



PMSST

# Journal of Applied Science, Innovation & Technology (JASIT)

Journal homepage: <https://prakitimitrango.com/documents-reports-and-publications/journal/>



## Research article

# Vertical hydroponics for sustainable soilless farming revolution in strawberry cultivation for urban dwellers

Madhurima Yadav\*, Sailendra Kumar, Anamta Rizvi, Sangeeta Saxena\*

Department of Biotechnology, Babasaheb Bhimrao Ambedkar University, Lucknow-226025, India



OPEN ACCESS

## ARTICLE INFOR

### Article history:

Received: 21 December 2023

Revised: 29 December 2023

Accepted: 29 December 2023

Published online: 30 December 2023

### Keywords:

Vertical hydroponics

Nutrient solutions

Strawberry

Growth

## ABSTRACT

Hydroponics is a soilless cultivation method and it has revolutionized traditional farming by delivering nutrients directly to plant roots through a water-based, controlled environment. Its adaptability to diverse crops has prompted exploration into tailored nutrient solutions. Vertical hydroponics, a variant of this technique, amplifies space efficiency by stacking plant beds vertically, optimizing land usage and enabling high-density crop cultivation. In this study, vertical hydroponics was employed to cultivate strawberry plants for approximately 100 days. Three distinct nutrient systems were established in triplicates, each with 16 strawberry saplings. The first system utilized NPK solution (19:19:19) supplemented with commercially available hydroponic solutions. The second system relied on kitchen waste solution, while the third one incorporated jaggery solution. The research aimed to evaluate the multifaceted benefits of these nutrient sources on plant growth, flowering, fruiting, average fruit weight, and the time required to achieve an optimal attributes. The findings offer comprehensive insights in elucidating their roles in enhancing nutrient uptake, plant vigor, yield and fruit quality. This research contributes significant guidance for optimizing nutrient strategies in vertical hydroponic strawberry cultivation.

## 1. Introduction

Commercial hydroponics is a modern technique that involves growing plants in nutrient solution without using soil as a growing medium. The main benefits of these systems are the reduction of soil problems such as soil borne pathogens, physical and chemical pollutants, and the reduction of herbicide use. Hydroponics improves the quality of fruits and flowers through the application of required concentration of nutrients (Gaikwad, 2020; Van Gerrewey et al., 2022). Strawberry (*Fragaria ananassa*) is a temperate berry fruit crop belonging to family Rosaceae. It is known to be one of the highly-valued fruit crops for confectionary industries owing to its attractive taste and odor. Apart from the vivid crimson colored heart-shaped structure, the strawberry is acknowledged for promoting human health. According to a study, the fruit merits the higher concentration of vitamin A

(60 IU/100 g) and ascorbic acid (vitamin C) up to 120 mg/100 g (Sharma and Godara, 2019). The higher content of minerals and anthocyanin makes it a good antioxidant as well (Rahaman et al., 2023a). As far as the global strawberry cultivation statistics is concerned, China leads the globe with the produce of over 3.7 million MT followed by USA which produces about 1.4 million MT strawberry annually (Kumar and Mishra, 2023). In India, the strawberry production is about 5000 MT annually and is cultivated on around 1000 hectares of land, which is by far very low as compared to China and USA (Kumar and Mishra, 2023). Haryana recorded the highest annual production of strawberries about 1650 MT. The strawberry cultivation in India is lower due to the fact that soil is generally used as growing substrate which subsequently results in soil borne diseases, microbes and nematodes. The strawberry cultivation statistics seemed to have increased

### \*Corresponding Authors:

E-mail address: [madhurima.yadav.74@gmail.com](mailto:madhurima.yadav.74@gmail.com) (M.Yadav), [dr\\_sangeeta\\_saxena@yahoo.com](mailto:dr_sangeeta_saxena@yahoo.com) (S.Saxena)



This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Copyright: © 2023 Prakriti Mitra Society for Science & Technology

logarithmically from past two decades over the world since the new strategies for cultivation under protective conditions and structures are introducing. In order to increase the productivity, the use of soilless media for growth are popularizing to avoid the soil-borne microbes, pest, nematodes and other diseases (Rahaman et al., 2023b; Thakur and Shylla, 2018). Hydroponics is the best ever alternative wherein the plants can be grown in a soil-less nutrient liquid medium (Adak and Gubbuk, 2015). Hydroponics has now become one of the crucial disciplines of horticulture to grow commercially important crops using the aqueous nutrient solvents without using soil. The hydroponic technology seems to be promising to address the concerns regarding the malnutrition elimination, climate change, sustainable use of natural resources, skill development and indoor urban cultivations (Adak and Gubbuk, 2015; Khan et al., 2020; Kumar and Mishra, 2023). The requirement of agricultural lands can be reduced significantly by at least 75% and the water conservation can be achieved by 90%, using this technology. The financial benefits along with food security by getting the microbe-free and pesticide-free crops are other positive aspects claimed by hydroponics experts (Sardare, 2013).

