



Comparative study of celery (*Apium graveolens*) on growth, yield and quality under different growing conditions

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There is an urgent need to reduce carbon emissions, increase food production for achieving sustainable goals and protecting the earth from greenhouse effect by keeping the earth temperature below 1.5°C (COP-28 2023). According to UN (2018) report due to rapidly increasing urbanization 70% of the world's population will become urban by 2050 as compared to 49% today that may increase 75% carbon emissions. Currently, cities around the world occupying 3% of the land (56% of the people) (World bank 2018) accounts for 60–80% of energy consumption and produce 75% of carbon footprint. Global urbanization from today till 2050 could increase net addition of 2.4 billion mankind to towns and cities. Conventional agriculture system is commonly based on soil and water but presently the agriculture resources are limiting factors due to unpredictable climatic conditions; soil infertility *vis-a-vis* increasing scarcity of water availability, rapid growth rate of urban population increasing greenhouse effect, global warming and decreasing per capita land availability and increasing demand of organic food bring us towards hydroponics cultivation. The challenges mentioned above have drawn worldwide interest to the adoption of intensive cropping systems, leading to the development of innovative technologies like soilless culture and hydroponics (Al-Karaki *et al.* 2012, Pant *et al.* 2018 and Agarwal *et al.* 2019). Hydroponics offers several advantages, including the ability to maximize space utilization by utilizing vertical space and achieving higher efficiency in nutrient usage. Hydroponics techniques also facilitate roof farming and indoor farming and requires less water as compared to conventional farming system. Hydroponics technology not only offers vertical utilization but also maintains quality and increases productivity.

Baby leaf vegetables (i.e. rocket, crisp head lettuce, endive, parsley, watercress) are the unexploited vegetable. Nowadays these crops are a part of the cultivation due to the

increased consumption and are mostly considered for salads, both as fresh market products and ready-to-use vegetables. Among leafy vegetables, celery (*Apium graveolens* L.) is one the important herbs which is grown in India during winter (*rabi*) season. The leaves stalk (edible part) and seed of celery herb are mostly used. It is an annual herb with an upright stem and compound leaves that has long stalks. The essential volatile oil extracted from celery is rich in selinene, d-limonene, sedanolide, and some sesquiterpenes (Chadha K L 2001). Therefore, a study was carried out to evaluate the growth, quality production and yield of celery under the hydroponic, soilless and soil conditions.

Present study was carried out during October 2022–January 2023 at Defence Institute of Bio-energy Research-Defence Research and Development Organisation, Haldwani, Nainital, Uttarakhand. During the study, maximum and minimum temperature recorded in the field was 28–32°C and under the low-cost shade net was 14–18°C, respectively. The selected variety for the trial was yellow (leaf celery). The celery nursery was raised in portraits by using a mixture of cocopeat, perlite, and vermiculite as the growing medium. After 25 days, the seedlings were transplanted into three different environments: hydroponic culture, soilless medium and traditional soil condition. To facilitate the growth of the crop in the hydroponics system, an 'A' frame unit was installed in-house using PVC pipes with a 4-inch diameter. Each unit had the capacity to accommodate 30 plants. Three pipes of equal length were attached to the structure, each containing 15 holes to support 15 plants. The hydroponic system was provided with a nutrient solution of pH ranging 6.5–7.5, along with an electrical conductivity (EC) of 1800±100 ppm during the experiment. The pH and EC levels were monitored using a portable pH meter and EC meter (HANNA). In the soil-less cultivation system, the crop was grown in a vertical frame unit consisting small pots which were fixed on a vertical mesh. These cups were filled with a mixture of coco peat, vermiculite, and perlite in a ratio of 3:1:1. The soil of crop growing area was sandy loam having pH 6–6.5. The crop

