0.35cm and 11.04±0.66cm) and soil-based systems (2.74±0.33cm and 10.8±0.62 cm) with the lowest values at P<0.05.

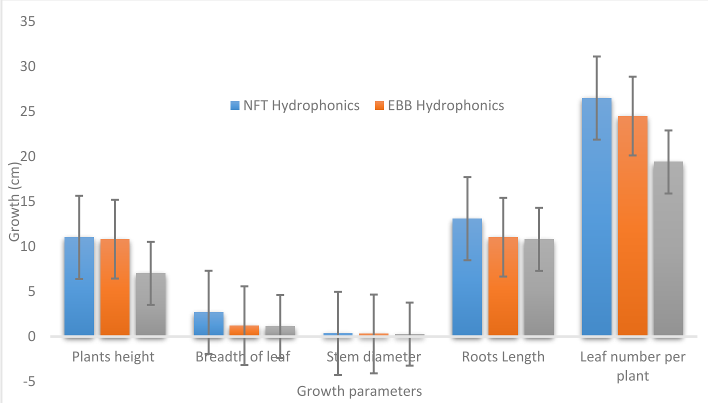

Figure 1: Comparison of growth parameters in Hydroponics and soil grown spinach. Comparing the growth and other attributes of spinach grown in soil-based and hydroponic systems (NFT & EBB), we found that the NFT hydroponics system produced the highest yields, while the soil-based system grew the least amount of spinach.

The proper nutrient supply to the plant determined the plant height of spinach crops. Better plant height results from providing balanced nutrients to plants produced in hydroponic systems. [14] also noted similar outcomes. The order of plant height and other metrics produced by spinach crops was NFT system>EBB & Flow system>soil-based system. Compared to soil-grown crops, the hydroponic system yielded a noticeably larger crop of leafy greens, which improved the NFT system's production per plant by increasing plant height, number of leaves, leaf area, and root length.
Our findings concur with those of [15], previous research has also shown that in hydroponic culture, nutrients are the main elements influencing plant growth and biomass production [16]. There was a considerable connection between leaf area, number, and fresh biomass [17]. According to the growth study, a vertical hydroponic system can significantly increase the yield of spinach and lettuce. The benefits of hydroponic farming include higher yield per unit area and water conservation. Compared to conventional farming, hydroponic crop production significantly lowers water loss and boosts fertilizer use efficiency [18-23]. According to preliminary evaluations, the hydroponic system in an inexperienced home is a great alternative to current methods for nutrient delivery and ambient conditions that provide the highest quality crop production. [23] in terms of input use and crop production advancement, hydroponic greenhouse farming is a better option with comparable outcomes [25].

3.2 Comparison of Physiochemical and micronutrients in NFT, EBB & Flow and Soil based system
The current study observed both soil-based and hydroponic systems for a year. Ten samples from each system were examined each month, and Table 1 displays the results of basic statistical analysis.
NFT hydroponic systems with spinach grown under varying growing conditions demonstrated significant effects (P<0.05) on plant quality parameters, such as pH, EC, dissolved oxygen,

nitrates, ammoniacal nitrogen, sulphate, phosphate, calcium, magnesium, sodium, and potassium concentrations in the inlet and outlet waters. Upon examining the physiochemical and micronutrient properties of spinach cultivated in a hydroponic system, the inlet water had pH levels ranging from 6.23 to 7.25, with an average value of 6.70±0.30. Conversely, the outflow waters displayed slightly higher pH levels, ranging from 6.24 to 7.85, with an average value of 6.91±0.48. The outflow waters had very low values, ranging from 202 to 234 µs/cm with a mean value of 215±8.33, while the inflow waters had very high values, ranging from 1818 to 1890µs/cm with a mean value of 1854±23. The outflow water's organic matter was degraded entirely, responsible for the most significant decrease in conductivity values.

Since dissolved oxygen is essential to plant growth, insufficient oxygenation can cause crop stress, root diseases, and, in certain situations, complete crop loss. The recommended limits are 5 mg/L and higher dissolved oxygen (DO), as lower concentrations are harmful and may even prove lethal to plants. Increased nutrient intake and conversion efficiency result from higher dissolved oxygen levels, which promote root growth and development and vegetative and blooming traits. The study's intake water DO levels ranged from 6.22 to 6.85 mg/L, with a mean value of 6.42±0.82. On the other hand, the outflow waters' DO levels were similarly well-maintained, ranging from 5.14 to 5.58 mg/L with a mean value of 5.28 ±0.27 mg/L.

In hydroponics, the ratio of ammonium (NH4+) to nitrate (NO3-) in a fertilizer solution can impact plant growth and uptake of nutrients. The two primary inorganic nitrogen forms that plants can absorb are NH4+ and NO3-, and they have distinct functions in photosynthesis, mineral absorption, and water absorption. The mean values of ammoniacal nitrogen and nitrates in the incoming waters are 144±24.73 and 13.93±0.34 mg/L, respectively, and range from 118 to 188 mg/L and 13.18 to 14.32 mg/L, respectively. The mean values of the other nutrients, such as phosphates and sulphates, were 19.67±3.17 mg/L and 26 to 34 mg/L, respectively.

