EFFECT OF ELECTRICAL CONDUCTIVITY ON YIELD AND QUALITY OF DIFFERENT VARIETY OF LETTUCE IN HYDROPONIC SYSTEM

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CERTIFICATE

This is to certify that thesis entitled, "EFFECT OF ELECTRICAL CONDUCTIVITY ON YIELD AND QUALITY OF DIFFERENT VARIETY OF LETTUCE IN HYDROPONIC SYSTEM" submitted to the faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of MASTER OF SCIENCE IN HORTICULTURE, embodies the result of a piece of bona fide research work carried out by KONA AFROZ BHUIYAN, Registration: 19-10209 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information received during the course of this investigation has been duly acknowledged.

Dated:
Dhaka, Bangladesh

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ABSTRACT

Hydroponic leafy greens like lettuce, can be an excellent source of nutrition for human health. This study was aimed to assess lettuce production, using two types of lettuce varieties (Hybrid Lettuce and Loose-leaf Lettuce) and four different electrical conductivity (EC_1=1.5, EC_2=2.0, EC_3=2.5 and EC_4=3.0 dS/m) of standard nutrient solution ratios. It was carried out in completely randomized design (CRD) with three replications in semi-green House at Horticulture Farm of Sher-e-Bangla Agricultural University, during September 2019 to February 2020. Vegetative growth, yield and physiological parameters were estimated in this experiment. In case of varieties, the highest plant height (22.95 cm), maximum number of leaves plant^{-1} (18.38) and the highest fresh weight (210.90 g/plant) were recorded from hybrid lettuce while the lowest in loose-leaf lettuce. For electrical conductivity in hydroponic nutrient solution, the highest leaf length (23.26 cm), maximum number leaves plant^{-1} (17.83) and the highest fresh weight (218.48 g/plant) were recorded from EC_3(2.5 dS/m) while the lowest in EC_1(1.5 dS/m). For varieties, had a higher ascorbic acid content (46.33 mg/100 g FW), β-carotene content (208.25 μg/100g) and net assimilation rate found in hybrid lettuce, compared to the lowest in loose-leaf lettuce. The content of ascorbic acid (44.00 mg/100 gm FW) and β-carotene (230.17 μg/100g), as well as the net assimilation were the highest for EC_3(2.5 dS/m), the lowest for EC_1(1.5 dS/m) in the context of nutrient solution. Therefore, it can be concluded that among the treatments combination, hybrid lettuce and EC_3(2.5 dS/m) would be much suitable for lettuce production in hydroponic system with highest yield.

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ABBREVIATIONS AND ACRONYMS

ANOVA	= Analysis of Variance
BCSIR	=Bangladesh Council of scientific and Industrial Research
CV %	=Percent Coefficient of Variation
DAT	= Days after transplanting
df	= Degrees of freedom
EC	=Electrical Conductivity
et al.,	= And others
ANOVA	= Analysis of Variance
LA	=Leaf Area
LAR	=Leaf Area Ratio
LDR	= Leaf Dry Weight
LMR	= Leaf Mass Ratio
RWR	= Root Weight Ratio
RGR	= Relative Growth Rate
NAR	= Net Assimilation Rate
RDR	= Root Dry Weight
Viz.	= namely

CHAPTER 1

INTRODUCTION

Agriculture-based emerging countries like Bangladesh must experience a substantial revolution in order to encounter diversified challenges of achieving food security for the growing population in responding to global environmental complications such as change of climate, natural resource degradation including soil erosion, and biodiversity loss (Dwivedi *et al*., 2017). As a climate-smart production system and for high production aptitude of hydroponics for horticultural crops comes first within the agriculture sector of Bangladesh under climate change. Diversified vegetables and crops species can be grown suitably over the years through hydroponics (Sharma *et al*., 2018).

The hydroponic cultivation system has swiftly highlighted worldwide which is the growing of horticultural crops in a soilless medium, or an aquatic-based environment (Gruda, 2021). The hydroponic culture required mineral nutrient solutions to support the plants, without soil, in water conditions (Son *et al*., 2020). This farming system might be the most intensive and exclusive culture system for utilizing all the resources efficiently (Son *et al*., 2020). Several studies suggested soilless culture in the greenhouse as an alternative to traditional field production for high-value vegetable crops (Son *et al*., 2020; Abusin and Mandikiana, 2020; Gruda, 2021). This intensive agriculture system can control the growing environment through the management of weather factors, the amount and composition of nutrient solution, and also the growing medium. Consequently, soilless culture suggestively improves the quality of crops compared to conventional soil-based culture (Asaduzzaman, 2015). This growing system facilitates mineral nutrients for plants with mechanical water for higher growth and development. Additionally, it has also been used as the standard methodology for plant biological research in diversified disciplines, as it allows more efficient use of water and fertilizers, as well as better control of biotic and abiotic factors. It is highly productive, conservative of water and land, and protective of the environment which proved to be an excellent alternative crop production system (Savvas, 2003).

The Hydroponics cultivation of vegetable crops can be possible at any adverse condition even in saline or acidic soils, or non-arable soils with poor structure and achieve high yields and high quality (Sharma *et al*., 2018). Hydroponics system can be control over soil-borne diseases and pests, which is especially required in the tropics, where pet infestation infestations are a major concern (Treftz and Omaye, 2016). Despite the considerable advantages of commercial hydroponics, there are still some disadvantages, which confine the further expansion of soilless cultivation. In hydroponics, it's absolutely essential, to begin with a laboratory analysis of the nutrient solution. The three main things are important *i.e*., the alkalinity, the electrical conductivity (EC), and the concentration-specific elements in hydroponics (Mattson and Peters, 2014). EC of nutrient solution significantly affected biomass production and water content. EC significantly impacted concentrations of 3-O-glucoside and uptake of phosphorous, potassium, iron, boron, zinc, and molybdenum Sublett *et al*., (2018).

Nutrient solutions and their constituents can influence the cultivation of quality vegetable crops in hydroponics since these systems allow the manipulation of crop fertilization to modify characteristics such as growth (Oki and Lieth, 2004) and mineral nutrient concentration in plant tissue (Gent, 2003). Additionally, Kappel *et al*., (2021) investigate the effect of electrical conductivity (EC) levels of the nutrient solution on the fresh weight, chlorophyll, and nitrate content of hydroponic-system-grown lettuce. The use of liquid organic fertilizer as a replacement or supplement to chemical fertilizer is an attractive solution for hydroponic planting. Plants can proficiently uptake nutritional components that dissolved in the liquid fertilizer as growth nutrients. The composition of nutrient solutions and the optimization of EC of nutrients in commercial hydroponics can reduce fertilizer costs. The specific formulation of nutrient composition with EC is required for most horticultural crops grown in soilless culture. For the promotion of nutrient utilization by the plant modified strength hydroponic solution like Rahman and Inden (2012) will be used along with it. The strength of the nutrient solution can be detected indirectly by measuring the EC of the solution. The ideal range for hydroponics is between 1.5 to 2.5 ds/m. Higher EC hinders nutrient absorption due to osmotic pressure whereas lower EC severity affects plant health and finally yield (Anonymous, 2002; Trejo-Téllez and Gómez-Merino, 2012). Moreover, EC and the proportion of different nutrient elements of the solution affect tissue composition in vegetable crops like lettuce. Lettuce is a plant of considerable agricultural and economic interest in salad vegetables and it is reported to respond well to nutrient solution additives in a hydroponic system. Considering the fact, the present study articulated to evaluate suitable EC (hydroponics solution additive) for better yield and quality of different lettuce varieties in hydroponic systems.

Objectives:

- To study the effect of electrical conductivity in nutrition solution on lettuce hydroponic system and
- To study the performance of lettuce varieties for better yield and quality in hydroponic system.

CHAPTER 2

REVIEW OF LITERATURE

Lettuce is one of the most popular and important vegetables for salad purposes that comprises with calcium, potassium, iron, protein, and adequate level of fiber content. It is cultivated commercially by hydroponics systems throughout the world. Being a succulent leafy vegetable its uptake much more available nutrition and transfers it to the leaves. Yet excess nutrition accumulated through higher electrical conductivity (EC) in the leaves, which might be showed plant toxicity. Some of the previous research findings related to the effect of electrical conductivity of nutrient solution on physiological growth and yield in hydroponic lettuce have been studied here.

Kappel *et al*., (2021) studied the effect of electrical conductivity (EC) levels of the nutrient solution on the fresh weight, chlorophyll, and nitrate content of hydroponic-system-grown lettuce. Seven popular cultivars ('Sintia,' 'Limeira,' 'Corentine,' 'Cencibel,' 'Kiber,' 'Attiraï,' and 'Rouxaï') of three Lactuca sativa L. types' (butterhead, loose leaf, and oak leaf) were grown in a phytotron in rockwool, meanwhile the EC level of the nutrient solutions were different: normal (<1.3 dS/m) and high (10 dS/m). The plants in the higher EC provided a lower yield but elevated chlorophyll content and nitrate level, although the 'Limeira' and 'Cencibel' cultivars had reduced nitrate levels. The results and the special characteristic of the lollo-type cultivars showed that the nitrate level could be very different due to salinity ('Limeira' had the lowest (684 µg/g fresh weight (FW)) and 'Cencibel' had the highest (4396 µg/g FW).

Hosseini et al., (2021) examined the consequence of five EC levels (2, 1.2, 0.9, 0.7, and 0.5 dS/m) of Hoagland nutrient solution on the growth and development of lettuce cultivar

‘Batavia-Caipira’. They studied the effects on several growth parameters (including the dry and fresh weight of leaves and roots, number of leaves, and leaf area) as well as the chlorophyll and nitrogen concentration of the leaves. The report showed the lettuce growth parameters significantly higher in the treatment with EC of 1.2 and 0.9 dS/m. These EC values are lower than the recommended EC value given as the optimum in the previous studies. Yet, the concentration of chlorophyll and nitrogen showed higher in full strength of nutrient solution with EC = 2 dS/m.

Kim *et al*., (2016) reported that, the salinity of irrigation water is a serious limitation to the production of certain vegetable crops and it has been considered as the major factor of irrigation water. They reported the growth and yield of lettuce indicated that the aspects that was significantly affected by saline irrigation water were crop yields rather than crop components such as number of leaves, leaf length, and leaf width. In this study, the point of salt concentration during an increase in salinity levels of irrigation water (EC) at which yield starts to decline for lettuce. Additionally, the study also confirmed that the nonstop irrigation of saline water under greenhouse environments could lead to a significant increase in electric conductivity (EC) level and Na^+ concentration in soil, eventually Na^+ concentration in leaves of crops.

Cometti *et al.* (2013) reported that the electrical conductivity (EC) of the nutrient solution influenced the behavior of lettuce growth by changing the temperature. The study found that the increase in EC did not reduce lettuce productivity when the extreme temperature of the nutrient solution was restricted to 26ºC. It also showed that cooling of the nutrient solution providing greater assimilation of biomass and higher water content in plants that increasing the yield of hydroponic lettuce in the tropical region.