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was grown at the spacing of 30 cm × 30 cm. Manure and fertilizers were applied as, farmyard manure (FYM) @20 t/ha, N @45 kg/ha, and P₂O₅ @30 kg/ha and K₂O @20 kg/ha. The cultural operations like weeding, irrigation, pesticide was practiced as per crops grown under field conditions. Harvesting was done 80–90 days after sowing (DAS), when 80% of umbels started to change from light brown to dark in colour. Data were collected randomly from five plants and the average was calculated on the basis of plant height (cm), number of stalks, length of stalk (cm), length of root (cm), fresh weight of stalk (gm), fresh weight of root (gm), fresh weight (gm), total weight (gm), dry weight of stalk (gm), dry weight of root (gm), and chlorophyll content. Soil Plant Analysis Development (SPAD) readings were also measured using a SPAD meter-502 (Konica Minolta) at the full-grown stage of the crop.

Statistical analysis: The significance of variation among the treatments was determined through analysis of variance (ANOVA) and critical difference (CD) at a 5% level of significance for each characteristic.

Defence Institute for Bio-energy Research has developed the hydroponics nutrient solution as given by Hoagland and Arnon (1950) with desired modifications. The nutrient application is important for growth, yield and quality of various vegetables crops. Standard protocols need to be followed while preparing nutrient solution and necessary measures to be taken to avoid chances of precipitation. Presence of cations (+) and anions (-) of all the essential macro- and micro-nutrients decides the EC in the solution. Usually, three categories of stock solutions were prepared for hydroponics nutrient solution. Among them category A consists KNO₃, KH₂PO₄, Na₂MoO₄ while category B consists Ca (NO₃), H₃BO₃, MnCl Boric acid to be dissolved in hot water and to be boiled afterwards and make the volume 1 litre by addition of 10 ml of this stock solution/100 litre of water. The solution consists N (300 ppm), K (200 ppm), P (25 ppm), Ca (150 ppm), Mg (60 ppm), Zn (2 ppm), Mn (3 ppm), Cu (less than 1 ppm), Bo (1 ppm), molybdenum (less than 1 ppm), sodium (less than 1 ppm) and sulphur (2 ppm) in nutrient solution used for growing crop. Iron stock solution was prepared separately by dissolving 66.6 g of chelating agent EDTA in 600 ml of distilled water and 8 g of sodium hydroxide pellets in 200 ml of warm water (74°C). In a separate container, 50 g of FeSO₄ was dissolved in 600 ml of distilled water, and 10 ml of 1% N H₂SO₄ was added. The solution was then warmed up to 78–82°C. Both solutions were mixed together

and exposed to aeration overnight to obtain the ready-to-use iron solution (1 ml/litre). Additionally, micro nutrients such as Mn²⁺, Zn²⁺, and Cu²⁺ were added to the solution.

Effect on vegetative and yield traits: The results vary significantly different on the growing conditions (Table 1, Fig. 1). Results showed that the higher plant height (56.67 cm), fresh weight of stalk (659.03 g), length of stalk (58.13 cm), length of root (39.70 cm), edible weight (694.50 g) was observed under hydroponically grown crop as compared to other growing conditions. Whereas higher number of stalks (21.47), fresh weight of root (157.95 g) found under soil growing condition as compared to other growing conditions. The total weight (796.63 g/plant) was also found higher under soil growing conditions but statistically as par with hydroponically grown. Whereas the minimum (32.93) plant height, length of stalk (35.67 cm), length of root (23.00 cm) was found under soil grown condition as compared to other grown conditions. On the other hand, maximum (157.93) fresh weight of root was found under traditionally grown crop and fresh weight of stalk was found minimum (462.93) under soilless grown condition. Similar finding has been reported by Zha *et al.* (2024) in lettuce crop and they recorded highest fresh weight under hydroponics grown crop as compared to soil. Lei *et al.* (2021) also recorded higher plant root length in lettuce crop which was grown under hydroponics vs soil medium. Higher productivity of crop was found under present experiment as compared to other grown conditions. This difference might be due to the application of inputs in right time, right quality and right manner in hydroponically grown culture which significantly effects on plant root growth and development, protection from soil-borne diseases and weed control under hydroponic farming as compared to traditional farming similar findings has been also reported by Lei *et al.* (2021). The result revealed higher (68.37 g) dry weight of stalk observed under hydroponically grown conditions (Table 2). Proper



Fig. 1 Performance of celery crop under hydroponic culture.

