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Impact of Nutrient Electrical Conductivity on Growth, Yield and Quality Attributes of Beet leaf (*Beta vulgaris* var. *bengalensis*) in a Hydroponics (Soil- less) system

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Abstract: To find an electrical conductivity (EC) in the nutrient solution used for beet leaf cultivation that optimizes the crop physiology, growth and quality, we conducted an experiment with four EC treatments (from EC 1000- 2750 ppm) by using hydroponic nutrient film techniques (NFT) under naturally ventilated poly house. An experiment was conducted from November to December 2023 at DIBER DRDO, Haldwani, UK India. The treatments of the experiment comprised four EC level viz. 1000-1250 ppm, 1500-1750 ppm, 2000-2250 ppm and 2500-2750ppm concentration. The experimental design used was complete randomized block design with three replications. The results showed higher (57.30 cm) plant height, number of leaf (11.50), length of leaf (48.30) was found under EC concentration 2500- 2750 ppm as compared to others. Higher (12.60) width of leaf, length of root (34.70), fresh weight (15.60 g.) of root, total yield (114.30 g) of plant, dry wright of leaf (12.10g.), dry weight of root (1.60g) and chlorophyll content were high in medium EC concentration (2000-2250 ppm) while as higher (93.40) fresh weight of leaf was found under EC concentration 1500- 1750 ppm. Based on growth and quality criteria, the optimal EC treatment would be EC 2500-2750 or EC 2000- 2250 ppm for beet leaf in the hydroponic system. Too high or too low EC would induce nutrient stress, leaf width and productivity of beet leaf crop.

Keywords*:* Modern Farming • Hydroponics • Nutrient Electrical Conductivity • Beet Leaf • Productivity.

Introduction

There is an urgent imperative to mitigate carbon emissions and enhance global food production systems in order to achieve sustainable development goals and safeguard the planet from the adverse impacts of the greenhouse effect. This includes maintaining the global temperature rise below 1.5°C, as emphasized in the COP28 summit (2023). According to the United Nations (2018), urbanization is rapidly accelerating, with projections indicating that 70 percent of the world's population resides in urban areas by 2050, compared to 49 percent at present. It is expected that the rapid growth rate of the population and food security demand are increasing due to the food crisis in upcoming years. Therefore, food production is being increased by using innovative agricultural production technologies such as hydroponics, soilless cultivation, aeroponics, and aquaponics (Raneem et al 2018, Kumar et. al 2024). With increasing scarcity of drought, increasing carbon foot print and greenhouse effect *vis- a- vis* increases levels of pesticides in vegetables cultivation are harmful for environment as well as for human health (Kumar et al 2024, Agarwal et al 2021). Hydroponics technology has been considering under sustainable agriculture which principally based on the application of inputs such as "Right time, Right manner, Right quantity". hydroponics is also beneficial for sufficient used of fertilizers, water consumption as compared to conventional farming (Kumar et al 2024). Being emerging

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technology, hydroponics farming is beneficial in the area where limited water resources and insufficient arable land pose significant challenges specially in front-line boarder area. Moreover, recycling the water flow under hydroponics may also perform a systematic approach to avoid water loss and environmental pollution (Sambo et al 2019). Inappropriate concentrations of macro and micro nutrients in hydroponic nutrient solutions whether excessively high or insufficient can adversely affect plant growth, leading to symptoms of nutrient toxicity or deficiency (Diang et al. 2018). The electrical conductivity (EC) is an index of the salt concentrations of nutrients ions, which is often used to evaluate the nutrient concentrations in hydroponic solutions (Savvas et al 2018). EC is significantly effective on plant growth and yield at different growth stages. Thus, at the initial stage of plants are requires lower concentration requirement of nutrient. Total concentrations of ions in dissolve solution are known as electrical conductivity (EC) which is most important parameter in hydroponics nutrient culture which indicates nutrient concentration in hydroponics solution (Pignata et al 2017). The application of low concentration of nutrients solution effects on nutrient disorders whereas high concentration leads toxicity in growing crops (Samarakoon et al 2006). EC is represented by ds^{-m} (desi siemens/meter). In soil-less culture, total salt concentration of a nutrient solution is the most important characteristic (Singh et al 2016) . In general, nutrient uptake is hindered by higher electrical conductivity (EC), as it increases the osmotic pressure of the nutrient solution. Lower EC may severely effect on crop life cycle (Signore et al 2016). This study aims to evaluate the effects of different electrical conductivity (EC) levels in nutrient solutions on the growth, yield, and quality of beet leaf. Furthermore, the study purposefully to identify the optimal electrical conductivity (EC) level for growth and eating quality of beet leaf, and to assess the impact of the formulated hydroponic nutrient solution on crop development.