Sublett *et al*., (2018) reported that, growing season and lettuce cultivar was the major factor influencing yield, biomass, and quality. Additionally, EC of nutrient solution significantly affected biomass production and water content. EC significantly impacted concentrations of 3-O-glucoside and uptake of phosphorous, potassium, iron, boron, zinc, and molybdenum. Effects of growing season and cultivar on leafy lettuce yield and quality were more distinct than the effect of nutrient solution EC treatment. Thus, greenhouse production of green and red-leaf lettuce cultivars in the south-eastern United States should be conducted in the spring and fall growing seasons with elevated nutrient solution EC of $\approx 4.0\ mS \cdot cm{-1}$ to maximize yield and quality.

Albano *et al*., (2017) stated that calcium (Ca) and magnesium (Mg) carbonates and bicarbonates contributed to severe water alkalinity. Frequent application to horticultural crops can be rise pH in nutrition solution that can lead to imbalance nutrient availability and may be hindered the plant-growth due to nutritional imbalance. The higher electrical conductivity leads the abnormal growth, leaf greenness, root systems by water acidification which does change the pH level of nutrient solution and plant tissue nutrient levels as well as growth over a long-term production cycle typical for horticultural crops.

Kadam, 2016 studied that, soil EC and pH is important factors as it affects the growth of plants. Soil EC is a measurement that correlates to soil properties affecting crop productivity, including soil texture, cation exchange capacity, drainage conditions, organic matter level and subsoil characteristics. pH of soil affects the ability of plant roots to absorb nutrients. This study helps farmer to understand nature of their soil and also soluble salts present in their soil.

Dyśko *et al.* (2008) studied that in the rooting area of plants, PO_4^{3-}, HPO_4^{2-} and $H_2PO_4^-$ ions can be found where the last two ions are the basic forms of P that taken by plants. On inert substrates, the higher amount of P available in a nutrient solution which presented its pH of acidic condition (pH 5). In alkaline and highly acidic solutions, the concentration of P decreases in a significant way.

Ismayilov *et al*., (2021) reported that, soil salinity severely affects soil ecosystem quality and crop production in semi-arid and arid regions. Measuring the EC (1:5) is more convenient, yet EC is not only affected by the concentration but also characteristics of the ions and the salinity chemistry. The objective of this study was to examine the relationship between EC and TSS of soils in a diluted extract (1:5) for eight classic salinity types. We analyzed extracts (1:5) of 1100 samples of a clayey soil (0–20 cm) collected from cultivated semi-arid and arid regions for EC, TSS, soluble cations (Na^+, $Ca2^+$, Mg^{2+}), and anions (HCO^{3-}, Cl^-, SO_4^{2-}). The findings suggest that once the salinity type of the soil is established, EC (1:5) values can be safely used for the evaluation of the soil salinity degree in the irrigated land in the context of sustainable soil and crop management.

Trejo-Téllez and Gómez-Merino (2012) reported that with the exception of carbon and oxygen, which are supplied from the atmosphere, the essential elements are obtained from the growth medium. Other elements such as sodium, silicon, vanadium, selenium, cobalt, aluminum, and iodine among others, are considered beneficial because some of them can stimulate the growth, or can compensate for toxic effects of other elements, or may replace essential nutrients in a less specific role. The most basic nutrient solutions consider in their composition are only nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur and they are supplemented with micronutrients. The nutrient composition determines the electrical conductivity and osmotic potential of the solution which can be lead toxicity in plant through higher number of nutrient uptakes at high nutrient concentration.

Aini et al., (2019) reported that the effect of three nutrient concentration level and inoculation of PGPR, AMF and consortium PGPR+AMF on plant growth, yield, and nutrient uptake in hydroponic romaine lettuce. The results showed that three level nutrients concentration with inoculation of AMF and/or consortium PGPR+AMF greatly changed the leaf anatomical traits, linked to increasing leaf thickness and leaf area that was increasing of plant fresh biomass. Three level nutrient concentration also increased root colonization, and macronutrient uptake. The result of this study showed that nutrient concentration with EC 0.9–1.8 dS/m may be recommended for production or cultivation of romaine lettuce, particularly using hydroponic substrate culture systems.

Samarakoon *et al.* (2006) reported that toxicities could occur in nutrient solutions over time, as the solution gets concentrated due to rapid water absorption. The leaf number of lettuces was not significantly affected by the treatments, since it did not either increase or decrease with increasing nutrient solution concentration. A solution concentration of 0.5 g/L of Albert‟s solution (having an EC of l.4 dS/m) with renewal at 2 weeks intervals could be identified as the best fertigation strategy under hot and humid conditions. Increasing solution concentrations above that level up to 2 dS/m increased the plant uptake of N, P, K and Ca but, without a significant increase in leaf growth and yield.

Dufour and Guérin (2005) reported that when a nutrient solution is applied continuously, plants can uptake ions at very low concentrations. So, it has been reported that a high proportion of the nutrients are not used by plants or their uptake does not impact production. It was determined that in anthurium, 60% of nutrients are lost in the leachate.

Andriolo *et al.* (2005) found the results whereby leaf number was not affected by salinity levels. Fresh mass decreased with increasing nutrient solution concentration but there was no significant difference between the treatments. These decreases meant that there was a decline in the yield of lettuce during the spring season.

Andriolo *et al.* (2005) reported that there was no significant difference in root dry mass among treatments because it did not show any specific tendency of either increasing or decreasing with increasing nutrient solution concentration. However, there were contrasting results between fresh mass and leaf dry mass whereby fresh mass was decreasing with an increase in nutrient concentration while leaf dry mass was increasing with increasing nutrient concentration. This could be attributed to the fact that plants grown at 1 mS/cm had more water content whereas plants grown at a higher EC level (4 mS/cm) had less water content but more dry matter content. This indicates that there were very few nutrients (nutrient deficiency) in the lower EC (1 mS/cm) while high salt content resulted in low chlorophyll content in the higher EC levels (4 mS/cm). Nitrogen significantly increased with increasing nutrient solution concentration. Phosphorus is good for root development but there was a conflicting relationship between the P content in the leaves and the dry root mass which could not be explained. Calcium (Ca) decreased with increasing the EC level while magnesium (Mg) remained constant, but both were slightly lower than the recommended range. However, potassium (K) was below the recommended range although it did not affect lettuce quality/taste.

Kang and Van Iersel (2004) reported that highly concentrated nutrient solutions lead to excessive nutrient uptake and therefore toxic effects may be expected. Conversely, there are pieces of evidence of the positive effects of high concentrations of nutrient solution. In salvia, the increase of Hoagland concentration at 200% caused those plants to flower 8 days previous to the plants at low concentrations, increasing total dry weight and leaf area. Voogt (2002) studied that in closed systems of hydroponic nutrient solution, the loss of nutrients from the root environment is brought to a minimum. Voogt (2002) indicates that the nutrient solution composition must reflect the uptake ratios of individual elements by the crop and as the demand between species differs, the basic composition of a nutrient solution is specific for each crop. It must also be taken into account that the uptake differs between elements and the system used. For instance, in open systems with free drainage, much of the nutrient solution is lost by leachate.

Resh (2012) reported that Hydroponics is a method of growing plants using mineral nutrient solutions in water without soil. It is a technology designed for arid countries like Namibia, where it is advantageous over soil-based vegetable production in that it conserves water avoids soil-borne diseases, makes vegetable production possible even in areas with poor soil fertility, and, generally enhances vegetable production and quality. Serio *et al.* (2001) found decreasing fresh shoot mass with increasing nutrient solution concentration. Liang *et al*., (2014) reported that traditionally, organic nutrient solution for hydroponics has not been feasible, despite the similarities in plant growth when either conventional or organic fertilizer is applied to the soil. It was not until the early 1990s when that organic nutrient solution for hydroponics was introduced. Challenges with these liquid nutrient solutions emerged, such as organic fertilizer being unsuitable to plant growth because nitrogen in organic sources is predominantly organic, hence unusable by plants. The forms of nitrogen absorbed by plants are nitrate and ammonium. Therefore, the nitrogen in manure requires to be mineralized prior to use by plants hydroponically.

Osman *et al*., (2009) reported that the use of mineral fertilizers for agriculture is relatively expensive worldwide and particularly in Africa (Sanchez, 2002). Yet nutrition required for food production (quality and quantity) remains a priority for food security in general, and for vegetable value chains in particular. Farmers, therefore, use little or no commercial fertilizer for fear of high cost (Mowa, 2015). Therefore, the current trend of depending on expensive fertilizers has failed to achieve the benefit of increased production from the use of available critical macro and micronutrients as a means of increasing the value addition of specialized products for the horticultural market. The goal in retrospect is to search for alternative means for specialized horticultural production.

Gruda (2012) found that different types of materials have long been traditionally used in horticulture and in the nursery industry. Over the last few decades, there has been, on the one hand, a significant increase in the number of materials used, arising from industrial processes, to be used with or in replacement of traditional materials. secondly, there has been a growing use of substrates of cultivation.

Voors *et al.,* (2016) reported that first, the adoption of hydroponics technology is practical to local farmers in that it uses simplified local resources such as cow dung manure, and goat manures which are abundantly available in the Erongo region as inputs. In contrast to the already failed adoption of hydroponics based on the non-accessible costly resources that come along with the use of hydroponics based on conventional hydroponic fertilizers. Therefore, in the second instance, access to finance for local farmers to participate in hydroponic vegetable production is another handicap for most cannot afford to sustain hydroponic operations based on the current costs associated with conventional hydroponics. In the third instance, with the abundance of organic sources of nutrients such as goat, cattle, and chicken manures in the Erongo region, local community members i.e. those raring goats can form social network groups where they could encourage those within their circles to upscale the local organic hydroponic solution for vegetable production in contrast to the conventional hydroponic nutrient solution which according to the locals is to be afforded by only certain members of society with financial abilities. Recently, there have been successful hydroponic production of tomatoes and other vegetables using organic nutrient solutions processed by microorganisms.

Chinta *et al.,* (2015) found that using an organic nutrient solution made from corn-steep liquor not only made successful Lactuca sativa (lettuce) production but also reduced root rotting. Fujiwara *et al.,* (2012) found the same effect of reducing root rotting was also observed in tomato plants when the organic nutrient solution was used. Furthermore, plant wilting was also reduced in this case. Chinta *et al* (2015) found that using an organic nutrient solution made from corn-steep liquor provided resistance to air-borne disease in vegetables.

Shinohara *et al.,* (2011) found that using organic nutrient solutions made from fish-based fertilizer or corn steep liquor hydroponically, produced tomato yields similar to those produced from conventional nutrient solutions. From the same organic nutrient solutions, Shinohara *et al.,* (2011) further established that when *Lactuca sativa* (lettuce) was grown, the organic system produced significantly greater and fresh *Lactuca sativa* (lettuce) head weight than in the conventional system.