The strawberry cultivation is highly dependent on modernized technological inputs including the greenhouses with plastic films, low tunnel, plastic mulch and shade screens inside polyhouses (Bradley and Marulanda, 2001). The other advanced contemporary cultivation practices are increasing to hike the production rates and quality. To begin such practices, a significant financial input is required however, the cultivation geometry can be changed to maximize the yield using the vertical hydroponic set-up for the strawberry cultivation (Adak and Gubbuk, 2015). Vertical hydroponic can change the cultivation geometry and maximize the yield of crops as it uses a vertical tower that supports the growth of multiple plants and requires less space and thus the production increases per unit area. It enables better use of vertical space and under controlled conditions such as temperature, light, humidity and CO<sub>2</sub>. This approach can be the best alternative one can choose to start the strawberry cultivation even in a small room or balcony unlike the large greenhouses with all elaborated expensive set-ups. A soilless cultivation system greatly reduces the labor-intensive practices, evades the risk of soil-borne diseases and increases the yield in arid locations and urban areas (Kumar and Mishra, 2023). The off-seasonal varieties can also be available year around with improvised quality and rapid growth are some of the remarkable positive aspects with vertical hydroponic systems. Nevertheless, the good yield and quality will be crucial for both the consumers who select the best fruits and the producers who grow in a more cost-efficient and sustainable fashion. Therefore, the present study might be helpful in paving the path for future of strawberry cultivation using different organic and inorganic growth media. The study aims to investigate the suitability of nutrient media out of different medium used and their influence on various parameters like flowering, flower yield, fruit yield and indices like plant height and root length of strawberry cultivated in vertical hydroponic system. The nutrient solutions used were NPK solution, kitchen waste solution and the jaggery solution used as liquid bio-fertilizer.

## 2. Materials and methods

The study was conducted in Department of Biotechnology, Babasaheb Bhimrao Ambedkar University, Lucknow, India during the months of September to January, 2022-23. The experimental protocol followed the Completely Randomized Design (CRD) involving three different nutrient treatments in triplicate (Kumar and Mishra, 2023). To perform the experiment, vertical hydroponics set-ups were needed and different media to grow the strawberry plants. Vertical hydroponics set-ups were constructed with simple PVC pipes, buckets, net-pots and electronic water pumps.

### 2.1 Designing of vertical hydroponics system

A PVC pipe of two meters length and 4 inches diameter was taken and sixteen cuts were made with the help of a blade in opposite and alternate directions on regular vertical intervals of about 20 cm. Then these cuts were pushed inwardly making holes for holding the net-pots into them for accommodation of sixteen plants. This pipe was placed vertically into a bucket. Another pipe of 0.5 inches diameter was assembled inside the main plant holding pipe and connected to a water pump to assist the flow of the media. The net-pots were filled with coco-coir to hold and support the plantlets. The uppermost portion of the main pipe was covered with a drain strainer to recollect the media into the main pipe to provide it to the growing plants and then to the bucket. A motor pump was assembled at the base of the pipes and placed at the bottom of the bucket to circulate the nutrient solution throughout the tower thereby ensuring the nutrient availability to the growing strawberry plants. A funnel and a tap were also assembled into the set-up to refill the media and to remove the media whenever needed (Fig. 1a). The small plastic mesh pots filled with coco-coir was used as inert support by holding the plant within the sockets of hydroponics tower set-up. The coco-coir provided the good water holding capacity and aeration for the plant roots (Fig. 1b).