Material and methods

An experiment was conducted under the naturally ventilated poly house during September to December 2023 at DIBER DRDO, Haldwani, UK India. Agro-meteorological data (Table. 1-3) were collected by using automatic weather station (METER group, ATMOS 41, Inc. USA) at DIBER, Haldwani and average of mean work was carried out. Under present experiment four EC level treatments *viz* T_1 (1000-1250ppm), T_2(1500-1750ppm) T_3 (2000-2250ppm) and T_4 (2500-2750ppm) were used which was replicated three times and completely randomized block design was used for experiment. For raising the nursery of palak seeds were shown in the portrays during the month of September 2023 after 20 days old seedlings were transplanted under each treatment. Hydroponics (NFT) system used for growing the crop was vertical 'A' frame unit which was designed by DIBER. This unit was fabricated and installed in naturally ventilated poly house. This unit can accommodate 80 plants/unit.

Electrical Conductivity (EC) and pH levels of each treatment were monitored at weekly interval, EC concentration checked by using quality meter (Hanna Instruments). The EC level of the treatment was maintained by adding nutrients or irrigation water. The pH level was maintained at 6.0–6.5 and when it decreased to 6 or less, the pH was balanced in the solution by adding 1 mL NaOH (1%N). Chlorophyll content was measured by using SPAD – 502 meters (Konica Minolta, Japan). Harvesting was done 25 to 30 after transplanting. Data was recorded randomly on five plants-replication and average of mean was worked out. In present experiment observations were recorded on plant height (cm), length of leaf (cm), width of leaf (cm), number of leaf $^{-plant}$, length of roots (cm), fresh weight of leaves $^{-plant}$ (gm), dry wt. of root $^{-plant}$ (gm), fresh wt. of roots^{-plant} (gm), total fresh yield$^{-\ plant}$ and SPAD reading work was carried out. Plants required 17 essential nutrients to complete the life cycle. The nutrients required in higher amount are known as macro nutrient while those required in lower amount are known as micro nutrient. The primary nutrients C, H, O are utilized by plants from the environment. The secondary macro nutrients (N, P, K, Ca, Mg, S) and Fe, Cl, B, Co, Cu, Mn, Mo, Zn micro nutrients are supplied through nutrient solution prepared artificially. DIBER has developed a hydroponic nutrient solution based on the formulation proposed by Hoagland and Arnon (1950), with specific adjustments tailored to local requirements. The application of nutrients plays a critical role in determining the growth, productivity, and quality of various vegetable crops. It is essential to adhere to established protocols during the preparation of nutrient solutions, with careful attention to practices that minimize the risk of chemical precipitation. The electrical conductivity (EC) of the solution is influenced by the presence of both cations (positively charged ions) and anions (negatively charged ions) derived from essential macro- and micronutrients. Generally, hydroponic nutrient solutions are prepared using three types of stock solutions. Category A includes compounds such as potassium nitrate (KNO_3), monopotassium phosphate (KH_2PO_4), and sodium molybdate (Na_2MoO_4). Category B contains calcium nitrate [$Ca(NO_3)_2$], boric acid (H_3BO_3), manganese chloride ($MnCl_2$), and boric acid, which are usually dissolved in hot water, then boiled until fully dissolved, and the final volume is adjusted to one liter. For application, 10 ml of this stock solution is added to every 100 liters of water. Category C consists of a separately prepared iron stock solution. The hydroponic nutrient solution prepared at DIBER, Haldwani has good availability of all necessary nutrients according to their concentration and ions reactions.

Statistics analysis: Present study was carried out by using Completely Randomized Design (CRD) following the procedure described by (Gomez and Gomez, 1984). During present study 4 treatments were used which was replicated 3 times. ANNOVA work was carried out to find mean value of observations. The significant of variation among the treatments was observed by applying analysis of variance (ANNOVA) and critical difference (C. D) at 5% level of significant for each character work was carried out.