Materska *et al.,* (2005) reported that there was no significant difference in root dry mass among treatments because it did not show any specific tendency of either increasing or decreasing with increasing nutrient solution concentration. However, there were contrasting results between fresh mass and leaf dry mass whereby fresh mass was decreasing with an increase in nutrient concentration while leaf dry mass was increasing with increasing nutrient concentration. This could be attributed to the fact that plants grown at 1 mS/cm had more water content whereas plants grown at a higher EC level (4 mS/cm) had less water content but more dry matter content.

Souri and Aslani (2018) found that plant growth, pod yield (79%), and pod quality were improved by the application of chelate fertilizers. Growth parameters such as plant height, number of leaves and lateral shoots shoot dry weight, pod number, and pod length were significantly increased by foliar application of the chelate fertilizers. The concentrations of nitrogen, potassium and iron in pods and above all in leaves were increased by foliar application of chelate fertilizers compared to control and soil applied NPK. Pod pH and TSS were not influenced by treatments; however, foliar application of the chelate fertilizers resulted in higher titratable acidity (40%), vitamin C (112%), and protein (35%) content of pods. The results indicate that organic-based chelate fertilizers can be effective safer alternatives for simple chemical salts in calcareous soils.

Azam *et al.* (2016) found that the effect of foliar applied different concentrations (5, 10, and 15 mM) of calcium chloride and potassium chloride to alleviate drought stress in bell pepper plants. Both experiments were conducted according to CRD (completely randomized design). Calcium and potassium significantly improved all parameters, i.e., photosynthesis rate, transpiration rate, leaf-free proline, leaf osmotic potential, fruit weight, etc. Calcium chloride at 10 mM showed better results than other treatments under normal irrigation while calcium chloride at 15 mM showed better results under drought conditions.

So, it may be concluded that drought tolerance in bell pepper could be improved by foliar application of calcium and potassium chlorides.

Peiris and Weerakkody (2015) conducted an experiment to study plant growth in terms of fresh weight (FW, g/ plant), dry weight (DW, g/plant), total leaf area (LA, cm2/plant), maximum root length (RL, cm), specific leaf weight (SLW, g/cm^2) and a number of leaves at harvest (NL) in leaf lettuce of variety Grand Rapid in three different organic-based liquid fertilizers. The highest FW was observed in T_3 (Glliricidia leaf extract) where the average EC and average pH were maintained at 0.43 dS/m and 5.85, respectively throughout the growing period. The highest NL and LA were also found in T_3, resulting in a higher production of photosynthetic tissues; where the lowest NL and LA were observed in T_1 (Compost tea liquid). The highest DW, partitioned to leaves (LDW) and roots (RDW) were recorded in T_3. T_1 and T_2 (Poultry manure liquid) showed significantly lower dry matter partition to leaves and roots even though the highest EC (0.77dS/m) during the study period was recorded in T_2. Although EC is an indirect indication of the strength of the nutrient solution, T_2 did not show a significant yield advantage to for some reason. The highest RL was also found in T_3; owing to its higher dry matter partitioning. But, the highest growth of root hairs was observed in T_1; which encourages nutrient absorption for plant survival, even at low EC levels. The study revealed that Glliricidia leaf extract was the most favorable organic-based liquid fertilizer for the best growth performance of leaf lettuce while Compost tea liquid was the lowest. Poultry manure was an intermediate performer in the case of vegetative growth in leaf lettuce.

CHAPTER 3

MATERIALS AND METHOD

3.1 Experimental site

The experiment was conducted in the semi-greenhouse (23º74'N and 90º35'E) at the Horticulture Farm, Sher-e- Bangla Agricultural University, Dhaka 1207, Bangladesh. The experiment was conducted from September 2019 to March 2020.

3.2 Experimental arrangement

The study was conducted in a structure using polyvinyl chloride (PVC) pipes. The structure consisted of four 5- feet growing tubes/beds made of 5" PVC pipe and a stand and trellis made up of strong and durable steel. The stand measuring 3 feet x 3 feet x 2.5 feet where the four growing tubes were installed and each pipe was considered as an experimental unit. Holes were made on the upper part of the pipe with the help of a drill machine and the distance between the two holes was 19.06 cm. Pipes were placed horizontally on this stand, as the holding plants become more exposed to sunlight. Every pipe accommodated up to 8 plants.

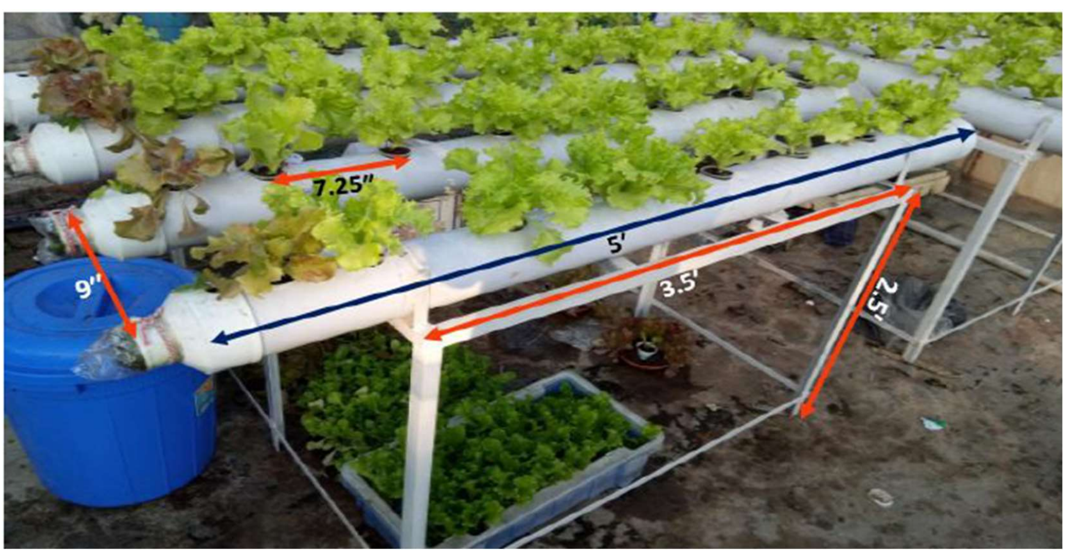


Plate 1. Growing lettuce plants on the horizontal hydroponic structure

3.3 Experimental design and treatment:

The two factors experiment was conducted in a completely randomized design (CRD) with three replications. The two factors were as follows:

Factor A: Two different types of variety denoted as V:

V_1 = Hybrid lettuce and

V_2= Loose-leaf lettuce

Factor B: Four different electrical conductivity in nutrient solution denoted as EC:

EC_1 = 1.5 dS/m,

EC_2 = 2.0 dS/m,

EC_3 = 2.5 dS/m, and

EC_4 = 3.0 dS/m

(a)

(b)

Plate 2. Lettuce plants on a hydroponic structure: (a) Hybrid (glossa) variety and (b) Loose-leaf variety

3.4.1 Preparation of nutrient solution:

The nutrient solution is the most important component of the hydroponic system and in this present study, the treatments nutrient solution was prepared by mixing modified hydroponic standard solution.

The standard nutrient solution was formulated following Rahman and Inden (2012) solution. The nutrient solution was prepared with distilled water and chemical-grade reagents. The ratio of Rahman and Inden (2012) solution were NO^{3-}N, P, K, Ca, Mg, and S of 17.05, 7.86, 8.94, 9.95, 6.0, and 6.0 mgL^{-1}, respectively. The rates of micronutrients were Fe, B, Zn, Cu, Mo, and Mn of 3.0, 0.5, 0.1, 0.03, 0.025 and 1.0 mgL^{-1}, respectively for both the nutrient solutions. The pH values for all nutrient media were determined prior to use. The pH was adjusted at 5.5 to 6.5 using citric acid for the organic nutrient solutions, but for the inorganic solution, the pH was adjusted by using nitric and phosphoric acids.

3.4.2 Collection of seed:

Seeds of lettuce were collected from the Siddik Bazar, Dhaka. Seed variety was selected basis of viability, environmental condition, and availability.

3.5 Seed sowing and Planting

Seeds of lettuce were collected from Siddik Bazar, Dhaka, in a sealed package and germinated in seedling trays. Each cell of tray was filled by a hydroponic planting basket (sauce cup) loaded with germinating media, consisting of 1/5 extract byproduct, 1/5 khoa, 1/3 coconut coir, and 1/3 sawdust (v/v). Trays were kept on applying mist until plants had two true leaves when they were moved to a greenhouse with natural day/night light conditions and an average temperature of 25 °C. All plants were watered with ¼th strength Rahman and Inden (2012) solution from the two true leaves stage, until seedlings were ready for transplantation. Four weeks after sowing, potted seedlings along with the same supporting media that used for seed germination were transplanted to the hydroponics systems at a spacing of 22×18cm. The respective treatment solutions had been filled with the individual pipes that can hold up to 16 liters of solution at controlling level. In these pipe channels the plant's roots grew freely on the growing media.

3.6 Interculture operations

Lettuce plants were grown in a pre-heated environment in a hydroponic system and all nutrients required for the plant were supplied artificially to the plants. The growing environment was clean and no insect-pest attacked the plants.

3.7 Harvesting and measurement

The crop was harvested after 42 days of sowing. This lettuce can be cut from the stem when it is young and fresh for a delightful salad. At random three plants from each treatment were harvested and washed with tap water. Substrates in the roots of plants from substrate cultivation treatment were gently washed off. The fresh weight of the whole plant, leaves, and roots was recorded for each plant with an analytical scale immediately after removing the free surface moisture with a soft paper towel. After assessing the leaf area, the leaves and roots were put separately in paper bags. Total yields were also recorded.

Plate 3. Harvested lettuce for data collection

3.8 Data collection

Different data on growth and physiological traits were recorded during the experiment. Data were collected from each plant described below.

3.8.1 Plant growth parameter

Growth components e.g., plant height, leaf breadth, leaf length, per plant leaves number fresh weight and dry matter of plant was assessed to study morphological traits among treatments.

3.8.1.1 Plant height

Plant height was measured in centimeter (cm) by a meter scale at 0, 7, 21, 28, 35 and 42 DAT (days after transplanting) from the point of attachment of supporting media up to the tip of the longest leaf.

3.8.1.2 Breadth of leaves

Breadth of leaves were measured in centimeter (cm) by a meter scale at 0, 7, 21, 28, 35, and 42 DAT. Fourth leaf was selected for measurement of breadth.

3.8.1.3 Length of leaves

Length of leaves were measured in centimeter (cm) by a meter scale at 0,7, 21, 28, 35, and 42 DAT. Fourth leaf was selected for measurement of length.

