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N Tripathy
School of Studies in Life Science, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh, India

D Mohan
School of Studies in Life Science, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh, India

T Patel
School of Studies in Life Science, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh, India

M Sahu
School of Studies in Life Science, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh, India

L Prabhas
School of Studies in Life Science, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh, India

Corresponding Author:
N Tripathy
School of Studies in Life Science, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh, India

A review study on cultivation of cultivars in hydroponic (Ebb and flow) technique

N Tripathy, D Mohan, T Patel, M Sahu and L Prabhas

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Abstract
As time has progressed, we have identified significant climate changes in the environment that negatively impact cultivar yield. Concurrently, the fast increase in population and the constant reduction in soil property have increased the requirement for alternative agricultural techniques. Soilless has appeared as a highly effective and eco-friendly technique under such situations, allowing optimized cultivar yield without dependency on soil. During the review study work, different soilless methods were studied, such as the nutrient film technique, ebb and flow technique, deep water culture, deep floating system, wick method, drip system, trench technique, grow bag system, hanging bag system, pot method, and aeroponics. Among these, the NFT was identified as highly effective in terms of efficiency and yield. Furthermore, various foreign cities, ebb and flow, and NFT methods have been properly applied in green wall systems. The soilless method has also been used in space research, where various models have been created to increase its efficiency under regulated environments. In the upcoming time, soilless farming can have a powerful capacity to function as a sustainable optional method to conventional cultivation. Its incorporation with space farming, precision agriculture, and engineering can open new ways for creation and viable agricultural advancement.

Keywords: Hydroponics, TDS, Ebb and Flow, Heat regulation, Tidal method, and Genome engineering

Introduction

Hydroponics originated from the Greek words “hydro” (water) and “ponos” (labour), is a soilless farming system in which plants are cultivated in nutrient solution (mineral nutrient solution) in an aqueous solvent to cultivate crops without soil, and hydroponics is also derived (the Bengal system, aquaculture, hydroculture, nutriculture, soilless culture, soilless agriculture, tank farming, chemical culture (Jan *et al.*, 2020; Khatri *et al.*, 2024 & Swain *et al.*, 2021) [22, 26, 41]. In accordance with projections by the Food and Agriculture Organization, the worldwide human population is anticipated to reach approximately 9 billion by 2050, presenting a significant constraint to food productivity. Plant growth primarily relies on crucial parameters such as air, nutrients, water, and soil; however, soil-based farming is often constrained by the presence of disease-causing microorganisms, poor water regulation, and reducing soil quality, which can decline plant productivity. In the framework of the soilless cultivation technique, it emerges as an effective way to overcome these constraints and enhance agricultural productivity (Velazquez-Gonzalez*et al.*, 2022; Macwan *et al.*, 2020 & Ikrang et *al.*, 2022) [20, 30, 48]. A variety of crops, which are lettuce, cucumber, herbs, and various flowering plants, have been successfully cultivated (Cifuentes-Torres *et al.*, 2021). Relative to traditional soil-based farming, hydroponics substantially improves essential nutrients and water use efficacy while decreasing the occurrence of crop diseases. The vertical hydroculture technique is a space-optimizing technique, making it notably appropriate for areas with poor soil conditions and adverse climatic conditions, as well as for urban farming. In soilless techniques, various plants necessitate specific Total Dissolved Solids (TDS) levels, which can be accurately controlled through fully automated, semi-automated, and manually controlled techniques. This method is helpful in reducing weed growth rate and facilitates crop management, removing the requirement for supplementary irrigation methods such as spraying. Additionally, in comparison to conventional soil-based systems, hydroponics can achieve water conservation of approximately 70-80%.

This technology has been extensively implemented in countries such as the Netherlands, the United Kingdom, the United States, Israel, and Canada (Szekely & Jijakli, 2022; Kannan *et al.*, 2022) [24, 44].

Soil-based cultivation shows a natural biological system in which microorganisms, comprising archaea, are intrinsically present and serve a crucial role in plant growth by facilitating auxin biological synthesis and increasing essential nutrient accessibility. In hydroponic techniques, an extensive range of crops, such as cucumber, strawberry, chili, tomato, and leafy green vegetables, can be successfully cultivated. Within these, spinach and lettuce are regarded as significantly promising crops, as they demonstrate effective nutrient uptake and robust growth in aquaculture and soilless methods (Kumar *et al.*, 2021, and Gohet *al.*, 2023) [17, 23]. Soilless techniques are developing as a viable option to traditional soil-based agriculture, especially in response to insufficient area accessibility and enhancing challenges caused by biotic and abiotic stress parameters. In countries like India, where there is a growing requirement to increase agricultural yield, a soilless system provides a notable capacity to enhance crop cultivation. Correspondingly, in Pakistan, where agricultural techniques deal with various limitations such as limited accessibility of cultivating machines, unavailability of standard tools, inconsistent monsoon sequence, and repeated pest incidences, hydroponic methods have been effectively applied for the farming of high-value saffron crops (Ampim et *al.*, 2022; Khan *et al.*, n.d.) [6, 25].

Different hydroponic systems, such as nutrient film technique (NFT), deep water culture (DWC), drip system, floating system, capillary action technique, ebb and flow technique (flood and drain), hanging bag technique, and grow bag technique, are popular plant cultivation technique used to grow various vegetable speices. Additionally, various regulated environment agriculture technique such as vertical farming, glasshouse, polyhouse, greenhouse, screen house, hoops house are widely applied to increase crop yield. The effectiveness and output of these indoor cultivation methods are notably affected by key environmental elements, such as light quality, carbon dioxide (CO_2), heat, and relative humidity (Atherton & Li, 2023;Ampim *et al.*, 2022) [6, 7].