Result and Discussions

Effect on growth and yield : Result was significantly varies on growth and yield of beet leaf crop except width of leaf and length of root. Result (Table 4) which revealed that higher (57.30 cm) plant height, number of leaf (11.50), length of leaf (48.30) was found under EC concentration 2500- 2750 ppm as compared to others. On the other hand, higher (12.60) width of leaf, length of root (34.70), higher (15.60 g.) fresh weight of root, total weight (114.30 g) of plant, dry wright of leaf (12.10g.), dry weight of root (1.60g) and chlorophyll content was found under 2000-2250 ppm EC level treatment as compared to others. Result (Figure a-c) was found that higher (93.40) fresh weight of leaf was found under EC concentration 1500- 1750 ppm. Under present experiment proper availability of macro and micro nutrients in hydroponics nutrient solution which plays a vital role on growth and chlorophyll pigmentation in crop. Efficient management of nutrients is challenging in modern farming technology. It has been tremendously increasing to standardize optimum EC concentration of nutrients solution in hydroponics. Nutrient concentration plays a vital role in the growth and development of plants. In this study, the vegetative characteristics of the palak crop are observed to progressively improve with increasing levels of electrical conductivity (EC). Ding et al (2020) also observed that fresh weight, dry weight, and leaf dimensions of pakchoi plants showed a positive response when increase levels of electrical conductivity (EC). Sritontip et al (2022) also observed that morphological traits of green leaf oak lettuce was found higher at EC concentration of 1.2 mS cm^{-1} than for EC 0.3 and 0.6 mS cm^{-1} which was grown under hydroponics. Yang et al (2023) also conducted experiment and reported that photosynthetic properties and morphological traits of *Eruca sativa* increased with increasing EC from 1.2 to 1.8 dSm^{-1} under hydroponic

Fig.: Performance of beet leaf under various concentration (a) EC1000-1250 ppm **(b)** EC 1500-1750 ppm **(c)** EC 2000-2250 ppm **(d)** EC 2500-2750 ppm

Seo et al (2009) also observed high content of *lactucin* in lettuce was slightly higher under high level EC concentration as compared to lower EC concentration under hydroponics. Shawan et al (2023) also reported significant variation in *Centella asiatica* which was cultivated under different electrical conductivity in a hydroponics system. They also found better provision for nutrients uptake which have positive effects on plant growth and photosynthesis. Nasir et al (2023) was also investigated higher yield of tomato was found under high level of EC as compared to lower concentration in hydroponics.

Table: 1. September 2023, Agrometeorological Data

Date and Timing	Solar Radiation AV (w/m2)	Wind Speed AV (m/s)	Wind Direction (Degree)	Air Temp AV (^{o}C)	Atmospheric Pressure (kPa)	RH AV (%)	Soil Temp (^{o}C)
2023/09/22 12:00:07	448.80	2.20	157.7	28.08	96.59	87.95	34.2
2023/09/22 13:00:07	320.85	2.266	154.9	28.74	96.51	85.54	35.7
2023/09/22 14:00:07	356.20	2.05	159.5	28.78	96.46	84.26	33.09
2023/09/22 15:00:07	174.61	1.25	22	28.281	96.36	86.35	29.4
2023/09/22 16:00:06	213.44	1.11	102	28.07	96.32	88.22	32.09
2023/09/22 17:00:08	191.25	0.87	98.9	29.02	96.33	83.14	31
AV	**284.19**	**1.62**	**115.83**	**28.49**	**96.42**	**85.91**	**32.58**