3.8.1.4 Number of leaves per plant

Number of leaves per plant were counted at 0, 7, 21, 28, 35, and 42 DAT. All the leaves of each plant were counted separately. Only the smallest young leaves at the growing point of the plant were excluded from the counting and the average number was recorded.

3.8.1.5 Fresh weight of plant

Leaves were detached by a sharp knife and fresh weight (g) of the plant was taken by an electric balance at harvest (42 DAT) and was recorded.

3.8.1.6 Percent dry matter of plant

The random samples of plants were sun dried for seven days then oven-dried at 70° C for 72 h. After drying, plants were weighed for constant dry weight on a scale accurate to 0.0001g. The dry matter of plant was estimated on percentage basis. The percentage of plant dry matter was calculated by using the following formula.

$$\% \text{ Dry matter of plant} = \frac{\text{Constant dry weight of plant}}{\text{Fresh weight of plant}} \times 100$$

3.8.2 Physiological traits

Different physiological parameters [Leaf area (LA), leaf area ratio (LAR), leaf mass ratio (LMR), root weight ratio (RWR), relative growth rate (RGR), and net assimilation rate (NAR)] were determined in the experiments. The parameters were measured as described

$$LAR = \frac{LA}{PDW} \text{ -- (1),}$$

Where LAR = leaf area ratio, LA = Leaf area (cm2), PDW = plant dry weight (g).

LMR= $\frac{LDW}{PDW}$--- (2),

where LMR = leaf mass ratio, LDW = leaf dry weight (g).

RWR= $\frac{RDW}{PDW}$ --- (3),

where RWR = root weight ratio, RDW = root dry weight (g).

RGR=($PDW1-PDW0$)/($t1-t0$)× PDW0 ----------------------------- (4),

where t = time, subscripts 0 and 1 refer to the transplanting and final harvest (days), respectively.

NAR= $\frac{RGR}{LAR}$ --- (5)

3.8.3 Estimation of ascorbic acid and β- Carotene content:

The estimation of ascorbic acid and β- Carotene on the edible part of lettuce was made by the Bangladesh Council of Scientific and Industrial Research (BCSIR).

3.9 Statistical analysis:

The collected data of growth components, physiological parameters, ascorbic acid and β-Carotene were analyzed using a factorial analysis of variance (ANOVA) and LSD analysis with a significance level of α= 0.05 using the 'Statistix 8.1' statistical package (Statistix 8.1, 2003) and Microsoft Excel (2021).

CHAPTER 4

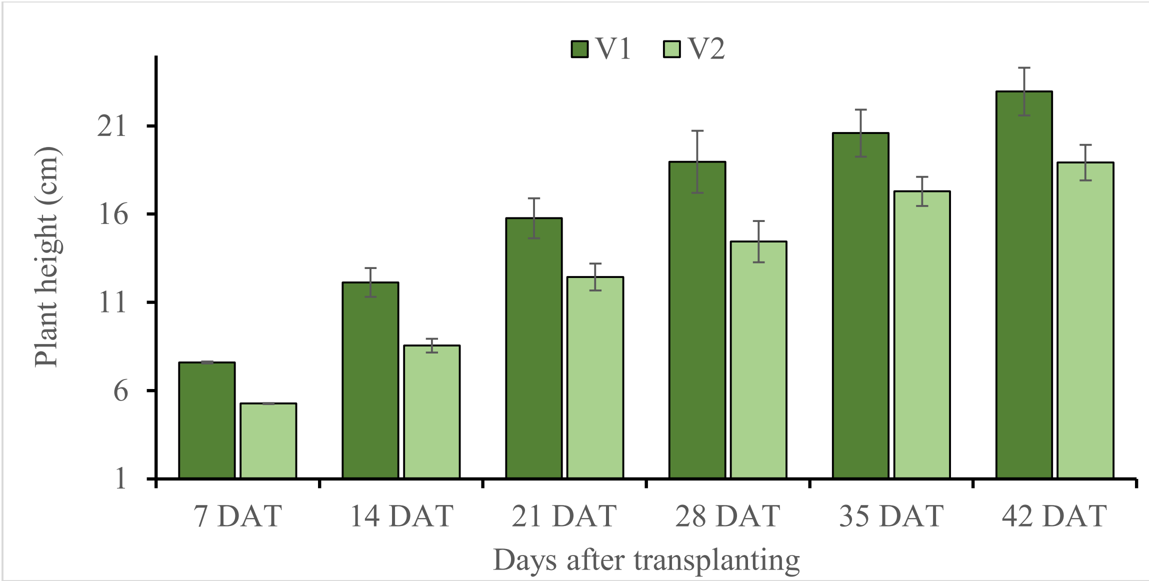
RESULTS AND DISCUSSION

The results of the experiment conducted under semi-greenhouse conditions were presented in the Table 1 to 10 and Figure 1 to 10. The experiment was conducted to determine the production of lettuce and the accumulation of nitrate in it as influenced by organic substrates. The results were presented and discussed in the following sub-headings.

4.1 Vegetative growth and yield parameters

4.1.1 Plant height

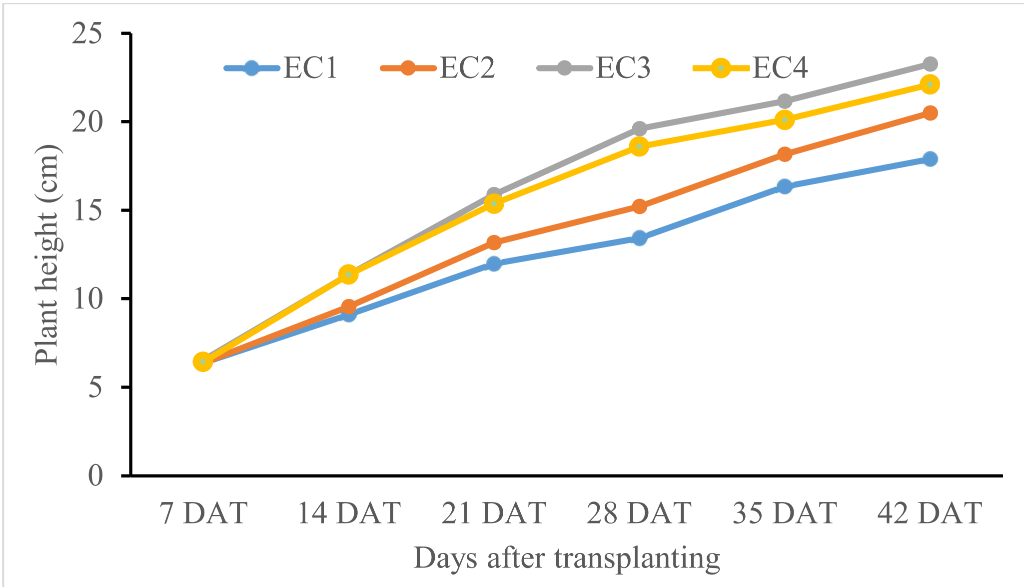
There were significant differences in plant height at 7, 14, 21, 28, and 42 days after transplanting (DAT) in respect of diffident treatments of varieties (Figure 1) and electrical conductivities (Figure 2). At 7 DAT, the tallest plant (7.60 cm) was found in V_1 and the shortest (5.27 cm) was found in V_2. At 14 DAT, the tallest plant (12.13 cm) was found in V_1 and the shortest (8.56 cm) was found in V_2. At 21 DAT, the tallest plant (15.77 cm) was found in V_1 and the shortest (12.44 cm) was found in V_2. At 28 DAT, the tallest plant (18.97 cm) was found in V_1 and the shortest (14.45 cm) was found in V2. At 35 DAT, the tallest plant (20.60 cm) was found in V_1 and the shortest (17.30 cm) was found in V_2. At 42 DAT, the tallest plant (21.95 cm) was found in V_1 and the shortest (18.93 cm) was found in V_2. The results revealed that the plant heights increased in the advancement of plant maturity. The plant growth and development certainly depend on the capability of nutrient solution uptake at specific electrical conductivity that influence by the varieties or cultivars. It also noticed that plant height might be deferred by the factor of varieties of lettuce (Pal, 2019; Sublett *et al*., 2018; Kappel *et al*., 2021).



Here, V_1 = Hybrid (Glossa) Lettuce, V_2= Loose-leaf Lettuce. Days after transplanting (DAT)

Figure 1. Main effects of varieties on plant height at different days after transplanting (DAT)

In the case of electrical conductivities, the tallest plant (6.54 cm) was found in EC_3 and the shortest (6.38 cm) was found in EC_1 and EC_2 at 7 DAT. At 14 DAT, the tallest plant (11.36 cm) was found in EC_3 which is statistically similar to EC_4, and the shortest (9.10 cm) was found in EC_1. At 21 DAT, the tallest plant (15.89 cm) was found in EC_3 and the shortest (11.98 cm) was found in EC_1. At 28 DAT, the tallest plant (19.60 cm) was found in EC_3 and the shortest (13.42 cm) was found in EC_1. At 35 DAT, the tallest plant (21.17 cm) was found in EC_3 and the shortest (16.34 cm) was found in EC_1. At 42 DAT, the tallest plant (23.26 cm) was found in EC_3 and the shortest (17.90 cm) was found in EC_1. The results revealed that the shortest plants at all dates were found in the plants grown in EC_1 and the tallest plant was found in EC_4 in all the cases. These might be due to balanced nutrition and electrical conductivity during the growth period of lettuce for growth and development, resulting in the tallest plant. The plant showed imbalance growth or sometimes limited development due to imbalance uptake of zinc, boron, molybdenum and lost expected fresh weight due to toxicity by higher electrical conductivity of nutrition solutions (Srivani and Manjula, 2019; Sublett *et al*., 2018). Similar results were observed by Ma *et al*., (2016), Kim *et al*., (2016) and Zeeshan *et al*., (2020) in lettuce and different crops.



Here, EC_1 = 1.5 dS/m, EC_2 = 2.0 dS/m, EC_3 = 2.5 dS/m, and and EC_4 = 3.0 dS/m. Days after transplanting (DAT)

Figure 2. Main effects of electrical conductivity on plant height at different days after transplanting (DAT)

Meanwhile, for the combination of varieties and nutrient solution, the plant height of lettuce significantly varied at 7, 14, 21, 28, 35, and 42 DAT (Table 1). At 7 DAT, V_1EC_3 performed the tallest (7.75 cm) as well as finally, at 42 DAT, V_1EC_3 showed the tallest (25.23 cm) height and V_2EC_1 showed the shortest plant in all observations. Data presented in Table 1 indicated that varieties and electrical conductivities alone and their interaction significantly influenced plant height. At all stages of plant growth, the varietal effect observed where V_1 showed better result and the electrical conductivity influenced in both varieties by nutrient (zinc, boron and molybdenum) uptake by plant (Sublett *et al*., 2018).

Kim *et al*., (2016), Srivani and Manjula (2019) also reported similar difference on lettuce in hydroponics system.