Table 1 Effect of growing systems on growth, development and yield of celery

Treatment	Plant height (cm)	No. of stalk	Fresh weight of stalk (g)	Length of stalk (cm)	Length of root (cm)	Fresh weight of root (g)	Total weight (g)	Edible weight (g)
Hydroponic	56.67	17.80	659.03	58.13	39.70	89.93	793.97	694.50
Soil-less	38.60	15.70	462.93	38.97	30.53	115.67	634.47	491.03
Soil	32.93	21.47	579.70	35.67	23.00	157.93	796.63	654.47
SEm±	0.90	0.85	26.23	0.87	0.99	2.89	42.49	44.07
CD (P=0.05)	3.10	2.96	90.76	3.00	3.44	10.00	NS	152.49

Table 2 Effect of growing systems on dry weight of stalk, dry weight of root and SPAD value of celery

Treatment	Dry weight of stalk (g)	Dry weight of root (g)	SPAD reading
Hydroponic	68.37	8.50	49.63
Soil-less	47.63	10.97	36.57
Soil	63.50	16.60	47.73
SEm±	1.07	1.06	1.43
CD ($P=0.05$)	3.70	3.68	4.96
CV%	3.09	15.32	5.56

SPAD, Soil plant analysis development.

nutrient absorbance through plant roots under hydroponic culture during experiment significantly effect on growth and yield of leave stalk (Fig. 2). There was a correlation between higher nutrients application as compared to low concentration. Proper application of nutrients had positively affected crop yield while low nutrient application during crop growth had negatively affected crop growth. Acedo *et al.* (2022) observed that leafy vegetables, viz. mint, red basil and rocket salad grown hydroponically were effected by low nutrient availability. Bohme *et al.* (2020) conducted an experiment on cultivation of Asian leafy vegetables under nutrient-film technique (NFT) and found higher yield of leafy mustard under hydroponics culture. Agarwal *et al.* (2021) also found higher growth under hydroponically grown spinach as compared to soil grown.

Effect on SPAD reading: SPAD values are positively correlated with the chlorophyll content (Jiang *et al.* 2017). The result significantly effect qualitative traits. Comparative correlation was also found between the chlorophyll content and SPAD values (R^2 value=0.98). Agarwal *et al.* (2021) found higher SPAD reading in spinach crop which was grown under hydroponic condition. In present experiment the highest (49.63) SPAD reading was found under hydroponically grown crop due to proper availability of nutrients. Similar finding has been reported by Thomas *et al.* (2021). They found highest SPAD reading at different DAT in lettuce crop which was grown hydroponically (NFT).

Present study concludes that hydroponically grown leafy vegetables showed superiority over both qualitative and quantitative characteristics. Being a modern and emerging technology for local investors, this can promote self-employment to farmers in urban areas which could turn into a profitable business with community cooperation under controlled and eco-friendly environment.

SUMMARY

An experiment was conducted during October 2022–January 2023 at Defence Institute of Bio-energy Research-Defence Research and Development Organisation, Haldwani, Nainital, Uttarakhand to evaluate the growth, quality production and yield of celery under the hydroponic, soilless and soil conditions. Higher crop productivity of celery crop was found under hydroponic system as compared