Table: 2. October 2023, Agrometeorological Data

Date and Timing	Solar Radiation AV (w/m2)	Wind Speed AV (m/s)	Wind Speed MN (m/s)	Wind Speed MX (m/s)	Wind Direction (Degree)	Air Temp AV (° C)	Atmospheric Pressure (kPa)	RH AV (%)	Soil Temp (° C)
2023/10/22 12:00:07	119	1.93	0.07	4.55	251.2	26.58	97.5	57.05	34.1
2023/10/22 13:00:07	541	1.71	0.34	4.25	239.6	26.88	97.4	53.94	34.3
2023/10/22 14:00:08	475	1.65	0.1	4.16	255.4	27.65	97.32	50.30	32.90
2023/10/22 15:00:09	376	1.67	0.11	3.9	289.5	28.06	97.28	46.97	34.4
2023/10/22 16:00:05	213	1.38	0.18	3.19	266.29	28.18	97.23	44.95	33.7
2023/10/22 17:00:05	40	1.36	0.11	3.26	303.1	27.50	97.2	46.04	28.2
AV.	**294**	**1.61**	**0.15**	**3.88**	**267.51**	**27.47**	**97.32**	**49.87**	**32.93**

Table: 3. November, 2023 Agrometeorological Data

Date and Timing	Solar Radiation AV (w/m^2)	Wind Speed AV (m/s)	Wind Speed MN (m/s)	Wind Speed MX (m/s)	Wind Direction (Degree)	Air Temp AV (° C)	Atmospheric Pressure (kPa)	RH AV (%)	Soil Temp (° C)
2023/11/01 12:00:07	234.09	1.52	0.11	4.2	275.6	28.04	97.58	58.76	36.1
2023/11/01 13:00:07	120.24	1.61	0.23	3.59	232.8	28.48	97.47	51.25	35.5
2023/11/01 14:00:06	273.62	1.67	0.13	3.9	244.00	29.21	97.39	48.97	34.3
2023/11/01 15:00:08	421.20	1.73	0.09	4.36	246.1	29.36	97.31	42.83	35.9
2023/11/01 16:00:09	510.59	1.53	0.05	4.76	278.5	29.40	97.26	45.52	35.7
2023/11/01 17:00:07	95.85	1.52	0.11	2.99	278.9	28.91	97.23	46.16	34.8
AV	**223.86**	**1.60**	**0.12**	**3.96**	**259.31**	**28.90**	**97.37**	**48.92**	**35.38**

Table 4: Effect of various level of EC concentration on growth and yield of beet leaf grown under Hydroponics (Soil-less)

Treatment	**Plant Height (cm)**	**No. of leaf**	**Length of Leaf (cm)**	**Width of Leaf (cm)**	**Length of root (cm)**	**Fresh wt. of Leaf (gm)**	**Fresh wt. of root (gm)**	**Total wt. of Plant (gm)**	**Dry wt. of Leaf (gm)**	**Dry wt. of root (gm)**	**Chlorophyll Content**	**TSS (%)**
000-1250 ppm	39.20	6.60	22.40	9.90	34.60	54.00	5.00	62.00	5.90	0.50	30.90	8.00
500-1750 ppm	42.90	9.80	36.50	11.40	32.60	93.40	14.80	110.40	10.40	1.40	37.20	7.70
2000-2250 ppm	52.30	11.50	46.00	12.60	34.70	93.00	15.60	114.30	12.10	1.60	54.30	8.40
2500-2750 ppm	57.30	11.50	48.30	10.70	30.80	88.20	14.80	102.40	9.80	1.40	46.70	6.80
SEm	1.30	0.80	5.30	0.80	1.30	2.50	0.90	1.20	0.70	0.10	1.20	0.30
C.D. (P<5%)	4.20	2.60	17.30	NS	NS	8.00	2.80	3.90	2.30	0.30	4.00	1.10

Conclusion

On the basis of obtained results, it may be concluded that various level of electrical conductivity significantly showed impacts on growth and yield of beet leaf. Hence, EC at concentration of 2000-2250 ppm could be used to enhance production of beet leaf crop under hydroponics. This study may also prove beneficial in regions facing limited water resources and land availability, where efficient agricultural practices are essential for sustainable crop production.

References

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*. *10* (10), pp.106-109

Conference of Parties (COP28) , 2023 – UNFCCC, UN Climate Change Conference in Dubai UAE. https://unfccc.int/cop28.

Ding X, Jiang Y, Zhao H, Guo D, He L, Liu F, Zhou Q, Nandwani D, Hui D, Yu J (2018). Electrical conductivity of nutrient solution influenced photosynthesis, quality, and antioxidant enzyme activity of pakchoi (*Brassica campestris* L. ssp. *chinensis*) in a hydroponic system. PLOS ONE, *13*(8): e0202090.