Table 1: Comparison of inlet and outlet waters of hydroponic systems

Parameter	Inlet water				Outlet water			
	Min	Max	Mean	Std	Min	Max	Mean	Std
pH	6.23	7.25	6.70	0.3	6.24	7.85	6.91	0.48
EC	1818	1890	1854.42	23.3	202	234	215	8.33
DO	6.2	6.85	6.42	0.18	5.14	5.58	5.28	0.27
Nitrates	13.18	14.32	13.93	0.34	0.78	1.22	0.99	0.13
Ammoniacal Nitrogen	118	188	144.33	24.73	14	22	19	2.46
Sulphates	26	34	30.83	2.48	0.9	9.94	5.74	2.91
Phosphates	14	24	19.67	3.17	1.2	4.58	2.61	1.1
All the units are mg/L except pH; EC (µs/cm).								

The concentration of nutrient solutions significantly impacted the nitrate contents in hydroponic culture [26]. The most frequent factor affecting plant development and production is the level of nitrate. One might argue that leafy vegetables are the primary source of nitrate intake for humans [27-30]. Similarly, the soil system recorded the lowest phosphate content, and the vertical NFT system revealed the considerably (P<0.05) highest values of phosphate content in spinach and lettuce. Green leafy vegetables are a common source of phosphorus, part of several essential compounds that sustain life [31]. Similarly, the vertical NFT system showed the highest sulphate level, followed by the horizontal NFT system, non-circulated soil, lettuce, and spinach. Overall, lettuce accumulated more phosphate and sulphate content than spinach, while spinach had a noticeably higher nitrate concentration than lettuce [32] also reported similar outcomes. When compared to soil, the hydroponic production system substantially impacted the primary and secondary nutritional content of the plants. According to [33] crops collected from soilless culture had higher potassium, phosphorus, and nitrate levels than crops grown in soil culture. In hydroponic systems, the plant growth periods maximize the delivery of nutrients and oxygen. It increases the yield of crops and the nutritional quality of plant output [34-35].

3.3 Nutrients in hydroponics water and soil

Table 2: Nutrients concentration of hydroponics water

Parameter	Inlet water				Outlet water			
	Min	**Maximum**	**Mean**	**Std**	**Min**	**Maximum**	**Mean**	**Std**
Ca	50.66	87.95	78.86	11.80	16.00	25.00	20.58	3.09
Mg	23.73	41.77	36.51	5.18	6.00	16.00	11.08	2.61
K	13.83	20.09	17.42	1.65	4.00	8.00	5.25	1.42
Na	71.87	128.00	112.94	17.37	18.00	32.00	25.08	3.85
B	0.06	0.11	0.09	0.02	0.02	0.04	0.03	0.010
Fe	0.11	0.21	0.16	0.03	0.03	0.05	0.04	0.000
Zn	0.01	0.06	0.03	0.01	0.00	0.01	0.01	0.000
Co	0.05	0.07	0.06	0.01	0.01	0.02	0.02	0.000
Ni	0.0025	0.0033	0.0026	0.0002	0.0020	0.0020	0.0020	0.0000

The values are statistically significant at $P \leq 0.05$. Units for all the values mg/L

Table 2 lists the nutrients found in spinach cultivated hydroponically. The results showed that nearly all nutrients were considerably higher in hydroponic systems than in soil-grown spinach (P<0.05).

Nutrient levels in input water were noticeably more significant than in exit waters. It was discovered that nutrients such as Ca, Mg, K, Na, B, Fe, Zn, Co, and Ni were significantly excellent in input water (Table 2). The amounts of Ca and Mg varied between 50.66 and 87.95 mg/L and 23.73 and 41.77 mg/L, with mean values of 78.86± 11.86 and 36.51± 5.18 mg/L, respectively. The outlet water had much lower values of these elements. Similarly, the mean values of Na and K were 112.94± 17.37 and 17.42± 1.65 mg/L, respectively, ranging from 71 to 128 and 13.83 to 20.09 mg/L. The highest concentrations of B, Fe, Zn, Co, and Ni, among other micronutrients, were determined to be 0.11, 0.21, 0.06, 0.07, and 0.0033 mg/L.

According to the current study, the soil sample cultivated spinach has different physiochemical characteristics, such as pH, Ec, organic carbon, and nutrient concentrations (N, P, K, Ca, Mg, Na, B, S, Fe, Zn, Cu, Mn, Cd, Co, and Ni elements) (Table 3).

Table 3: Nutritional composition of soil used for the growth of spinach.