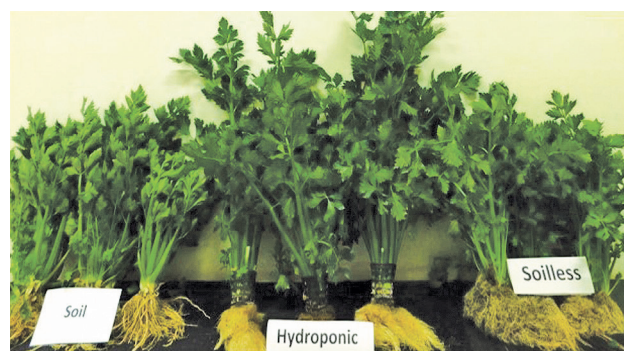


Fig. 2 Comparative performance of celery crop at harvesting time under different growing medium.

to other medium. The experiment revealed that there is a better provision for vertical space utilization and protection from soil-borne disease under hydroponic farming as compared to traditional farming. This experiment paved a new way for the need and future perspective of hydroponic technology to achieve the desirable quality of vegetable crop production by using modern farming technology such as hydroponics on a small and medium scale. The present experiment also summarized that this farming plays an important role in crop production to maintain market growth in coming years. In this respect, hydroponics is an emerging technology which play a vital role in urban and pre-urban area and positively effective in the ways to promote healthy and developed future for the planet and its people.

REFERENCES

- Agarwal A, Prakash O, Sahay D and Bala M. 2019. Innovative horticulture: Hydroponics (soil-less cultivation) for urban farming. *New Age Protected Cultivation* 5(2): 38–40.
- Agarwal A, Yadav P K, Prakash O, Sahay D and Bala M. 2021. Comparative Performance of spinach (*Spinacia oleracea*) as affected by growing media hydroponics vs soil. *Research and Reviews: Journal of Botanical Sciences*.
- Al-Karaki G N and Al-Hashimi M. 2012. Green fodder production and water use efficiency of some forage crops under hydroponic conditions. *International Scholarly Research Notices* 2012(1): 9246–72.
- Bohme M H, Dewenter M and Gohlke A. 2020. Aquaponics using Asian leafy vegetables-Potential and challenge. *Acta Horticulturae* 1273: 115–22.
- Conference of Parties (COP28)–UNFCCC, UAE.
- Chadha K L. 2001. *Handbook of Horticulture*, pp. 380. Indian Council of Agricultural Research, New Delhi.
- Fimbres-Acedo Y E, Traversari S, Cacini S, Costamagna G, Ginepro M and Massa D. 2022. Testing the effect of high pH and low nutrient concentration on four leafy vegetables in hydroponics. *Agronomy* 13: 41.
- Hoagland D R and Arnon D I. 1950. The water-culture method for growing plants without soil. California Agricultural Experimental Station; Circular 347.
- Jiang C, Johkan M, Hohjo M, Tsukagoshi S and Maruo T. 2017. A correlation analysis on chlorophyll content and SPAD value in tomato leaves. *Horticulture Research* 71: 37–42.
- Lei chuneli and Engeseth J Nicki. 2021. Comparison of growth characteristics, functional qualities, and texture of

- hydroponically grown and soil-grown lettuce. *LWT-Food Science and Technology* **150**. <https://doi.org/10.1016/j.lwt.2021.111931>
- Pant T, Agarwal A, Bhoj A S, Joshi R P, Prakash O and Dwivedi S K. 2018. Vegetable cultivation under hydroponics in Himalayas: Challenges and opportunities. *Defence Life Science Journal* **3**: 111–19.
- Thomas T, Biradar M S, Chimmad V P and Janagoudar B S. 2021. Growth and physiology of lettuce cultivars under different growing system. *Plant Physiology Reports* **26**(3): 526–34. <https://doi.org/10.1007/s40502-021-00591-3>
- United Nations for Food and Agriculture Organization (FAO). 2018. How to Feed the World in 2050. Available online: https://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf
- World Bank. Urban population (per cent of total population). 2018. Available online: <https://data.worldbank.org/indicator/SP.URB>
- Zha L, Wang Z, Huang C, Duan Y, Tian Y, Wan H and Zhang J. 2024. Comparative analysis of leaf vegetable productivity, quality, and profitability among different cultivation modes: A case study. *Agronomy* **14**: 76.