### 2.2 Nutrient solution preparation

Three different nutrient solutions were used to assess the difference in growth and fruiting in strawberry plants. The nutrient solutions used for the experiment were NPK solution (19:19:19) supplemented with commercially available hydroponics nutrient solutions (nutes and greens), kitchen waste solution. The third nutrient solution taken for the experiment was jaggery solution which was prepared by using jaggery, chickpea flour, cow-dung manure and vermicompost. For the preparation of NPK solution, 40 grams of NPK powder was dissolved in 20 liters of water (according to IFFCO, India) and 20 mL of nutes and 40 mL of greens were added to the solution (as per instructions). Kitchen waste solution was prepared by rotting of degradable kitchen waste like vegetable and fruit peels, rotten fruits and vegetable and a little water to assist degradation. After a few weeks the water was collected and used as nutrient solution. 500 mL of this concentrated kitchen waste solution was added to 20 liters of water and used to run in the set-up. The jaggery solution was prepared by dissolving 1 kilogram of each jaggery and chickpea flour, 200 mL of vermicomposting prepared from tea, a handful of garden soil and 200 grams of cow dung manure in 10 liters of water and kept incubation for three days with stirring at definite intervals. After three days, the media was filtered using a muslin cloth. A 500 mL of this concentrated jaggery solution was added to 20 liters of water. The pH of each medium was maintained between 5.5 - 6. All

the three prepared nutrient solutions were used thrice for the cultivation of strawberry and completion of the experiment.

### 2.3 Flowering and flower yield

Two weeks old strawberry saplings were planted into the net-pots filled with coco-coir (Fig. 1b). About 16 saplings were taken and placed into the holes of vertical hydroponic set-up (Fig. 1c) containing NPK solution and turn on the switch to run the set-up. In the same manner, two other set-ups were structured one with kitchen waste solution and another one with jaggery solution. The set-ups were observed every day for the growth of plantlets and refilling or removal of media whenever needed. The days of initiation of flowering and the total number of flowers per plant blooming in one growing season were recorded. The experiments were repeated thrice.

### 2.4 Fruit yield and average fruit weight

The beginning of fruiting, the days of maturation of fruits and the number of fruits per plant were recorded for each set-up. The weight of fruits collected from each set-up was also recorded. The experiments were repeated thrice.

### 2.5 Plant height and root length

The plants with matured strawberry fruits from each experimental set-ups were taken and observed for height and root length assessments. Plant height and root lengths were measured in centimetres. 16 plants replicates were taken from each set-up and the study was repeated thrice.

### 2.6 Statistical analyses

The data obtained during the investigations were subjected to one-way ANOVA followed by Tukey's test for multiple comparison. The data obtained were represented as mean  $\pm$  SD; n = 90 for calculation of average fruit weight and n = 48 for all other experiments ( $p < 0.05$ ). Statistical analysis was done by using Microsoft Excel and GraphPad Prism 5.