Urban places widely face substantial limitations such as water deficit and constrained land accessibility. Soilless offers a highly efficient and environmentally sustainable strategy to these limitations by facilitating hydroponics with improved water use. Furthermore, strategy opens new prospects for city area farming by converting poorly utilized and unused areas to not only increase local food resource cultivation but also promote local population and environmental sustainability (Noxolo & Kanosvamhira, 2026) [33]. In city area, a soilless farming method could be promising and eco-friendly option to cultivate plants, that has ability to replace soil and facilitates managed production under limited land availability (de Castro Silva *et al.*, 2021) [13]. Soilless farming systems also provide innovative and effective strategies for the cultivation of fodder for livestock. The method facilitates the farming of animal feed under regulated environments without the need for soil. It offers a cost-efficient and consistent technique for long, prolonged fodder production (Abdula *et al.*, 2022) [4].

Hydroponics techniques

1. **DWC (Deep Water Culture):** Among different hydroponic techniques, deep water culture is recognized as highly appropriate for leafy green vegetables, as these crops need limited structural stabilization. In this technique, plant roots persist immersed in a nutrient-oxygenated solution, securing effective nutrient assimilation and oxygenation. In the incident of pump collapse, the setup offers enough time periods for fixing the pump failure problem (Mariyappillai *et al.*, 2020) [31]. (Figure 1).
2. **NFT (Nutrient Film Technique):** Nutrient film technique is widely applied for the production of microgreen plants. In this technique, a thin layer of nutrient media consistently flows over the plant roots, providing effective nutrient uptake. The nutrient solution is drained out and recirculated from the nutrient tank, and oxygenation is regulated using air stones to facilitate oxygen accessibility (Mariyappillai et al., 2020). (Figure 2) [31].
3. **Ebb and Flow (Flood and Drain):** The ebb and flow technique is favorable for various types of plants. It promotes efficient nutrient solution delivery by fixed-time interval solution immersion of the root zone with nutrient media, subsequently followed by drainage into the reservoir tank. This technique permits the growing media to maintain enough nutrients and moisture and supports crop growth. The use of strong containers with good water-holding capacity is necessary for its performance (Sharma *et al.*, 2018) [40]. (Figure 3).
4. **Drip system:** The drip technique is another efficient soilless system that provides nutrient media to the root area with high water-use effectiveness, resulting in enhanced crop cultivation. The use of organic nutrient media may result in clogging in pipelines; chemical nutrients are commonly recommended in this method (Sharma *et al.*, 2018) [40] (Figure 4).
5. **Root dipping system:** The root dipping method is an easy and cost-effective soilless technique that does not demand the use of equipment such as water and aeration pumps. In this technique, crops are propagated in net pots, with the lower 2-3 cm area of the root explicitly dipped in the nutrient media tank, facilitating a constant nutrient supply to the plant roots. Due to its limited structural demands, this method is recognized as significantly affordable and simple to maintain (Mariyappillai *et al.*, 2020). (Figure 5) [31].
6. **Floating method:** The floating system shows an effective soilless strategy in which cultivars are secured in a foam sheet, enabling them to persist stabilized on the surface of the nutrient media while their crop roots are constantly immersed (Mariyappillai *et al.*, 2020) [31].
7. **Capillary action system:** The capillary action system uses net pots of differing sizes based on plant type, which are fixed with nutrient media. In this method, nutrient absorption arises spontaneously through capillary action, promoting the transport of the nutrient media from the nutrient tank to the crop roots without the requirement for extrinsic energy supply (Mariyappillai *et al.*, 2020) [31]. (Figure 7).
8. **Hanging Bag system:** The hanging bag method is an open soilless technique in which the nutrient media is delivered from the top using a water pump and sprinkler

equipment. The nutrient solution is supplied onto a growing media such as coco fiber, enabling crop roots to uptake the needed nutrients effectively. In this technique, tubular polythene bags are supported upright, and crops are cultivated within these bags. Extra nutrient solution flows out downwardly and is gathered back into a nutrient tank for recirculation. This method allows effective upright space consumption (Mariyappillai *et al.*, 2020) [31]. (Figure 8).

9. **Grow bag technique:** The grow bag system is other soilless technique that used polythene grow bags packed with chemically inactive media such cocopeat. Micro pores are formed on the outer layer of the bags, into which crops are implanted. Nutrient media is delivered through tubes immediately to the root area. For outflow openings/slits are created across the lateral surface of the bags, enabling extra nutrient solution to flow out. This technique secures sufficient nutrient accessibility and avoids water saturation around the plant roots (Mariyappillai *et al.*, 2020) [31]. (Figure 9).
10. **Trench / trough system:** The trench system is a soilless technique in which flow channels are established either explicitly on the ground or coated with water-resistant substrates to avoid seepage. Crops are cultivated within these flow channels using appropriate substrates such as cocopeat, sand, or rock-based media. The nutrient media is delivered through a drip fertigation or hand operation, facilitating constant delivery of nutrient solution to the crop roots. This technique offers efficient root stabilization extensively utilized for commercial-scale production (Mariyappillai *et al.*, 2020) [31]. (Figure 10).
11. **Pot system:** The pot system is the same as the trench technique; pots are used for plant farming. Various types (different sizes) of pots are chosen based on the particular needs of the crops. These pots are packed with suitable media, and nutrient media are delivered either hand-operated or through drip techniques. This technique provides adaptability and is appropriate for limited-scale farming (Mariyappillai *et al.*, 2020) [31]. (Figure 11).
12. **Aeroponics system:** The aeroponics system is a modern soilless technique in which crop roots are elevated in the air and are not integrated in any solid substrate. Nutrient media is supplied directly to the plant roots in the form of micro aerosol spray at continuous cycles. Cultivars are stabilized using structure such as Styrofoam sheets, while the plant roots persist aerially exposed in an oxygen-rich surrounding. This technique increases nutrient absorption, promotes oxygenation, and is especially appropriate for leafy cultivars (Mariyappillai *et al.*, 2020) [31]. (Figure 12).
13. **Wick system:** The wick system (soilless system) is a distinct soilless technique in which a cotton thread is applied to uptake nutrients from the nutrient solution and deliver for cultivars (Ahmed*et al.*, 2021) [3]. Organic nutrient solutions are not options for agricultural cultivars instead offers aneffective technique for nutrient resource exploitation (Ortiz, 2020) [34]. Adeyemi applied organic nutrient media and organic mineral nutrient solution in his research work (Adeyemi*et al.*, 2020) [1].