Parameter	Min	Maximum	Mean	Std
pH	7.09	8.65	8.01	0.56
EC(Ms)	0.11	0.18	0.14	0.03
OC	0.05	1.34	0.52	0.05
Total-N	362	1470	782	32
Total-P	175	645	285	126
Total-K	393	2236	795	659
Total-Ca	1908	20638	14599	6493
Total-Mg	1142	2700	1771	685
Total-Na	234	423	334	68
Total-B	24.15	120	54.61	32.88
Total-S	64	499	222	196
Total-Fe	8874	16533	10793	2722
Total-Zn	8.39	38.05	16.85	9.66
Total-Cu	6.67	14.59	10.21	3.07
Total-Mn	159.69	328.35	248.48	57.68
Total-Cd	0.09	0.73	0.33	0.21
Total-Co	6.67	12.18	8.13	1.84
Total-Ni	8.19	29.03	12.73	7.43

The pH of the soil samples in which the spinach was cultivated ranged from 7.09 to 8.65, with a mean value of 8.01±0.56. The electrical conductivity and organic carbon (OC) levels ranged from 0.11 to 0.18Ms/cm and 0.05 to 1.34%, respectively, with mean values of 0.14±0.03Ms/cm and 0.54±0.05%, respectively. For optimal results, spinach thrives in soil with a pH of 6.5 to 8 and an electrical conductivity (EC) range between 1.8 and 2.3. It is worth noting that soil organic carbon is typically found in higher concentrations in the topsoil. The organic carbon content of most highland soils typically falls between the range of 0.5% to 3.0%. According to [36] cation antagonism is a major factor influencing the lower absorption of cations at low pH (high hydronium ion concentrations). [37] also noted decreased cation concentrations in the leaves of geranium plants grown on low-pH substrates. Results suggested that cations and hydrogen ions competed for root binding sites, that low-pH stress affected the activity of cation channels and membranes, or that there was less uptake into the shoot tissue.

Three key elements nitrogen (N), phosphorus (P), and potassium (K)—are necessary for all plant life activities. N and P are crucial constituents of various vital organic compounds, including proteins, amino acids, nucleic acids, enzymes, vitamins, and numerous others. These compounds are essential for multiple biochemical and physiological processes encompassing plant growth and development. Additionally, potassium is necessary to properly function many plants metabolic processes. It does this by accelerating the translocation of assimilates and other solutes from plant leaves to edible plant parts, which improves quality parameters. Potassium also plays a critical role in the relationship between plants and water. According to [38] satisfactory vegetable development, production, and quality require the addition of N, P, and K elements to the crops through external treatments.

The soil's N, P, and K levels had mean values of 782±32, 285±12, and 795±59 mg/kg, respectively, varied from 362 to 1470, 175 to 645, and 393 to 2236 mg/kg. Table 2 provides the other nutritional content. It is possible to attribute the increases in spinach yield and its constituent parts that resulted from the optimal combination treatment of NPK fertilizer ratios and levels to the stimulatory effects of the nutrients potassium, phosphorus, and nitrogen on the activation of significant physiological processes and the biosynthesis of vital plant organic components required for good plant vegetative growth traits (Table 2). The findings presented by [39-41] are consistent with these discoveries.

Compared to soil-grown spinach, hydroponically grown spinach has the highest nutritious value. According to the current research, spinach grown in hydroponic systems showed higher mineral concentrations (mg/kg) of Ca, Mg, Na, B, S, Fe, Zn, Cu, Mn, Cd, Co, and Ni than in soil. The results of the current experiment agree with those of Monsees, [42] and [43]. Hydroponic technology can control temperature, water, and nutrient levels to grow premium, soil-compatible vegetable crops. Increasing the macro- and micronutrient compositions of the growth solution does not necessarily translate into increased leafy vegetable yield and quality. Compared to soil-grown systems, hydroponic spinach exhibited superior quality and production, faster harvesting, and a higher nutritional content based on macro- and micronutrient profiles [44]. Overall, improved fertilizer control by the hydroponics system resulted in higher spinach yield. It is essential to support hydroponic systems in arid and semi-arid regions were finding arable land and irrigation water for growing vegetables high in nutrients is challenging.

4. Conclusions

Hydroponics has gained popularity as a promising crop-growing method in recent years. Given the year-round feasibility of growing short-duration crops like vegetables in small places with minimal labour, hydroponics can benefit impoverished and landless areas and areas with limited soil and water resources. This study aimed to investigate soil and hydroponic growth rates the hydroponic system by growing spinach compared to the conventional soil system. After evaluating the data and findings, we may infer that the hydroponic system is superior to the traditional soil system. The end outcome unequivocally demonstrates that the hydroponic planting method outperforms the conventional method in effectiveness. Plants grown in hydroponic systems grow more quickly. The plant's height, stem diameter, leaf size, and leaf number all exhibit this impact, indicating a higher yield. By conducting this experiment on a larger scale in the future, it will be possible to meet the demands of the current futures market.

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