Table 1. Interaction of varieties and electrical conductivity on plant height of lettuce at different days after transplanting

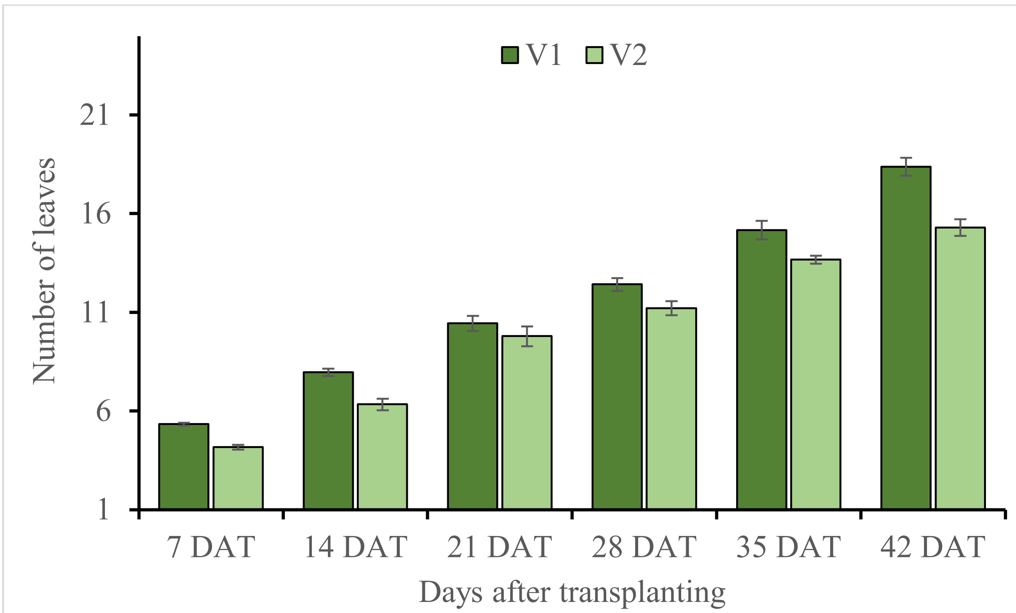
	Plant Height (cm) at different days after transplanting (DAT)					
Treatments	**7 DAT**	**14 DAT**	**21 DAT**	**28 DAT**	**35 DAT**	**42 DAT**
V_1EC_1	7.49 d	10.35 d	13.48 b	15.47 d	17.49 c	19.19 d
V_1EC_2	7.52 c	11.18 c	14.17 b	16.57 c	19.32 b	22.80 c
V_1EC_3	7.75 a	13.60 a	17.68 a	22.77 a	23.17 a	25.23 a
V_1EC_4	7.64 b	13.41 b	17.74 a	21.08 b	22.41 a	24.60 b
V_2EC_1	5.26 f	7.86 g	10.47 f	11.37 e	15.19 d	16.60 f
V_2EC_2	5.25 f	7.92 g	12.18 e	13.87 e	17.01 c	18.20 e
V_2EC_3	5.33 e	9.12 f	14.10 c	16.44 c	19.17 b	21.28 c
V_2EC_4	5.24 f	9.32 e	13.00 d	16.12 cd	17.82 c	19.63 d
p-value	0.047	0.043	0.041	0.042	0.039	0.029

Means with different letter is significantly different by Tukey's HSD test at $P \leq 0.05$. Here, V_1 = Hybrid (Glossa) Lettuce, V_2= Loose-leaf Lettuce. EC_1 = 1.5 dS/m, EC_2 = 2.0 dS/m, EC_3 = 2.5 dS/m, and and EC_4 = 3.0 dS/m.

4.1.2 Number of leaves

Variation was recorded for amount of leaves/plant of lettuce at 7, 14, 21, 28 35 and 42 days after transplanting (DAT) with application of different varieties (Figure 3) and electrical conductivities (Figure 4). At 7 DAT, the maximum number of leaves/plant (5.33) was counted in V_1 and the minimum number of leaves/plant (4.17) was found in V_2. At 14 DAT, the maximum number of leaves/plant (7.96) was found in V_1 and the minimum number of leaves/plant (6.33) was found in V_2. At 21 DAT, the maximum number of leaves/plant (10.44) was found in V_1 and the minimum number of leaves/plant (9.79) was found in V_2. At 28 DAT, the maximum number of leaves/plant (12.42) was found in V_1 and the minimum number of leaves/plant (11.21) was found in V_2. At 35 DAT, the maximum number of leaves/plant (15.17) was found in V_1 and the minimum number of leaves/plant (13.67) was found in V_2. At 42 DAT, the maximum number of leaves/plant (18.38) was found in V_1 and the minimum number of leaves/plant (15.29) was found in V_2.

Similarly, varietal effect was reported on number of leaves plant^{-1} was also obtained in different research (Pal., 2019; Kappel *et al*., 2021). The plant leaves and apical growth developments positively depends on the capability of nutrient uptake that influence by the cultivars (Pal., 2019).

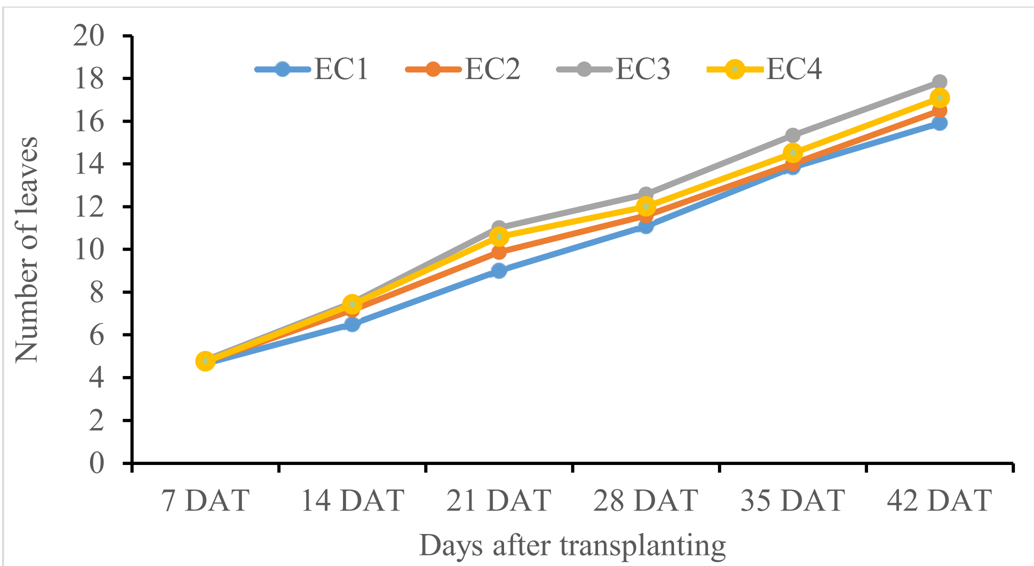


Here, V_1 = Hybrid (Glossa) Lettuce, V_2= Loose-leaf Lettuce. Days after transplanting (DAT)

Figure 3. Main effects of varieties on number of leaves of lettuce at different days after transplanting (DAT)

In case of nutrient solution, the maximum number of leaves/plant (4.83) was found in EC_3 and the minimum number of leaves/plants was found in EC_1 (4.67) which was statistically similar to that of EC_2 and EC_4 (4.75) at 7 DAT. At 14 DAT, the maximum number of leaves/plant (7.50) was found in EC_3 and the minimum number of leaves/plant (6.50) was found in EC_1. At 21 DAT, the maximum number of leaves/plant (11.00) was found in EC_3 and the minimum number of leaves/plant (9.00) was found in EC_1. At 28 DAT, the maximum number of leaves/plant (12.58) was found in EC_3 and the minimum number of leaves/plant (11.08) was found in EC_1. At 35 DAT, the maximum number of leaves/plant

(15.33) was found in EC_3 and the minimum number of leaves/plant (13.83) was found in EC_1. At 42 DAT, the maximum number of leaves/plant (17.83) was found in EC_3 and the minimum number of leaves/plant (15.92) was found in EC_1. The results revealed that the minimum amount of leaves/plant at all dates were found in the plants grown in EC_1 and the maximum number of leaves/plants was found in EC_3 in all the cases which showed similarity with several previous findings (Srivani and Manjula, 2019; Sublett *et al*., 2018). These might be occurred due to favorable condition and availability of more nutrients at suitable electrical conductivity for plant growth (Kim *et al*., 2016; Zeeshan *et al*., 2020).



Here, EC_1 = 1.5 dS/m, EC_2 = 2.0 dS/m, EC_3 = 2.5 dS/m, and and EC_4 = 3.0 dS/m. Days after transplanting (DAT)

Figure 4. Main effects of electrical conductivity on no. of leaf of lettuce at different days after transplanting

Meanwhile in case of combined interaction of varieties and nutrient solution, significant variation was observed at 7, 14, 21, 28, 35 and 42 DAT (Table 2) in terms of number of leaves of lettuce. Although, at 7 DAT, the maximum number of leaves/plant (5.50) was found in V_1EC_4 which were statistically similar to V_1EC_1 and V_1EC_2, whereas the minimum number of leaves/plant (4.00) was found in V_2EC_1 and V_2EC_4. At 14 DAT, the maximum number of leaves/plants observed in V_1EC_3 and V_1EC_4 showed statistically similar result. But at 21, 28, 35 and 42 DAT it was found that the maximum number of leaves/plant number of leaves in V_1EC_3. The pH and EC with other properties were more favorable and ensured appropriate condition for the elongation of lettuce plant with optimum vegetative growth and the ultimate results was the maximum amount of leaves/plant in V_1EC_3. The combined effect also showed similarity with several research previously occurred and it was proven that the specific electrical conductivity (2.5 dS/m) showed better result on lettuce production in hydroponics system (Kim *et al*., 2016).