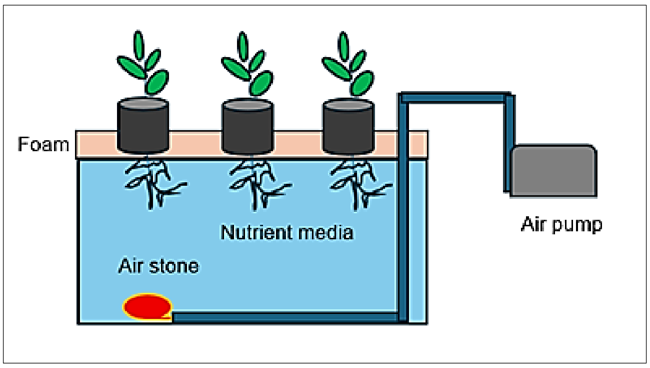

Fig 1: Deep water Culture (Yuvaraj & Subramanian *et al.*, 2020) [50]

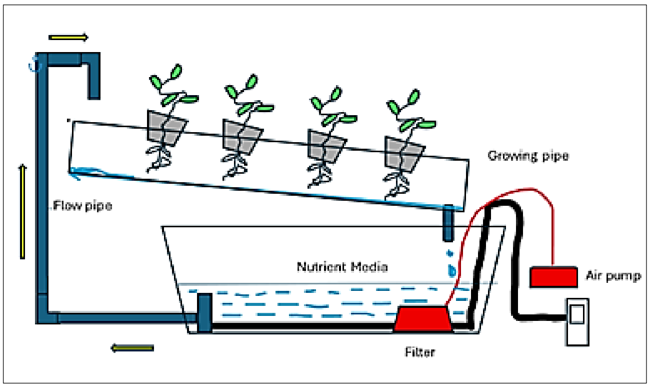

Fig 2: Nutrient Film Technique (Rani*et al.*, 2022) [38]

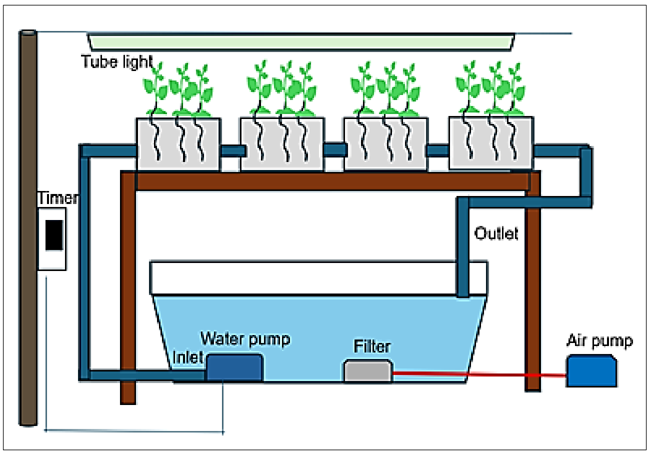

Fig 3: Ebb and Flow System (Muhammad *et al.*, 2018) [29]

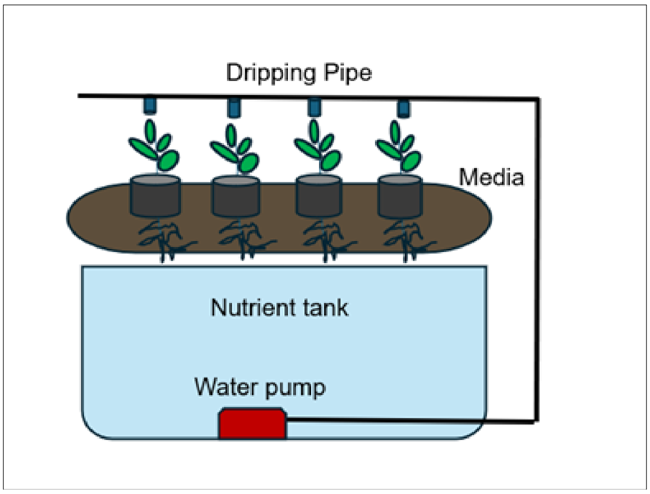

Fig 4: Drip System (Eldridge *et al.*, 2020) [14]

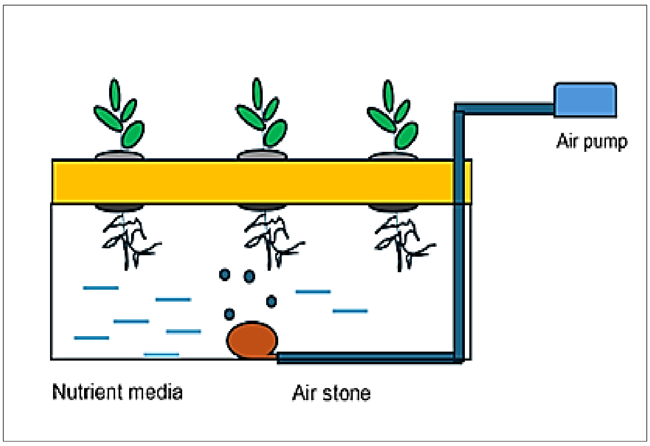

Fig 5: Root dipping system (Mariyappillai *et al.*, 2020) [31]

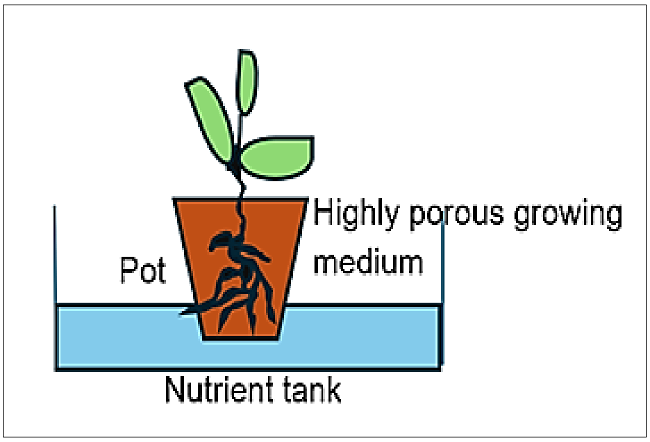

Fig 6: Capillary action method (Mariyappillai *et al.*, 2020) [31]