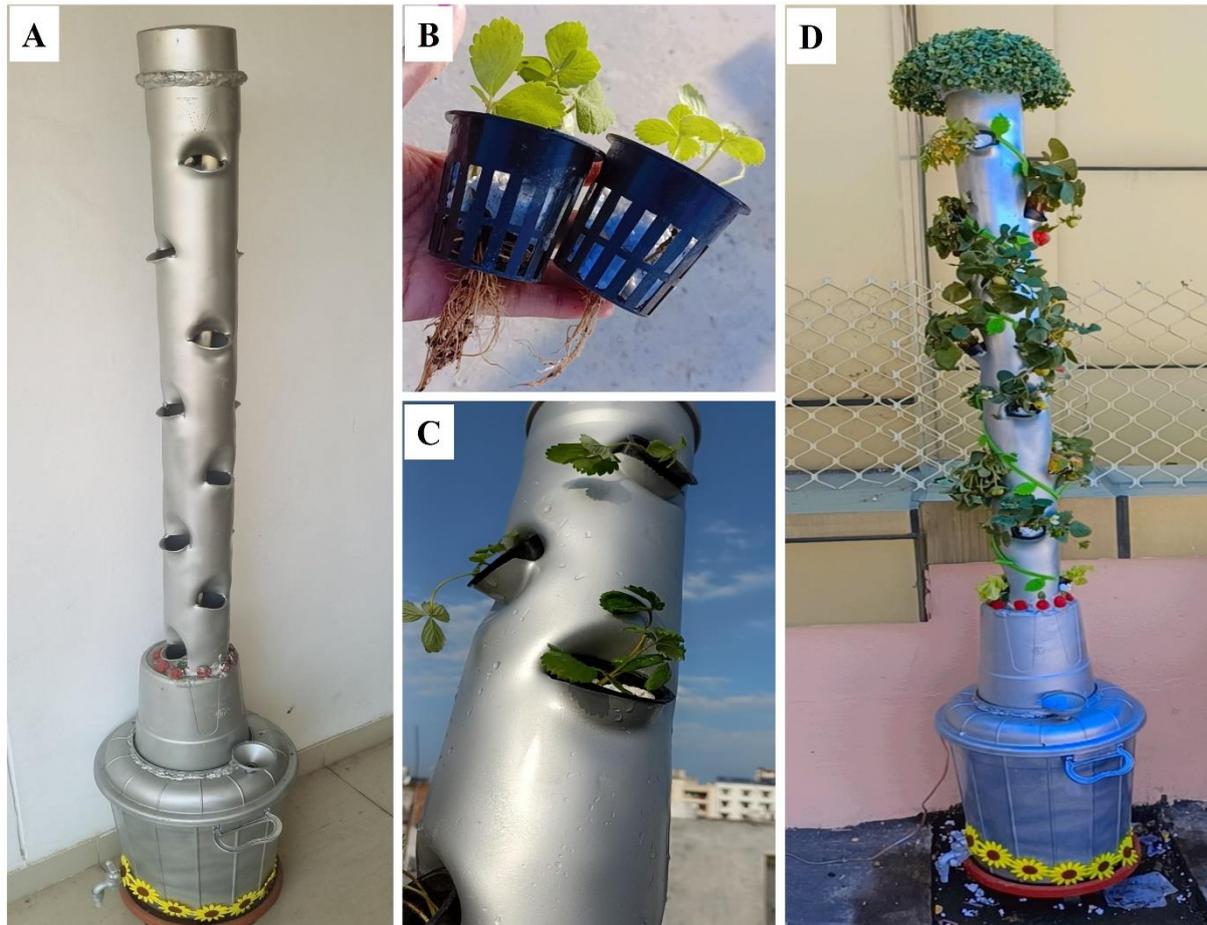
## 3. Results and Discussion

Vertical hydroponics is the growing of crops in vertically stacked layers. Vertical hydroponics has many advantages including high yield per unit area, high water efficiency, cost effective, less labor intensive and suitable for small sunny areas such as balconies, terraces and rooftops. As the set-up was randomly designed with PVC pipes and buckets, it was very affordable and gave very good results (Fig. 1). NPK solution containing commercially available nutes and greens solution (micro and macro nutrient solutions) promotes the overall growth of plant and well known and used in hydroponics. Kitchen waste also consists of various elements and nutrients and used for composting that's why it was used as a growing medium for the strawberry plants. Uniquely formulated jaggery solution used to estimate its potential to promote the growth of strawberry plants and its constituents were jaggery, chickpea flour, cow-dung manure and vermicompost tea. Jaggery and chickpea flour provide the medium for the growth of microbes essential for the growth of plantlets. The initiation of flowering occurred approx. on day 47, 52 and 49 in NPK solution, kitchen waste solution and jaggery solution, respectively, which showed that in order to initiate flowering in strawberry plants, NPK solution was best followed by jaggery solution (Fig. 4). The number of flowers produced per plant were approx. 12.5, 10 and 13.5 and the number of fruits obtained per plant were approx. 11, 9 and 12