Table 2. Interaction of varieties and electrical conductivity on leaf number of lettuces at different days after transplanting

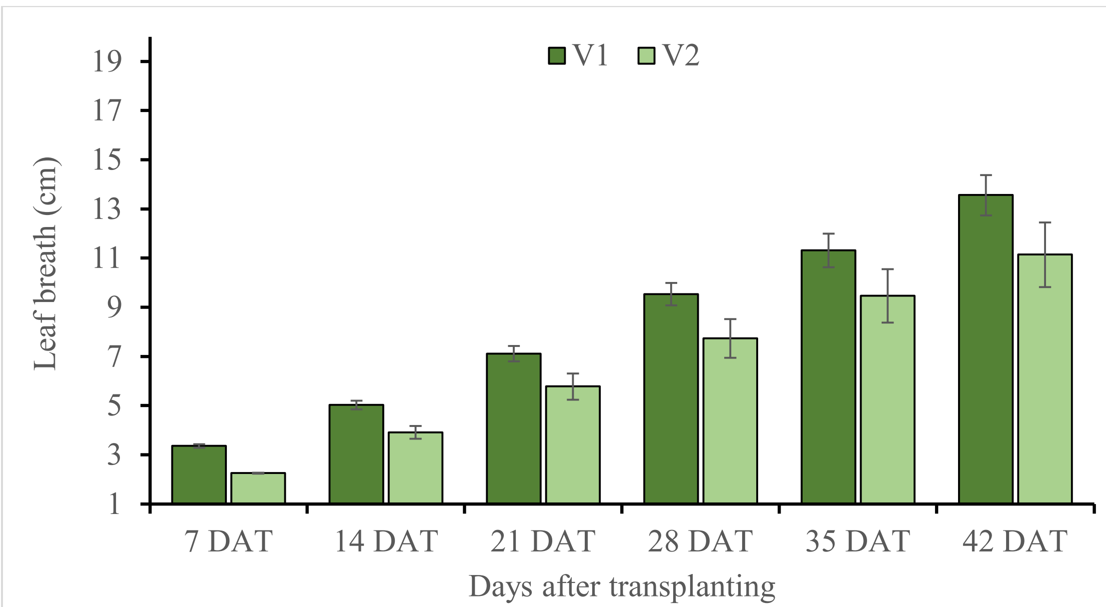
	Number of leaves at different days after transplanting (DAT)					
Treatments	**7 DAT**	**14 DAT**	**21 DAT**	**28 DAT**	**35 DAT**	**42 DAT**
V_1EC_1	5.33 ab	7.50 b	9.50 c	11.50 c	14.33 c	17.50 c
V_1EC_2	5.33 ab	7.83 b	10.25 b	12.50 ab	14.67 c	18.17 b
V_1EC_3	5.17 b	8.17 a	11.33 a	13.00 a	16.50 a	19.67 a
V_1EC_4	5.50 a	8.33 a	10.67 b	12.67 a	15.17 a	18.17 b
V_2EC_1	4.00 d	5.50 e	8.50 d	10.67 d	13.33 d	14.33 e
V_2EC_2	4.17 c	6.50 d	9.50 c	10.67 d	13.33 d	14.83 e
V_2EC_3	4.50 c	6.83 c	10.67 b	12.17 b	14.17 c	16.00 d
V_2EC_4	4.00 d	6.50 d	10.50 b	11.33 c	13.83 d	16.00 d
p-value	0.044	0.039	0.033	0.039	0.029	0.029

Means with different letter is significantly different by Tukey's HSD test at $P \leq 0.05$. Here, V_1 = Hybrid (Glossa) Lettuce, V_2= Loose-leaf Lettuce. EC_1 = 1.5 dS/m, EC_2 = 2.0 dS/m, EC_3 = 2.5 dS/m, and and EC_4 = 3.0 dS/m.

4.1.3 Leaf breath

Leaf breath of lettuce was significantly influenced by diffident varieties (Figure 5) at 7, 14, 21, 28, 35 and 42 days after transplanting (DAT). At 7 DAT, the widest leaf breath (3.36 cm) was found in V_1 and the narrowest (2.26 cm) was found in V_2. The widest leaf breath 5.03 cm) was found in V_1 and the narrowest (3.91 cm) was found in V_2 at 14 DAT. At 21 DAT, the broad leaf (7.12 cm) was found in V_1 and the small leaf (5.78 cm) was found in

V_2. At 28 DAT, the extensive leaf breath (9.53 cm) was found in V_1 and the narrowest (7.73 cm) was found in V_2. At 35 DAT, the widest leaf breath (11.32 cm) was found in V_1 and narrowest (9.47 cm) was found in V_2. At 42 DAT, the widest leaf breath (13.57 cm) was found in V_1 and the narrowest (11.14 cm) was found in V_2. The findings previously obtained by Pal (2022) were comparable to the present analysis. The leaves growth and developments highly depend on the capability of nutrient uptake that influence by the cultivars (Pal., 2019).

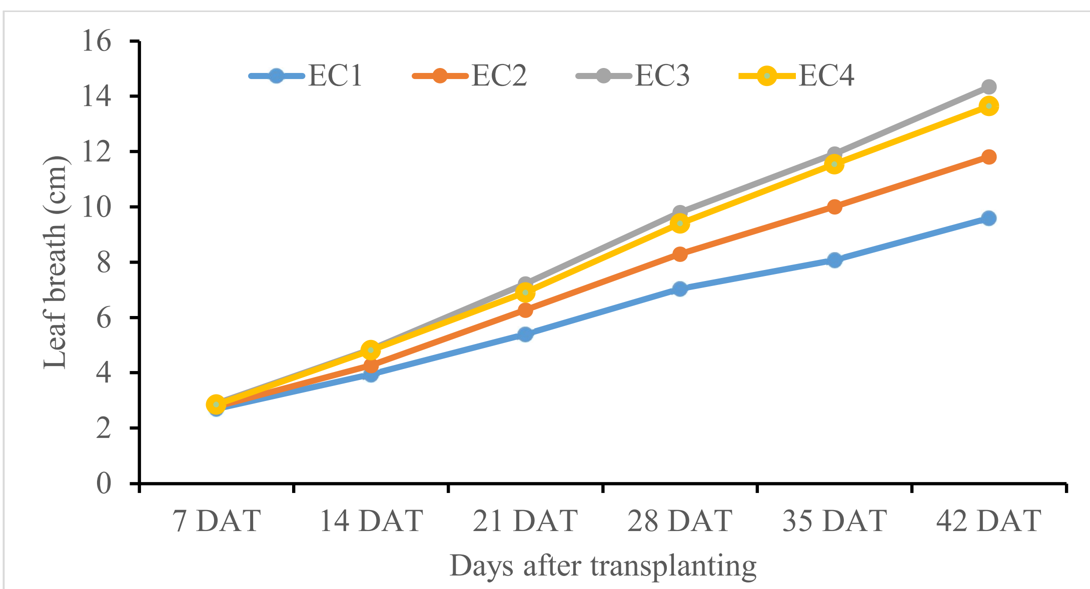


Here, V_1 = Hybrid (Glossa) Lettuce, V_2= Loose-leaf Lettuce. Days after transplanting (DAT).

Figure 5. Main effects of varieties on leaf breathe of lettuce at different days after transplanting (DAT)

Leaf breath differed significantly among the four treatments of nutrient solution at different DAT (Figure 6). The widest leaf breath at 7 DAT (2.90 cm) was found in EC_3 which is statistically similar that of EC_4 (2.85) and the narrowest (2.71 cm) was found in EC_1. The widest leaf breath (4.85 cm) was found in EC_3 and the narrowest (3.95 cm) was found in EC_1 at 14 DAT. At 21 DAT, the broad leaf (7.22 cm) was found in EC_3 and the small leaf

(5.39 cm) was found in EC_1. At 28 DAT, the widest leaf breath (9.80 cm) was found in EC_3 and the narrowest (7.03 cm) was found in EC_1. At 35 DAT, the broadest leaf breath (11.92 cm) was found in EC_3 and the narrowest (8.08 cm) was found in EC_1. At 42 DAT, the widest leaf breath (14.35 cm) was found in EC_3 and the narrowest (9.60 cm) was found in EC_1. The results revealed that the maximum leaf breath at all dates were found in plants grown in EC_3 and the lowest leaf breath at all dates were observed in the plants grown in EC_1. The results showed the similarity with the previous result reported by Ma *et al*., (2016) and Kim *et al*., (2016). Leaves breath influenced by the specific nutrient uptake by plants and that deficiency can be deformed the proper leaves developments. These phenomena occurred due to unavailability of more or less nutrients at higher or lower electrical conductivity (Kim *et al*., 2016; Zeeshan *et al*., 2020).



Here, EC_1 = 1.5 dS/m, EC_2 = 2.0 dS/m, EC_3 = 2.5 dS/m, and and EC_4 = 3.0 dS/m. Days after transplanting (DAT)

Figure 6. Main effects of electrical conductivity on leaf breathe of lettuce at different days after transplanting

In case of combined effect of varieties and electrical conductivities, the significant variation was found at 7, 14, 21, 28, 35 and 42 DAT (Table 3) in terms of leaf breath of lettuce. At 7 DAT, the broadest leaf (3.53 cm) was found in V_1EC_3 and the narrowest leaf breath (2.22 cm) was found in V_2EC_1. At 28 DAT, the narrowest leaf breath observed in V_2EC_1 (5.77 cm) and the widest for V_1EC_3 (10.30 cm) and V_1EC_4 (10.13 cm) which were statistically similar. But at 42 DAT it was found that the maximum leaf breath in V_1EC_3 (14.97 cm). The widest leaf breath almost all dates were found in V_1EC_3 and lowest were found in V_2EC_1. At all stages of plants, the varietal effect observed where V_1 showed better result and the electrical conductivity influenced in both varieties by nutrient like zinc, boron and molybdenum uptake at specific electrical conductivity (Sublett *et al*., 2018).

Table 3. Interaction of varieties and electrical conductivity on leaf breath of lettuce at different days after transplanting

Treatments	Leaf breath (cm) at different days after transplanting (DAT)					
	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT	42 DAT
V_1EC_1	3.20 b	4.60 b	6.20 d	8.30 c	9.37 d	11.33 e
V_1EC_2	3.30 ab	4.87 b	7.32 b	9.40 b	11.37 b	13.37 c
V_1EC_3	3.53 a	5.38 a	7.53 a	10.30 a	12.20 a	14.97 a
V_1EC_4	3.40 a	5.27 a	7.42 ab	10.13 a	12.33 a	14.60 b
V_2EC_1	2.22 c	3.30 d	4.58 f	5.77 e	6.80 f	7.87 g
V_2EC_2	2.26 c	3.67 d	5.23 e	7.20 d	8.67 e	10.27 f
V_2EC_3	2.27 c	4.32 c	6.90 c	9.30 b	11.63 b	13.73 c
V_2EC_4	2.30 c	4.37 bc	6.40 d	8.67 c	10.77 c	12.70 d
p-value	0.045	0.039	0.041	0.038	0.031	0.029

Means with different letter is significantly different by Tukey's HSD test at $P \leq 0.05$. Here, V_1 = Hybrid (Glossa) Lettuce, V_2= Loose-leaf Lettuce. EC_1 = 1.5 dS/m, EC_2 = 2.0 dS/m, EC_3 = 2.5 dS/m, and and EC_4 = 3.0 dS/m.