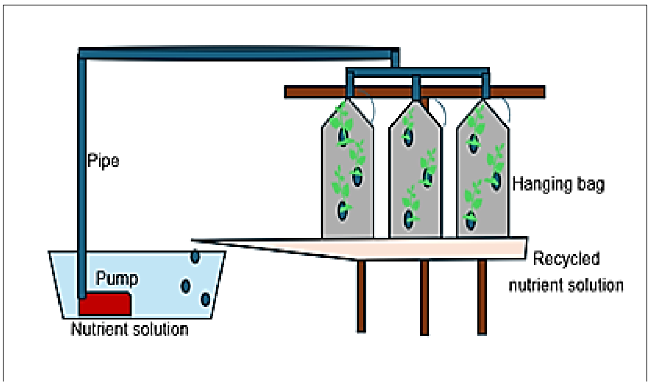

Fig 7: Hanging bag system (Mariyappillai *et al.*, 2020) [31]

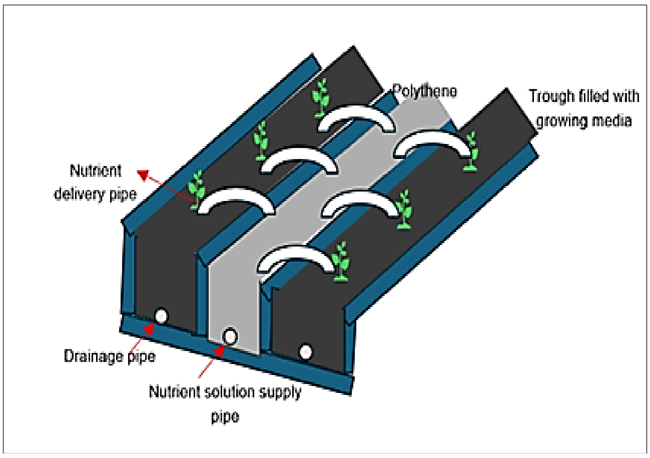

Fig 8: Trench / trough system (Mariyappillai *et al.*, 2020) [31]

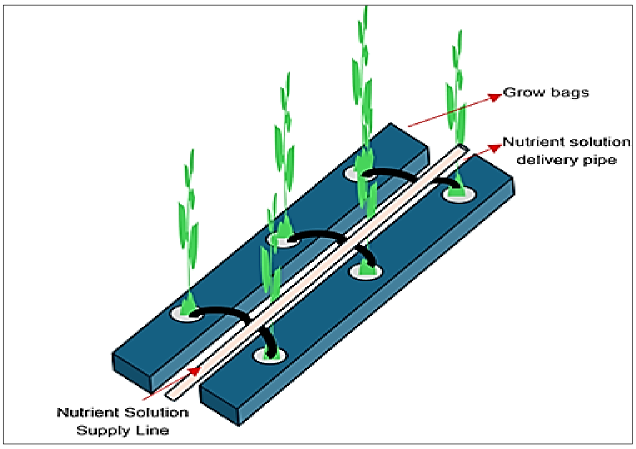

Fig 9: Grow bag technique (Hasan *et al.*, 2018) [18]

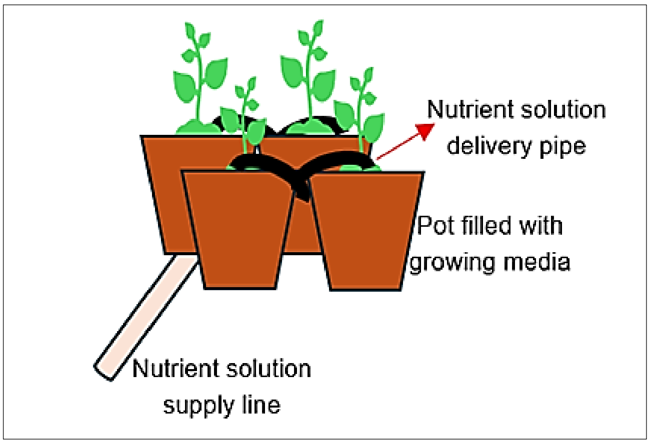

Fig 10: Pot system (Whankate*et al.*, 2024) [49]

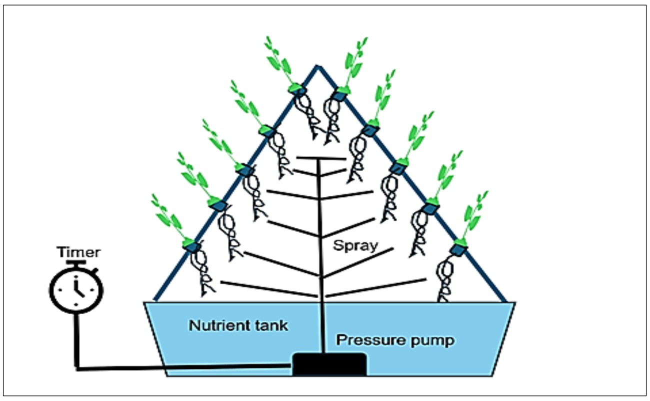

Fig 11: Aeroponics (Hakim, 2019) [19]