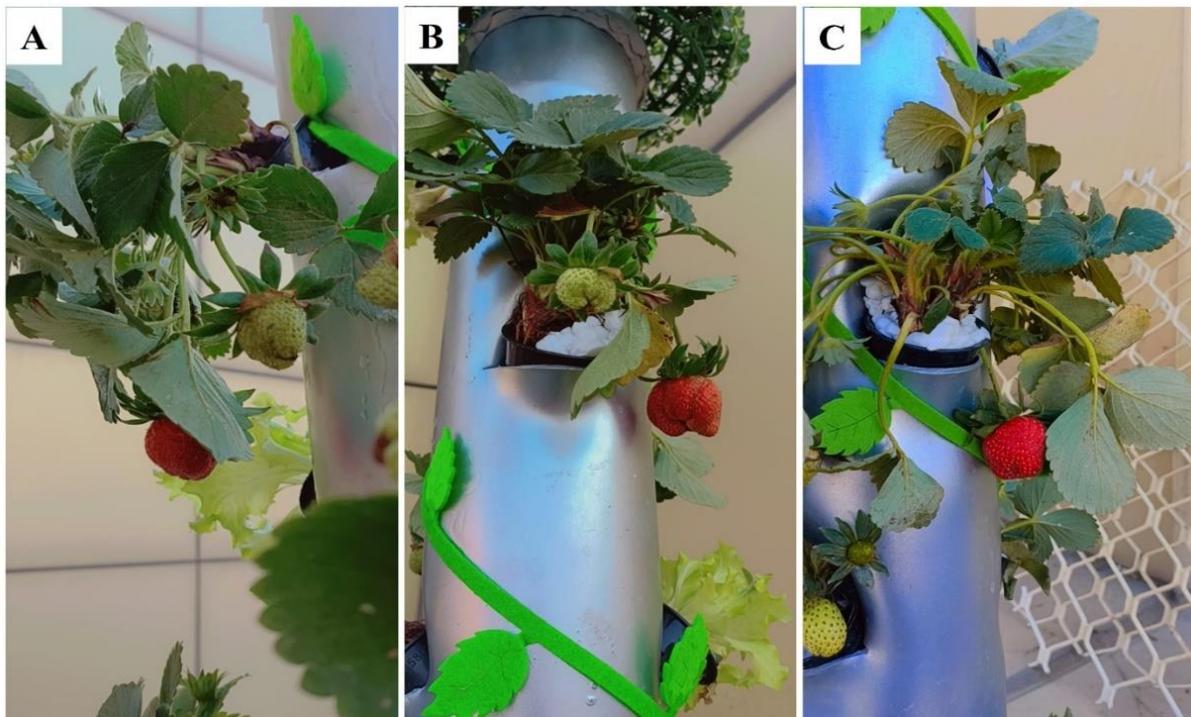
collected from the plants grown in NPK solution, kitchen waste solution and jaggery solution respectively proving that the number of flowers per plant as well as the number of fruits collected from each plant was highest in plants grown in jaggery solution (Fig. 3). However, approx. 90% of flowers were developing into fruits in both NPK and kitchen waste solutions and approx. 87% in jaggery solution. It took approx. 90, 94 and 91 days for complete maturation of fruits in NPK solution, kitchen waste solution and jaggery solution, respectively (Fig. 2 and Fig. 4). The average fruit weight was also found higher in jaggery solution followed by NPK solution and kitchen waste solution which were recorded approx. 20, 17.78 and 15.74 grams respectively (Fig. 5). The higher average fruit weight and fruit number might be due to enriched nitrogen, available sugar and microbes essential for the overall development of plant. Average plant height and root length was observed to be higher in NPK solution followed by jaggery solution and kitchen waste solution (Fig. 6). Overall, NPK solution was found best for early onset of flowering and growth of root and shoot but jaggery solution was found best for producing higher number of flowers as well as fruits. The jaggery solution can be proved an excellent organic liquid fertilizer that in the performed experiments supported the growth of strawberry plants very well and significantly higher than the commercially available hydroponics solutions. *Jeevamrutha*, a commercially available nutrient solution is known to promote remarkable biological activity in soil and thereby imparting nutrients to the growing crops in fields. The enormous microbiota which grows exponentially in this media acts as soil tonic (Palekar, 2006). Nitrogen fixers such as *Azotobacter*, *Azospirillum* and various other phosphorus and potassium solubilizing microbes like *Pseudomonas fluorescence* and *Bacillus silicus* respectively are some microbes thrive in cow-dung which is used in formulation of the jaggery solution (Boraiah et al., 2017). These essential bacterial population promoted the overall growth of strawberry plants in jaggery solution by providing them the required amount of nitrogen and minerals. The results obtained from the proposed study clearly indicated that jaggery solution can be used as a potent and affordable substitute for the cultivation of plants in hydroponics systems as compared to other commercially available nutrient solutions.