Kumar H., Agarwal A., Yadav P. K., Ballabh B., Prakash O., and Singh D.P., (2024). Comparative study of celery (*Apium graveolens*) on growth, yield and quality under different growing conditions. *The Indian Journal of Agricultural Sciences, 94*(7), pp.791-794

Kumar H., Agarwal, A., Yadav, P. K., Sahay, D., Prakash, O., Ballabh, B., Meena, H. S. and Singh, D.P.2024. Performance of cherry tomato (*Solanum lycopersicum var. cerasiformae*) for biochemical quality traits under hydroponics. *J. Crop and Weed, 20(1)*, pp.31-35.

Kumar H., Agarwal A., Prakash O., Dayal R, Kumar S, Ballabh B., and Singh D.P., (2024). Indigenous and European Leafy vegetables cultivation under Modern farming- Hydroponics (Soil less). *Bharatiya Vaigyanik evam Audyogik Anusandhan Patrika*. *32*(2) pp.62- 68

Nasir N and Sato T (2023). Effect of nutrient-solution concentration on growth, yield, and fruit quality of tomato grown hydroponically in a single-truss production system. *Journal of Horticultural Research*, 31 (2).

Pignata G, Casale M and Nicola S (2017). Water and nutrient supply in horticultural crops grown in soilless culture: resource efficiency in dynamic and intensive systems. In: Tei F, Nicola S, Benincasa P (eds.) *Advances in Research on Fertilization Management of Vegetable Crops. Cham: Springer eBooks* , pp. 183–219.

Samarakoon U C, Weerasinghe P A and Weerakkody W A P (2006). Effect of electrical conductivity of the nutrient solution on nutrient uptake, growth and leaf lettuce in stationary culture. *Tropical Agriculture Research*, 18, pp. 13–21.

Sambo P, Nicoletto C, Giro A, Pii Y, Valentinuzzi F, Mimmo T, Lungli P, Orzes G Mazzelto F, Astolfi S, Terzano R, Ceso S (2019). Hydroponics solution for soilless production systems: Issues and opportunity in a small-agriculture perspective. *Frontiers in Plant Science*. 10 ,923, pp. 1-17.

Savvas D and Gruda N (2018). Application of soilless-culture technologies in the modern greenhouse industry—A review. *European Journal of Horticultural Science*, 83, pp. 280–293.

Seo M W, Yang D S, Kays S J, Kim J H, Woo J H and Park K W (2009). Effects of nutrient solution electrical conductivity and sulfur, magnesium, and phosphorus concentration on sesquiterpene lactones in hydroponically grown lettuce. *Scientia Horticulturae*, 122, pp. 369–374.

Shawan Md R A, Azad Md O K, Ryu B R, Na J K and Chai Ki Y (2023). The electrical conductivity of nutrient solution influenced the growth, centellosides content and gene expression of *Centella asiatica* in a hydroponic system. *Agriculture*, *13,* 2236.

Signore A, Serio F, Santamaria P (2016). A targeted management of the nutrient solution in a soilless tomato crop according to plant needs. *Frontiers in Plant Science*, *7*, 391.

Singh H, Bruce D, (2016). *Electrical Conductivity and pH Guide for Hydroponics*. Technical Report; Oklahoma State University, Stillwater, OK, USA. HLA pp. 6722- 2-6722-.

Sritontip C, Nuon D, Tong R, Sritontip P, Chidburee A, Thonglek V (2022). Effects of micro-nano bubbles and electrical conductivity of nutrient solution on the growth and yield of green oak lettuce in a hydroponic production system. *Journal of Science and Agricultural Technology*, *3* (1), pp.16–24.

United Nations. World Urbanization Prospects: The 2018 Revision. 2018. Available online: https://population.un.org/wup/https://population.un.org/wup/Publications/FilesWUP2018-Report.pdf

Yang T, Samarakoon U, Altand J and Ling P (2023). Photosynthesis, biomass production, nutritional quality, and flavor-related phytochemical properties of hydroponic- grown arugula (*Eruca sativa* Mill.) 'Standard' under different electrical conductivity of nutrient solution. *Agronomy*, 11, 1340.