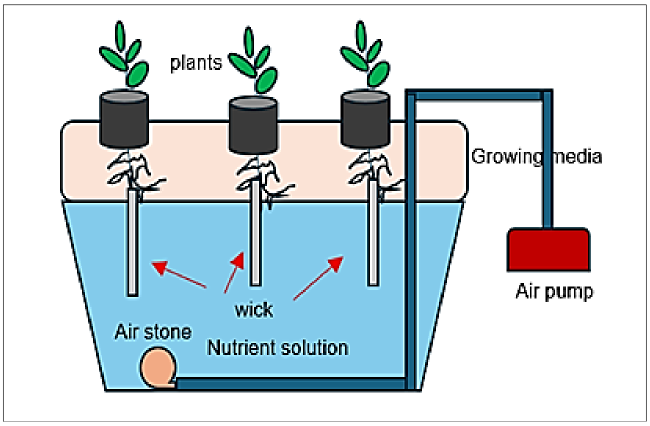

Fig 12: Wick system (Sousa *et al.*, 2024) [46]

Methodology

Selection of plant species and hydroponic system

Different researchers used various plant/crop species to assess the effectivity of different soilless methods. Khan chose saffron (*Crocus sativus*) and analyzed its farming applying ebb and flow, nutrient film technique, and drip systems in a comparative study with soil-based techniques (Khan *et al.*, n.d.) [25]. Boldrin farmed canna lily (*Canna indica*) applying a semi-hydroponic and ebb and flow (flood and drain) technique (Boldrin *et al.*, 2020) [9]. *Gymnocalycium mihanovichii* was reported and studied under hydroponic system (Park & Lee, 2023) [37]. Lim employed micro-tom (*Solanum lycopersicum*) and investigated its growth under nutrient film technique and ebb and flow technique (Lim*et al.*, 2024). Equally selected crop lettuce (*Lactuca sativa*) and investigated its efficiency applying nutrient film technique and ebb and flow (flood and drain) system, while Cekin identified lettuce (*Lactuca sativa*) crops for test studies under various soilless techniques comprising sandponics, mediabeds, deep water culture, and NFT (AL-Kinani *et al.*, 2021 and Cekin et *al.*, 2024) [2, 11]. The spinach (*Spinacia oleracea*) cultivar and growth rate under NFT (flood and drain), and soil-based systems was studied (Indira & Rani, 2024) [21, 38]. Srivani also used spinach (*Spinacia oleracea*) and investigated it under DWC and nutrient film techniques (Srivani *et al.*, 2022) [41]. Adeyemi and Sahoo applied maize (Zea mays) as the test study crop, and Suchitrarani applied strawberry (*Fragaria × ananassa*) for farming studies (Adeyemi *et al.*, 2020 and Sahoo *et al.*, 2024) [1, 45].

Growing media: The various types of media /growing media used by different researchers are compiled in tabulation given below.

Table 1: various growing media

S. No.	Growing media	Reference
1.	Sand, vermiculite, coconut fibre, phenolic foam, expanded clay.	Boldrin*et al.*, 2022 [9]
2.	Gravel, sand, peat, vermiculite, pumice, saw dust, cocopeat, vermicompost, peatmoss, perlite, *viz.* sand, rice hulls, stones.	Patil *et al.*, 2020 [35]
3.	Rockwool, coco coir, perlite, vermiculite, oasis cubes, sand, rice hulls.	Gaikwad & Maitra, 2020 [15]
4	Vermiculite, perlite, sand, coco coir, Pumice, Stones, expanded clay, foam, cubes, rockwool cubes.	Pinkerton*et al.*, 2022 [36]

Nutrient solution - Ahmed used an organic nutrient media / nutrient solution generated fromfish waste in his research study / work. He observed that it was extensively effective

Table 2: Composition of nutrient solution by various researchers (AI Meselmani, 2022) [5]

Elements	From taken by plants (mg L^{-1})	Hoagland & arnon (mg L^{-1})	Hewitt (mg L^{-1})	Cooper (mg L^{-1})	Steiner (mg L^{-1})
Nitrogen	NH_4^+, NO3-	210	168	200-236	168
Phosphorus	HPO_4^{-2}, $H_2PO_4^-$	31	41	60	31
Potassium	K^+	234	156	300	273
Calcium	Ca^{2+}	160	160	170-185	180
Sulfur	SO_4^{2-}	64	48	68	336
Magnesium	Mg^{2+}	34	36	50	48
Iron	Fe^{2-}, Fe^{3+}	2.5	48	12	2-4
Copper	Cu^{2+}	0.020	2.8	0.1	0.02
Zinc	Zn^{2+}	0.05	0.06	0.1	0.11
Boron	H_3BO_3, BO_3^-, $B_4O_7^{2-}$	0.5	0.54	0.3	0.14
Manganese	Mn2+, Mn4+	0.5	0.54	2	0.62
Molybdenum	MoO_4^{2-}	0.01	0.04	0.2	Not considered

Table 3: pH, EC and TDS for different crops (Luckardi *et al.*, 2026) [28]

S. NO.	Vegetables	Scientific name	pH	ppm	Ec (Ms/cm)
1	Ampalaya (Bitter ground)	*Momordica charantia*	6.4-6.7	1190-1750	2.38-3.5
2	Asparagus	*Asparagus officinalis*	6.0-6.8	1400-2800	2.0-4.0
3	Basil	*Ocimum Basilicum*	5.5-6.5	700-1120	1.0-1.6
4	Beans	*Phaseolus vulgaris*	6.0-6.5	N/A	N/A
5	Broccoli	*Brassica oleracea var. italica*	6.0-6.5	1960-2450	2.8-3.5
6	Cabbage	*Brassica oleracea capitata*	6.5-7.0	1750-2100	2.5-3.0
7	Capsicum	*Capsicum annuum*	6.0-7.5	1260-1540	1.8-2.2
8	Cauliflower	*Brassica oleracea var. botrytis*	6.0-7.0	1050-1400	0.5-2.0
9	Celery	*Apium graveolens*	6.0-7.0	1260-1680	1.8-2.4
10	Cucumber	*Cucumis sativus*	5.8-6.0	1190-1750	1.7-2.5
11	Eggplant	*Solanum melongena*	5.5-6.5	1750-2450	2.5-3.5
12	Kangkong	*Ipomoea aquatica*	5.5-6.0	600-1200	1.2-2.4
13	Leeks	*Allium ampeloprasum var. porrum*	6.5-7.0	980-1260	1.4-1.8
14	Lettuce	*Lactuca sativa*	5.5-6.5	560-840	0.8-1.2
15	Melon	*Cucumis melo*	5.5-6.0	1400-1750	2.0-2.5
16	Mustasa (Mustard	*Brassica juncea*	5.5-6.5	600-1200	1.2-2.4