## 4. Conclusion

The strawberry cultivation is considered to be easily done using vertical hydroponics system especially for city dwellers and urban farmers. The two homemade organic nutrient solutions (kitchen waste solution and jaggery solution) used in the study were found to be suitable for hydroponically grown strawberries and the results were found comparable to NPK solution which is commercially available for hydroponics; however, the percentage development of fruits from the total number flowers was observed higher in kitchen waste and NPK solution than that of jaggery solution. Interestingly, the overall fruit yield was found to be higher in jaggery solution as compared to other solutions which clearly makes it a better choice for hydroponics enthusiasts. Besides, the design of vertical hydroponic system is completely different from other market set-ups as it contains funnel and tap to ensure easy filling and drain of nutrient solution. The ornamental asset of the set-up is far different and attractive than other set-ups available in the market, highly striking for installation at



**Fig. 1** a) Vertical hydroponics set-up b) strawberry plantlets of two weeks old c) plantlets transferred to vertical hydroponics column and d) full grown strawberry plants with fruits



**Fig. 2** Mature fruits grown in a) NPK solution b) kitchen waste solution and c) jaggery solution

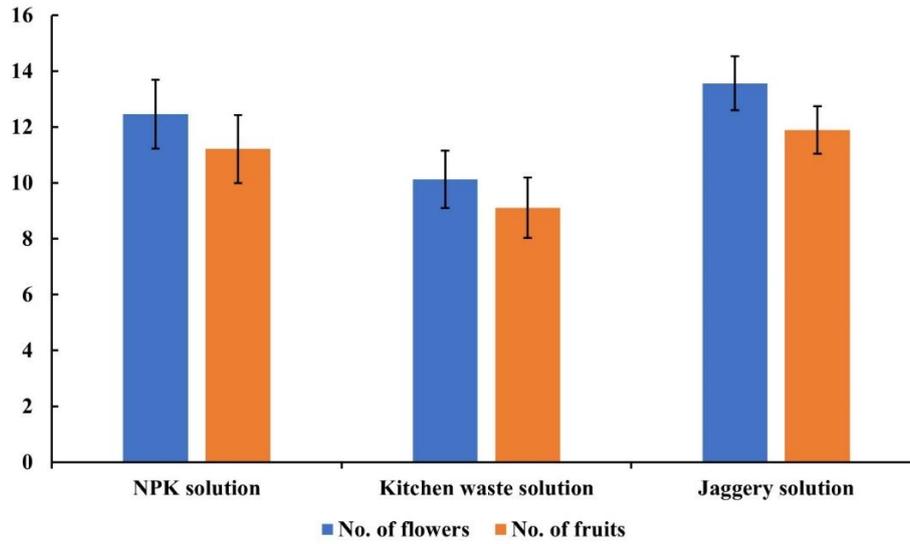


Fig. 3 Graph showing the number of flowers and number of fruits produced per plant

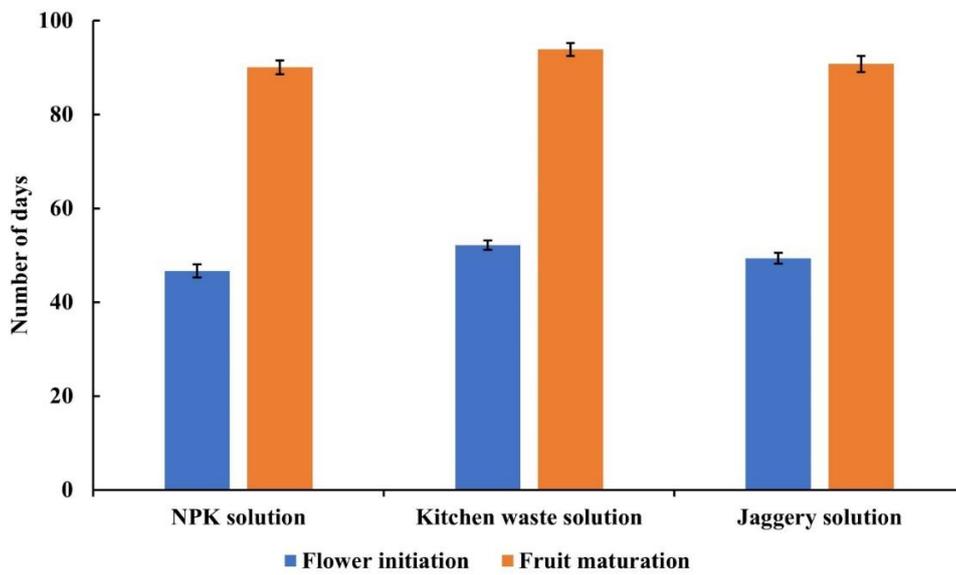


Fig. 4 Graph showing number of days taken for initiation of flowering and fruit maturation in the different nutrient solution