4.1.4 Fresh weight of lettuce

Marketable lettuce quality is determined primarily by the size of the plant and its fresh weight. Insignificant difference of fresh weight at transplanting time but differed at harvesting among the treatments (Table 4). The total fresh weight increased in increasing days until maturity. At harvest time, for varieties total fresh weight was found higher in V_1 (210.90g / plant) the lowest fresh weight found in V_2 (186.83 g / plant) and for nutrient solution it was found to be higher in EC_3 (218.48 g / plant) the lowest fresh weight found in EC_1 (177.07 g / plant). Higher fresh weight of leaf was found (170.06 g/plant) in V_1 and the lowest was in V_2 (154.77 g/plant) in response to varieties and for the electrical conductivities, the highest and lowest weight found in EC_3 (177.72 g/plant) and EC_1 (145.65 g/plant) respectively. Fresh weight of stem found greater for varieties in V_1 (10.77 g/plant) and the lowest found in V_2 (8.02 g/plant). For electrical conductivity, higher fresh weight of stem was in EC_3 (11.45 g/plant) and lowest in EC_1 (6.83 g/plant). It was revealed that balanced nutrition and optimum level of nitrogen ensured maximum vegetative growth resulting highest fresh weight/ plant. The results obtained earlier by Domingues *et al*., (2012), Ma *et al*., (2016), Srivani and Manjula (2019) and Zeeshan *et al*., (2020) were similar with the present study. The fresh weight of plant entirely depends on overall growth and developments of number of leaves, plant height and leaves breath of plants which also showed potential differences in this study. It could be happened due to nutritional unavailability at different electrical conductivity among the treatment which also explained at several previous findings (Domingues *et al*., 2012; Ma *et al*., 2016). In case of root, higher fresh weight (30.08 g/plant) found in V_1 and minimum fresh weight (24.04 g/plant) was in V_2 for varieties. In response to electrical conductivity higher root fresh weight found in EC_3 (29.32 g/plant) and lowest in EC_1 (24.58 g/plant). Sublett *et al*., (2018) and Hosseini *et al*., (2021) also reported that the varieties and electrical conductivity in nutrient solution affected the growth and developments of lettuce by formation of chlorophyll content as well as other growth-related plant phytochemicals.

Table 4. Main effects of varieties and electrical conductivity on fresh weight (g) of lettuce

Treatments	Fresh weight (g) at different days after transplanting (DAT)			
	Total	Leaf	Stem	Root
Varieties (V)				
V_1	210.90 a	170.06 a	10.77 a	30.08 a
V_2	186.83 b	154.77 b	8.02 b	24.04 b
p-value	0.006	0.006	0.006	0.006
Electrical Conductivity (EC)				
EC_1	177.07 d	145.65 d	6.83 d	24.58 d
EC_2	193.95 c	158.47 c	8.47 c	27.02 c
EC_3	218.48 a	177.72 a	11.45 a	29.32 a
EC_4	205.95 b	167.82 b	10.82 b	27.32 b
p-value	0.043	0.041	0.029	0.029

Means with different letter is significantly different by Tukey's HSD test at $P \leq 0.05$. Here, V_1 = Hybrid (Glossa) Lettuce, V_2= Loose-leaf Lettuce. EC_1 = 1.5 dS/m, EC_2 = 2.0 dS/m, EC_3 = 2.5 dS/m, and and EC_4 = 3.0 dS/m.

Table 5. Interaction of varieties and electrical conductivity on fresh weight (g) of lettuce

Treatments	Fresh weight (g) at different days after transplanting (DAT)			
	Total	Leaf	Stem	Root
V_1EC_1	190.50 e	154.63 f	8.23 e	27.63 d
V_1EC_2	208.53 c	167.37 d	10.33 c	30.83 b
V_1EC_3	223.40 a	179.60 a	12.33 a	31.47 a
V_1EC_4	221.17 b	178.63 b	12.17 b	30.37 bc
V_2EC_1	163.63 g	136.67 h	5.43 g	21.53 g
V_2EC_2	179.37 f	149.57 g	6.60 f	23.20 f
V_2EC_3	213.57 d	175.83 c	10.57 c	27.17 d
V_2EC_4	190.73 e	157.00 e	9.47 d	24.27 e
p-value	0.019	0.038	0.033	0.046

Means with different letter is significantly different by Tukey's HSD test at $P \leq 0.05$. Here, V_1 = Hybrid (Glossa) Lettuce, V_2= Loose-leaf Lettuce. EC_1 = 1.5 dS/m, EC_2 = 2.0 dS/m, EC_3 = 2.5 dS/m, and and EC_4 = 3.0 dS/m.

In case of combined effect of varieties and electrical conductivity of nutrient solution, the significant variation of fresh weight was found at harvesting (Table 5). The highest total fresh weight in all cases were found in V_1EC_3 (223.40 g/plant) and lowest were found in V_2EC_1 (190.50 g/plant). The result showed similarity with Kappel *et al.*, (2021) and Hosseini et al., (2021) where studied on several varieties with different electrical conductivity level of nutrition solutions and found that specific electrical conductivity influences to formation of plant growth phytochemicals.

4.1.5 Dry weight of lettuce

Plant dry weights of lettuce were not varied significantly at transplanting time but difference in harvesting across the treatments (Table 6). Average total dry weight was higher in V_1 (12.29 g/plant) and the lowest dry weight found in V_2 (10.99 g/plant). In case of dry leaf higher weight found in V_1 (9.93 g/plant) and the lowest leaf dry weight found in V_2 (9.05 g/plant). Dry weight of stem found greater (0.65 g/plant) in V_1 and the lowest dry weight of stem (0.52 g/plant) found in V_2. On the other hand, higher root dry weight (1.72 g/plant) found in V_1 and minimum dry weight (1.42 g/plant) found in V_2. The plant fresh weight directly related to dry weight and the studied varieties showed significant variation on its fresh weight which are very common phenomena regarding on different cultivars of lettuce plant.

Lettuce's dry weight differed significantly from four treatments of electrical conductivity (Table 6) as well. Upon drying the harvested lettuce plant, the highest total dry weight was in EC_3 (12.50 g/plant) and lowest was in EC_1 (10.72 g/plant). In case of dry weight of leaf found higher (10.15 g/plant) in EC_3 and the lowest leaf dry weight (8.85 g/plant) found in EC_1. Dry weight of stem found greater (0.69 g/plant) in EC_3 and the lowest dry weight of stem (0.44 g/plant) found in EC_1. In case of root, higher dry weight (1.66 g/plant) found in EC_3 and minimum dry weight (1.44 g/plant) found in EC_1. This might be because of the proportion of nutrient supply at suitable electrical conductivity for the plants (Sublett *et al*., 2018). Andriolo *et al*. (2005), Kappel *et al*., (2021) and Pal (2012) stated that lettuce growth was affected by different electrical conductivity of nutrient solution. The results of this experiment also compatible with that.

Table 6. Main effects of varieties and electrical conductivity on dry weight (g) of lettuce

	Dry weight (g) at different days after transplanting (DAT)			
Treatments	**Total**	**Leaf**	**Stem**	**Root**
Varieties (V)				
V_1	12.29 a	9.93 a	0.65 a	1.72 a
V_2	10.99 b	9.05 b	0.52 b	1.42 b
p-value	0.011	0.019	0.017	0.013
Electrical Conductivity (EC)				
EC_1	10.72 c	8.85 c	0.44 c	1.44 c
EC_2	11.29 b	9.20 b	0.54 b	1.55 b
EC_3	12.50 a	10.15 a	0.69 a	1.66 a
EC_4	12.05 b	9.75 b	0.67 a	1.64 a
p-value	0.029	0.033	0.031	0.039

Means with different letter is significantly different by Tukey's HSD test at $P \leq 0.05$. Here, V_1 = Hybrid (Glossa) Lettuce, V_2= Loose-leaf Lettuce. EC_1 = 1.5 dS/m, EC_2 = 2.0 dS/m, EC_3 = 2.5 dS/m, and and EC_4 = 3.0 dS/m.

In the event of combined effect varieties and nutrient solution (Table 7) the lowest plant dry weight for all cases were found in V_2EC_1 (9.91 g/plant) and the highest were found in V_1EC_3 (12.84 g/plant). The maximum vegetative growth and development had been facilitated to ensure the highest dry weight / plant and which basically obtained because of the interaction and possible impact of various levels of inorganic and organic nutrition uptakes at specific electrical conductivity. Kappel *et al*., (2021) and Hosseini et al., (2021) also reported similar result on several varieties with different electrical conductivity level of nutrition solutions.

Table 7. Interaction of varieties and electrical conductivity on dry weight (g) of lettuce

	Dry weight (g) at different days after transplanting (DAT)			
Treatments	**Total**	**Leaf**	**Stem**	**Root**
V_1EC_1	11.54 d	9.40 d	0.55 c	1.59 b
V_1EC_2	12.10 c	9.73 d	0.62 bc	1.75 a
V_1EC_3	12.84 a	10.37 a	0.70 a	1.77 a
V_1EC_4	12.69 b	10.20 b	0.71 a	1.78 a
V_2EC_1	9.91 f	8.30 e	0.32 e	1.29 c
V_2EC_2	10.48 e	8.67 e	0.47 d	1.35 c
V_2EC_3	12.15 c	9.93 c	0.67 b	1.55 b
V_2EC_4	11.42 d	9.30 d	0.62 bc	1.50 c
p-value	0.033	0.034	0.033	0.041

Means with different letter is significantly different by Tukey's HSD test at $P \leq 0.05$. Here, V_1 = Hybrid (Glossa) Lettuce, V_2= Loose-leaf Lettuce. EC_1 = 1.5 dS/m, EC_2 = 2.0 dS/m, EC_3 = 2.5 dS/m, and and EC_4 = 3.0 dS/m.

4.2 Physiological growth traits

Significant variation was recorded on physiological growth parameters of lettuce plants with application of different varieties and electrical conductivity (Table 8). In case of leaf area (LA), the higher (323.17 cm^2) leaf area was found in the plants grown in V_1 and the lower (250.94 cm^2) was found in V_2. Leaf area is an important determinant of light interception and consequently of transpiration, photosynthesis and plant productivity (Dufour and Guérin, 2005). In case of Leaf Area Ratio (LAR), the lower (106.45 cm^2 g^{-1}) Leaf Area Ratio (LAR) was found in V_1 while the highest (158.03 cm^2 g^{-1}) was found in V_2. Lower LAR is one of the vital criteria for achieving higher plant metabolites. In case of Leaf Mass Ratio (LMR), the higher (0.931 g g^{-1}) Leaf Mass Ratio (LMR) was found in V_2 and the lower (0.923 g g^{-1}) was found in V_1. Higher LMR is one of the crucial parameters for achieving high plant metabolites which had ability to increase the interception of light that influences the growth and developments of plant leaves (Prieto *et al*., 2007). In case of Root Weight Ratio (RWR), the lower RWR (0.0085084 g g^{-1}) was found in V_2 while the higher (0.0874941 g g^{-1}) was found in V_1. Lower RWR is one of the crucial criteria for producing higher plant metabolites. Net assimilation rate (NAR) and relative growth rate (RGR) of lettuce was also significantly influenced by the treatment of varieties (Table 8). The highest net assimilation of lettuce was found in V_1 (0.0000081 $gcm^{-2}d^{-1}$). On the other hand, V_2 (0.0000028 $gcm^{-2}d^{-1}$) showed the lowest net assimilation rate. It might be happened due to this experiment's associated environmental conditions, especially light intensity and temperature. Prieto et al. (2007) reported that the plants showed an increased ability to intercept light at maximized NAR of plant physiology. The highest relative growth rate (RGR) of lettuce was found in V_1 (0.0008585 $g\ g^{-1}d^{-1}$). On the other hand, V_2 (0.0004505 $g\ g^{-1}d^{-1}$) showed the lowest relative growth rate.