	Greens)				
17	Okra	*Abelmoschus esculentus*	6.5	1400-1680	2.0-2.4
18	Onions	*Allium cepa*	6.0-6.7	980-1260	1.4-1.8
19	Pak-choi (Bok-choi)	*Brassica rapa subsp. Chinensis*	7.0	1050-1400	1.5-2.0
20	Peppers (Bell, green)	*Capsicum annuum*	5.8-6.3	1400-2100	2.0-3.0
21	Peppers (Super-hot)	*Capsicum chinense*	6.0-6.5	2100-2450	3.0-3.5
22	Petchay	*Brassica rapa subsp. Chinensis*	5.5-6.5	600-1200	1.2-2.4
23	Pumpkin	*Cucurbita maxima*	5.5-7.5	1260-1680	1.8-2.4
24	Strawberry	*Fragaria × ananassa*	5.5-6.0	800-1200	1.6-2.0
25	Tomato	*Solanum lycopersicum*	5.5-6.5	1400-3500	2.0-5.0
26	Watermelon	*Citrullus lanatus*	5.8	1050-1680	1.5-2.4
27	Zucchini	*Cucurbita pepo*	5.8	1260-1680	1.8-2.4

Major findings and achievements

Khan observed the effective farming of saffron (*Crocus sativa*) under regulated environments, obtaining up to 4 cultivation cycles per year. Each production cycle needed approximately 2.5-3 months for completing the cycle (Khan *et al.*, n.d.) [25]. Abd EI-Aziz Amr & Hisham Fathy found that the integration of green walls greatly enhanced heat regulation by 4-6ºC and decreased the cooling energy demand by approximately 12%. Additionally, the utilization of NFT occurred in a 30-35% decrease in cooling energy demand, with reported heat decreasing between 2 and 8 °C (Abd EI-Aziz Amr & Hisham Fathy, 2025) [8]. AL-Kinani reported that the lettuce cultivated in NFT presented a higher yield (25 days) for market and ebb and flow technique with a cultivar cycle (35-40 days) (AL-Kinani *et al.*, 2021) [2]. Srivani used an assembled classifier model in a soilless technique, obtaining a reliability of 79% in water culture techniques and 64% in NFT techniques (Srivani *et al.*, 2022) [41]. Ampim observed that indoor cultivation is an encouraging and effective method; however, it needs also research and notable funding for extensive adoption (Ampim *et al.*, 2022) [6]. Indira and Rani observed that spinach (*Spinacia oleracea*) presented better plant growth in the nutrient film technique (NFT) method contrasted with the ebb and flow technique and soil-based farming. Increased factors involve plant height, fresh leaf, number of leaves, leaf area, and total production (Indira & Rani, 2024) [21, 38].

Scope of advancement/future prospects of technology development

Setiawan used a pump control technique and reported that the tidal system can efficiently control the on/off process of water pumps. This technique enables the time interval of the water pump process to be controlled, thereby resulting in energy efficiency (Setiawan *et al.*, 2022) [43]. Atherton and Li reported that various medicinal plants need various types of soilless methods, according to their morphological structure (Atherton & Li, 2023) [7]. Soilless techniques have also been investigated for practical applications in space research work, highlighting their capacity for use in regulated and challenging environments (Madaik & Thalyari, 2025) [32]. Srivani proposed that intelligence models for crop growth forecasting can be established to increase technique effectivity and yield (Srivani *et al.*, 2022) [41]. Lim observed that the incorporation of cultivars in vertical cultivation methods is practical work and may constitute a substantial innovation in genome engineering, space farming, and precision agriculture (Lim *et al.*, 2024) [27].

Advantages

- Soilless techniques provide a regulated growing climate that may decrease crop contact with exogenous biotic/abiotic stress parameters such as UV radiation. Furthermore, when compared to traditional agriculture farming, soilless methods enable simpler, effective yielding of cultivars (Swain *et al.*, 2021) [41].
- The soilless technique enables the farming of cultivars even at the time of "off season," especially when market values are high (Swain *et al.*, 2021) [41].
- Soilless methods provide various advantages over conventional cultivation, such as effective utilization of assets, rapid crop growth rate, and a regulated environment with consistent conditions. These techniques maintain constant cultivar quality and even growth, enable enhanced crop density, and impact good disease management (Khatri *et al.*, 2024) [26].
- Soilless (hydroponics) methods provide minimum human resources, and subsequent to primary one-time expenditure, the technique becomes functional; it offers higher production (Bunyuth & Mardy, 2024) [10].
- In hydroponics (soilless), a controlled condition is offered to crops manually, whereas the conventional method is mainly dependent on climatic parameters (Dubey & Nain, 2020) [12].

Limitations

- In the soilless method, the expenditure of establishment for the area used is very high (Swain *et al.*, 2021) [41].
- Soilless farming needs trained cultivators who can efficiently regulate climate conditions and exhibit appropriate training in crop growth maintenance and nutrient concepts (Swain *et al.*, 2021) [41].
- Hydroponics technique needs technical proficiency, and initial expenditure is very high (Khatri *et al.*, 2024) [26].
- Soilless farming needs a skilled person who can effectively maintain the setup, as the hydroponic method is a complicated procedure including nutrient transport and entire crop health maintenance (Bunyuth & Mardy, 2024) [10].
- ·The scarcity of seeds causes challenges for cultivators, as reduced presence enhances their price, thereby increasing the overall cost in soilless cultivation (Ghorbel *et al.*, 2022) [16].
- ·In spite of offering good production, the soilless technique includes particular technical and economic difficulties, such as transport and balanced nutrient media to crops (Thapa *et al.*, 2024) [47].

Conclusion

Hydroponics (soilless) includes different technique types, with approximately thirteen various setups being founded.