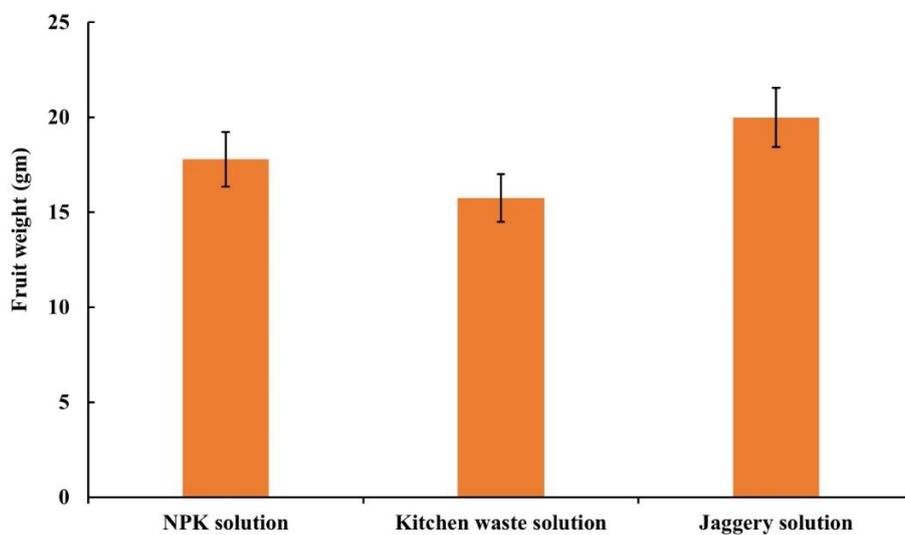
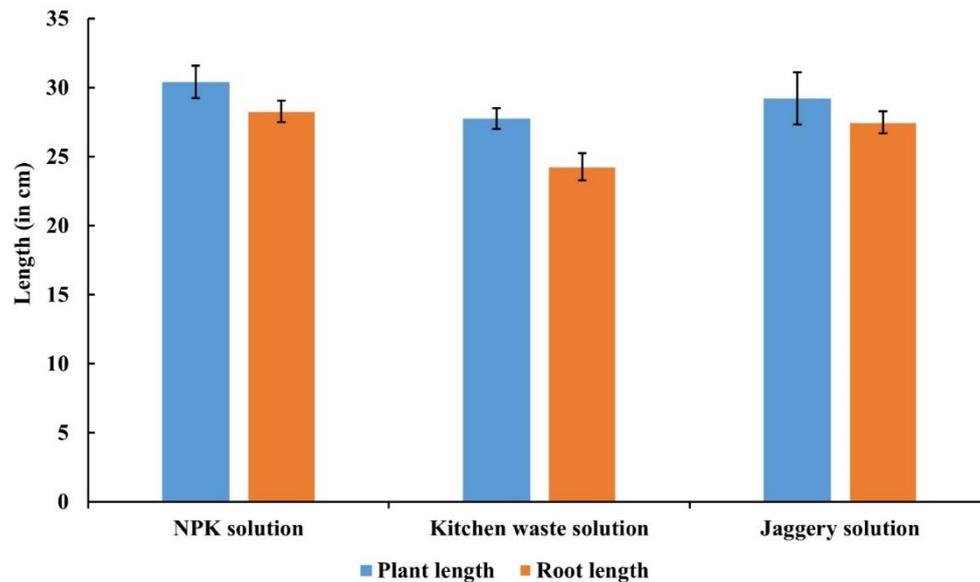


Fig. 5 Average weight of strawberry fruits collected from different nutrient solution containing set-ups



**Fig. 6** Graph representing the overall plant height and root length grown in different nutrient solutions

### Acknowledgement

Authors would like to acknowledge Ministry of Social Justice and Empowerment for providing National fellowship for Other Backward Classes to Sailendra Kumar and Department of Science and Technology for providing DST-INSPIRE fellowship to Anamta Rizvi. We would also like to acknowledge Department of Biotechnology, Babasaheb Bhimrao Ambedkar University for providing essential infrastructural and instrumental facilities.

### Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

### Author contribution

Conceptualization, methodology, software, data curation, investigation, validation, formal analysis, writing- original draft preparation was done by Madhurima Yadav, Sailendra Kumar and Anamta Rizvi. Conceptualization, supervision, resources, reviewing and editing was done finalized and reviewed by Sangeeta Saxena. All authors commented on previous versions of the manuscript. All authors read and agreed to the final manuscript.