Among these, the NFT and ebb and flow (flood and drain) methods are most usually utilized by researchers, whereas other methods, including deep water culture, capillary mat technique, sandponics, and soil-based, have also been used. Particularly cultivars, such as saffron (*Crocus sativus*), have indicated enhanced farming effectiveness under the ebb and flow technique. In regulated environmental conditions, green wall techniques are being used for heat regulation, especially in NFT methods, where they promote increased temperature reduction effectiveness. Additionally, well-developed technologies, such as classifier models, have been used in hydroponic research work for system improvement and assessment. Comparative research studies mainly indicate that NFTs provide higher yield effectiveness than ebb and flow techniques. Furthermore, tidal methods are also utilized to enhance functional control within soilless setups.

Hydroponics (soilless farming) has also been used in space technology, emphasizing its capacity for future agricultural creation. However, this review study demonstrates that research studies on medicinal plants under soilless farming conditions persist minimally, indicating a substantial possibility for further research (research gap). The incorporation of hydroponics with engineering, precision agriculture, and space farming may open new ways for technological development and viable cultivar cultivation. Overall, soilless farming has the ability to act as an optional agricultural technique in the future by resolving climatic challenges and securing constant crop productions, although it is connected with both advantages and limitations that need further improvement.

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References

1. Adeyemi TA, Adeoye SA, Ogunyemi TJ, Adedeji EA, Oluyemi B, Ojo VOA. Comparison of nutrient solutions from organic and chemical fertilizer sources on herbage yield and quality of hydroponically produced maize fodder. Journal of Plant Nutrition. 2020; 44(9):1258-1267.
2. AL-kinani HAA, Jerca OI, Bobutac V, Draghici EM. Comparative study on lettuce growing in NFT and ebb and Flow system. Scientific Papers. Series B, Horticulture. 2021; 65(1):451-458.
3. Ahmed ZF, Alnuaimi AK, Askri A, Tzortzakis N. Evaluation of lettuce (*Lactuca sativa* L.) production under hydroponic system: Nutrient solution derived from fish waste vs. inorganic nutrient solution. Horticulturae. 2021; 7(9):292-308.
4. Abdula AH. Contribution of hydroponic feed for livestock production and productivity. Science Frontiers. 2022; 3(1):01-07.
5. Al Meselmani MA. Nutrient solution for hydroponics. In: Recent Research and Advances in Soilless Culture. London: IntechOpen; 2022.
6. Ampim PA, Obeng E, Olvera-Gonzalez E. Indoor vegetable production: An alternative approach to increasing cultivation. Plants. 2022; 11(21):2843-2865.
7. Atherton HR, Li P. Hydroponic cultivation of medicinal plants-plant organs and hydroponic system: technique and trends. Horticulturae. 2023; 9(3):349-372.
8. Abd EI-Aziz AMH, Hisham Fathy M. Hydroponic green walls as a sustainable solution for thermal comfort energy efficiency. Journal of Engineering and Applied Science. 2025; 72(1):15-32.
9. Boldrin KVF, Paiva PDDO, Barbosa JCV, Torquetti SDS, Almeida EFA, Reis S, Landgraf PRC. Semihydroponic and ebb-and-flow systems for calla lily cultivation. Ornamental Horticulture. 2022; 28(2):142-149.
10. Bunyuth Y, Mardy S. Hydroponic systems: an overview of benefits, challenges, and future prospects. Indonesian Journal of Social Economics and Agricultural Policy. 2024; 1(1):10-18.
11. Cekin D, Hassanen M, Hassanen M, Hassan N, Lothmann R, Sewilam H. Comparative analysis of closed hydroponic systems and planting season for lettuces. Turkish Journal of Agriculture and Forestry. 2024; 48(3):344-353.
12. Dubey N, Nain V. Hydroponic-the future of farming. International Journal of Environment, Agriculture and Biotechnology. 2020; 5(4):857-864.
13. de Castro Silva MG, Huther CM, Ramos BB, da Silva Araujo P, da Silva Hamacher L, Pereira CR. A global overview of hydroponics: nutrient film technique. Revista Engenharia na Agricultura - REVENG. 2021; 29:138-145.
14. Eldridge B, Manzoni LR, Graham CA, Rodgers B, Farmer JR, Dodd AN. Getting to the roots of aeroponics indoor farming. New Phytologist. 2020; 228(4):1183-1192.
15. Gaikwad DJ, Maitra S. Hydroponics cultivation of crops. Protected Cultivation and Smart Agriculture. 2020; 1:279-287.
16. Ghorbel R, Chakchak J, Kosum N, Cetin NS. Hydroponic technology for green fodder production: concept, advantages, and limits. 6th International Students Science Congress Proceedings. Izmir, Turkey: 2022. p. 112-120.
17. Goh YS, Hum YC, Lee YL, Lai KW, Yap WS, Tee YK. A meta-analysis: Food production and vegetables crop yields of hydroponics. Scientia Horticulturae. 2023; 321:112339-112352.
18. Hasan M, Sabir N, Singh AK, Singh MC, Patel N, Khanna M, Pragnya P. Hydroponics technology for horticultural crops. Technical Bulletin TB-ICN. 2018; 188:01-30.
19. Hakim MA. Experimental study on suitable type of water for growing hydroponic lettuce [Master's thesis]. Dhaka: Bangladesh University of Engineering and Technology; 2019.
20. Ikrang EG, Ehiomogue PO, Udoumoh UI. Hydroponics in precision agriculture - a review. Annals of the Faculty of Engineering Hunedoara. 2022; 20(2):143-148.
21. Indira D, Rani AS. Comparative study on the growth performance of *Spinacia oleracea* L. (spinach) in

hydroponic and soil-based systems. Agriculture Archives: An International Journal. 2024; 3(2):19-25.
22. Jan S, Rashid Z, Ahngar TA, Iqbal S, Naikoo MA, Majeed S, Nazir I. Hydroponics - a review. International Journal of Current Microbiology and Applied Sciences. 2020; 9(8):1779-1787.
23. Kumar S, Singh M, Yadav KK, Singh PK. Opportunities and constraints in hydroponic crop production systems: A review. Environment Conservation Journal. 2021; 22(3):401-408.
24. Kannan M, Elavarasan G, Balamurugan A, Dhanusiya B, Freedon D. Hydroponic farming-A state of art for the future agriculture. Materials Today: Proceedings. 2022; 68:2163-2166.
25. Khan KA, Khan JM, Ali S, Nasreen S, Noureen A, Hameed MS, *et al*. Hydroponically growth of saffron (flow ebb vertical system 530x155 ft) concept to design. [Project Technical Note]. Ghazi University; n.d.
26. Khatri L, Kunwar A, Bist DR. Hydroponics: advantages and challenges in soilless farming. Big Data in Agriculture. 2024; 6(2):98-105.
27. Lim Y, Seo MG, Lee S, An JT, Jeong HY, Park Y, Kwon CT. Comparative yield evaluation of mini-tomato cultivar in two hydroponic systems. Horticulture, Environment, and Biotechnology. 2024; 65(2):239-250.
28. Luckardi S, Rafdhi AA, Sari AW, Zangana HM, Soegoto ES. How to improve hydroponic leafy vegetable plant productivity by balancing nutrient solution, total dissolved solids (TDS), and pH. ASEAN Journal of Science and Engineering. 2026; 6(1):101-116.
29. Muhammad D, Handika V, Bintoro A. Design and realization of fuzzy logic control for ebb and flow hydroponic system. International Journal of Scientific & Technology Research. 2018; 7(9):138-144.
30. Macwan J, Pandya D, Pandya H, Mankad A. Review on soilless method of cultivation: hydroponics. International Journal of Recent Scientific Research. 2020; 11:37122-37127.
31. Mariyappillai A, Arumugam G, Raghavendran VB. The techniques of hydroponic system. Acta Scientific Agriculture. 2020; 4(7):79-84.
32. Madaik S, Thalyari J. Soilless cultivation: aeroponics and hydroponics. Advances and Trends in Agriculture Science. 2025; 3:49-74.
33. Noxolo BM, Kanosvamhira TP. Assessing the viability of hydroponics for low-income farmers in South Africa’s urban agriculture sector: An urban political ecology perspective. Urban Agriculture & Regional Food Systems. 2026; 11(1):e70036.
34. Ortiz JCR. Nutritive solutions formulated from organic fertilizers. In: Solankey SS, Akhtar AIL, Rodriguez-Fuentes H, editors. Urban Horticulture: Necessity of the Future. London: IntechOpen; 2022. p. 111-126.
35. Patil ST, Kadam US, Mahale DM, Dhekale JS. Hydroponic growing media (substrates): a review. International Research Journal of Pure and Applied Chemistry. 2020; 21(23):106-113.
36. Pinkerton M, Whitman B, Wooten H, Gomez C. Common media used in hydroponics: EP623/ENH1359. Edis. 2022; (4):01-08.
37. Park KY, Lee JS. Effect of ebb-and-flow system with double-tier bench on growth and yield of hydroponically grown *Gymnocalycium mihanovichii* ‘I-Hong’. Journal of Bio-Environment Control. 2023; 32(2):132-138.
38. Rani RS, Kumar HH, Mani A, Reddy BS, Rao CS. Soilless cultivation technique, hydroponics-A review. Current Journal of Applied Science and Technology. 2022; 41(13):22-30.
39. Rajaseger G, Chan KL, Tan KY, Ramasamy S, Khin MC, Amaladoss A, Haribhai PK. Hydroponics current trends in sustainable crop production. Bioinformation. 2023; 19(9):925-938.
40. Sharma N, Acharya S, Kumar K, Singh N, Chaurasia OP. Hydroponics as an advanced technique for vegetable production: An overview. Journal of Soil and Water Conservation. 2018; 17(4):364-371.
41. Swain A, Chatterjee S, Viswanath M, Roy A, Biswas A. Hydroponics in vegetable crops: A review. The Pharma Innovation Journal. 2021; 10(6):629-634.
42. Srivani P, Yamuna Devi CR, Manjula SH. Prediction and comparative analysis using ensemble classifier model on leafy vegetable growth rates in DWC and NFT smart hydroponic system. In: IoT with Smart Systems: Proceedings of ICTIS 2021, Volume 2. Singapore: Springer Nature Singapore; 2022. p. 795-804.
43. Setiawan D, Hamzah S, Siswati L, Ariyanto A, Guntoro. Water pump control system in hydroponic plants using the ebb and flow method. IOP Conference Series: Earth and Environmental Science. 2022; 1041(1):012020.
44. Szekely I, Jijakli MH. Bioponics as a promising approach to sustainable agriculture: A review of the main methods for producing organic nutrient solution for hydroponics. Water. 2022; 14(23):3975-3992.
45. Sahoo S, Sahoo D, Sahoo KK. Optimization of an efficient hydroponic cultivation method for high yield of strawberry plants. South African Journal of Botany. 2024; 167:429-440.
46. Sousa RD, Braganca L, da Silva MV, Oliveira RS. Challenges and solutions for sustainable food systems: The potential of home hydroponics. Sustainability. 2024; 16(2):817-835.
47. Thapa U, Hansda NN, Kundu S, Giri A, Tamang D, Rahaman AO. Advancements in hydroponic systems for sustainable vegetable production: A comprehensive review. Archives of Current Research International. 2024; 24(11):317-328.
48. Velazquez-Gonzalez RS, Garcia-Garcia AL, Ventura-Zapata E, Barceinas-Sanchez JDO, Sosa-Savedra JC. A review on hydroponics and the technologies associated for medium-and small-scale operations. Agriculture. 2022; 12(5):646-668.
49. Whankate RA, Deokar SP, Patil NS. Urban horticulture and vertical farming. Technology of Horticulture Science. 2024; 247:15-30.
50. Yuvaraj M, Subramanian KS. Different types of hydroponics system. Biotica Research Today. 2020; 2(8):835-837.