### Conflict of interest

The authors report there are no competing interests to declare.

### Data availability

The datasets generated during analysis of the current study are available from the corresponding author on reasonable request.

### References

Adak, N., Gubbuk, H., 2015. Effect of planting systems and growing media on earliness, yield and quality of strawberry cultivation under soilless culture. *Not Bot Horti Agrobo*, 43(1), 204-209. <https://doi.org/10.15835/nbha4319815>

- Boraiah, B. Devakumar, N., Shubha, S. Palanna, K., 2017. Effect of Panchagavya, jeevamrutha and Cow Urine on Beneficial Microorganisms and Yield of Capsicum (*Capsicum annuum* L. var. grassum). *Int. J. Curr. Microbiol. Appl. Sci.* 6(9), 3226-3234. <https://doi.org/10.20546/ijcmas.2017.609.397>
- Bradley, P., and Marulanda, C., 2001. Simplified hydroponics to reduce global hunger. *Acta Hort.* 554, 289-296. <https://doi.org/10.17660/actahortic.2001.554.31>
- Gaikwad, D.J., 2020. Hydroponics Cultivation of Crops. *Protected Cultivation and Smart Agriculture* 279-287. <https://doi.org/10.30954/ndp-pcsa.2020.31>
- Khan, M. M., Akram, M. T., Janke, R., Qadri, R. W. K., Al-Sadi, A. M., and Farooque, A. A., 2020. Urban horticulture for food secure cities through and beyond covid-19. *Sustainability (Switzerland)*, 12(22), 9592. <https://doi.org/10.3390/su12229592>
- Kumar, S., and Mishra, S., 2023. Nutrient Management for Growth, Yield and Quality of Strawberry (*Fragaria ananassa*) in Vertical Hydroponics System. *Int. J. Clim. Chang.* 13(10), 183-194. <https://doi.org/10.9734/ijecc/2023/v13i102629>
- Palekar, S., 2006. *Shoonya bandovalada naisargika krushi pub.* Swamy Anand, Agri Prakashana, Bangalore
- Rahaman, M. M., Hossain, R., Herrera-Bravo, J., Islam, M. T., Atolani, O., Adeyemi, O. S., Owolodun, O. A., Kambizi, L., Daştan, S. D., Calina, D., and Sharifi-Rad, J., 2023a. Natural antioxidants from some fruits, seeds, foods, natural products, and associated health benefits: An update. *Food Sci Nutr.* 11(4), 1657-1670. <https://doi.org/10.1002/fsn3.3217>
- Rahaman, M. M., Hossain, R., Herrera-Bravo, J., Islam, M. T., Atolani, O., Adeyemi, O. S., Owolodun, O. A., Kambizi, L., Daştan, S. D., Calina, D., and Sharifi-Rad, J., 2023b. Natural antioxidants from some fruits, seeds, foods, natural products, and associated health benefits: An update. *Food Sci Nutr.* 11(4), 1657-1670. <https://doi.org/10.1002/fsn3.3217>

- Sardare, M. D., 2013. A Review on Plant Without Soil - Hydroponics. *Int. J. Res. Eng. Technol.* 02 (03), 299–304. <https://doi.org/10.15623/ijret.2013.0203013>
- Sharma, V. K., Godara, A. K., 2019. Growth responses of strawberry (*Fragaria* × *Ananassa* Duch.) Plants grown at different planting density using PVC pipe under protected cultivation. *Bangladesh J. Bot.*, 48(1), 1-7. <https://doi.org/10.3329/bjb.v48i1.47403>
- Thakur, M., Shylla, B., 2018. Influence of Different Growing Media on Plant Growth and Fruit Yield of Strawberry (*Fragaria* × *Ananassa* Duch.) Cv. Chandler Grown under Protected Conditions. *Int. J. Curr. Microbiol. Appl. Sci.* 7(04), 2724-2730. <https://doi.org/10.20546/ijcmas.2018.704.310>

- Van Gerrewey, T., Boon, N., Geelen, D., 2022. Vertical farming: The only way is up? *Agronomy* 12(1), 2. <https://doi.org/10.3390/agronomy12010002>

**Cite this article:**

**Yadav, M., Kumar, S., Rizvi, A., Saxena, S., 2023. Vertical hydroponics for sustainable soilless farming revolution in strawberry cultivation for urban dwellers. *J. Appl. Sci. Innov. Technol.* 2 (2), 96-102.**