Table 8. Main effects of varieties and electrical conductivity on physiological traits of lettuce

Treatments	LA (cm^2)	LAR ($cm^2\ g^{-1}$)	LMR ($g\ g^{-1}$)	RWR ($g\ g^{-1}$)	NAR ($gcm^{-2}d^{-1}$)	RGR ($g\ g^{-1}d^{-1}$)
Varieties (V)						
V_1	323.17 a	106.454 b	0.923 a	0.0874941 a	0.0000081 a	0.0008585 a
V_2	250.94 b	158.033 a	0.931 b	0.0850884 b	0.0000028 b	0.0004505 b
p-value	0.007	0.011	0.019	0.022	0.023	0.022
Electrical Conductivity (EC)						
EC_1	268.32 d	129.025 c	0.925 c	0.08406783 d	0.00000536 d	0.00061983 d
EC_2	274.85 c	128.458 d	0.927 b	0.08537650 c	0.00000549 c	0.00065017 c
EC_3	305.60 a	136.000 a	0.930 a	0.08947600 a	0.00000553 a	0.00067600 a
EC_4	299.45 b	135.492 b	0.927 b	0.08624467 b	0.00000551 b	0.00067200 b
p-value	0.029	0.031	0.031	0.041	0.039	0.043

Means with different letter is significantly different by Tukey's HSD test at $P \leq 0.05$. Here, V_1 = Hybrid (Glossa) Lettuce, V_2= Loose-leaf Lettuce. EC_1 = 1.5 dS/m, EC_2 = 2.0 dS/m, EC_3 = 2.5 dS/m, and and EC_4 = 3.0 dS/m.

In case of electrical conductivity, the highest leaf area (LA), leaf area ratio (LAR), leaf mass ratio (LMR), root weight ratio (RWR), net assimilation rate (NAR) and relative growth rate (RGR) of lettuce was found in EC_3. The lowest leaf area (LA), leaf area ratio (LAR), leaf mass ratio (LMR), root weight ratio (RWR), net assimilation rate (NAR) and relative growth rate (RGR) of lettuce were found in EC_1. The results revealed that the highest relative growth rate was found in EC_2. Meanwhile EC_1 denoted the lowest relative growth rate. Aini et al., (2019) also reported that the leaf anatomical traits *viz.* leaf thickness and leaf area as well as root colonization can be affected by the electrical conductivity of nutrient solution which also showed in this experiment.

The physiological growth parameters of lettuce had been substantially affected by the combination of varieties and nutrient solution treatment (Table 9). For the leaf area (LA), highest leaf area (LA) was found in V_1EC_3 (341.83 cm^2) and the lowest was found in V_2EC_1 (233.50 cm^2). The highest leaf area ratio (LAR) of lettuce was found in V_2EC_3 (163.233 cm^2 g^{-1}) and the lowest found in V_1EC_1 (103.900 cm^2 g^{-1}). In case of leaf mass ratio (LMR), the lowest leaf mass ratio (LMR) was found in in V_1EC_1 (0.919 gg^{-1}) while the higher was found in V_2EC_3 (0.934 gg^{-1}). The lowest root weight ratio (RWR) of lettuce was found in V_2EC_1 (0.07921067 gg^{-1}). On the other hand, the highest root weight ratio was found in V_2EC_3 (0.09273300 gg^{-1}). Root colonization affected by the electrical conductivity of nutrition solutions which influenced the biomass accumulation of lettuce in hydroponics system (Aini et al., 2019). Lettuce's net assimilation rate (NAR) and relative growth rate (RGR) are the lowest in V_2EC_1 and are 0.00000279 $gcm^{-2}d^{-1}$. On the other hand, the maximum net assimilation rate was demonstrated in V_1EC_4 and V_1EC_3 (0.00000820 $gcm^{-2}d^{-1}$) and relative growth rate in V_1EC_3 (0.00088500 g $g^{-1}d^{-1}$). It can be showed due to higher nutrient concentration at EC_4 which lead the toxicity at plant mechanism and eventually suppress the ultimate growth. The similar result showed by Trejo-Téllez and Gómez-Merino (2012) and (Sublett *et al*., 2018) where examine the plant toxicity at higher EC of nutrition in hydroponics system.

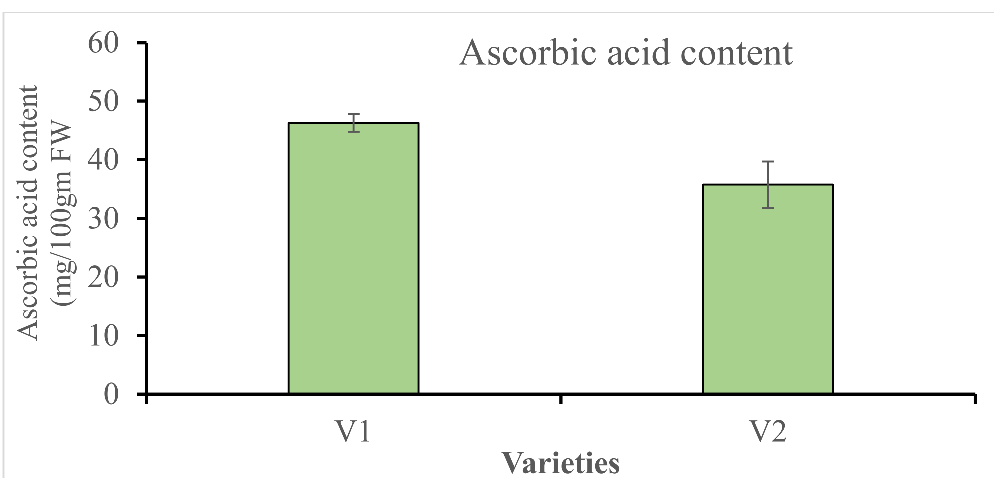
Table 9. Interaction of varieties and electrical conductivity on physiological traits of lettuce

Treatments	LA (cm^2)	LAR (cm^2 g^{-1})	LMR (g g^{-1})	RWR (g g^{-1})	NAR ($gcm^{-2}d^{-1}$)	RGR (g $g^{-1}d^{-1}$)
V_1EC_1	303.13 d	105.150 f	0.919 f	0.08892500 b	0.00000793 c	0.00081400 b
V_1EC_2	312.37 c	103.983 g	0.922 e	0.08786300 b	0.00000818 b	0.00085267 b
V_1EC_3	341.83 a	108.767 d	0.925 d	0.08621900 c	0.00000820 a	0.00088500 a
V_1EC_4	335.33 b	107.917 e	0.923 e	0.08696933 c	0.00000820 a	0.00088233 a
V_2EC_1	233.50 h	152.900 a	0.930 c	0.07921067 e	0.00000279 f	0.00042567 f
V_2EC_2	237.33 g	152.933 a	0.931 b	0.08289000 d	0.00000281 e	0.00044767 e
V_2EC_3	269.37 e	163.233 b	0.934 a	0.09273300 a	0.00000285 d	0.00046700 c
V_2EC_4	263.57 f	163.067 c	0.931 b	0.08552000 d	0.00000281 e	0.00046167 d
p-value	0.041	0.039	0.039	0.033	0.043	0.041

Means with different letter is significantly different by Tukey's HSD test at $P \leq 0.05$. Here, V_1 = Hybrid (Glossa) Lettuce, V_2= Loose-leaf Lettuce. EC_1 = 1.5 dS/m, EC_2 = 2.0 dS/m, EC_3 = 2.5 dS/m, and and EC_4 = 3.0 dS/m.

4.3 Ascorbic acid and β- carotene content

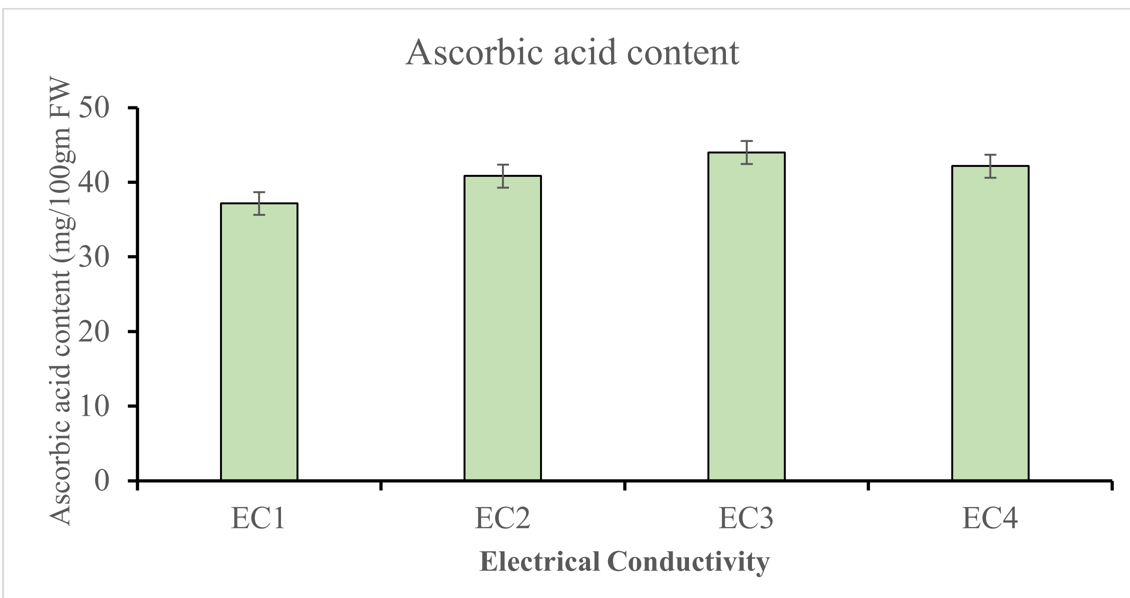
Ascorbic acid content of lettuce was significantly affected by addition of different varieties (Figure 7). The highest ascorbic acid content of lettuce was found in V_1 (46.33 cc). On the other hand, the lowest ascorbic acid content of lettuce was found in V_2 (35.75 cc). Ismail and Cheah (2003); Sublett *et al.*, (2018) also reported in different organically grown vegetables were higher in vitamins than that can be defer by varieties.



Here, V_1 = Hybrid (Glossa) Lettuce, V2= Loose-leaf Lettuce.

Figure 7. Effects of varieties on ascorbic acid content of lettuce

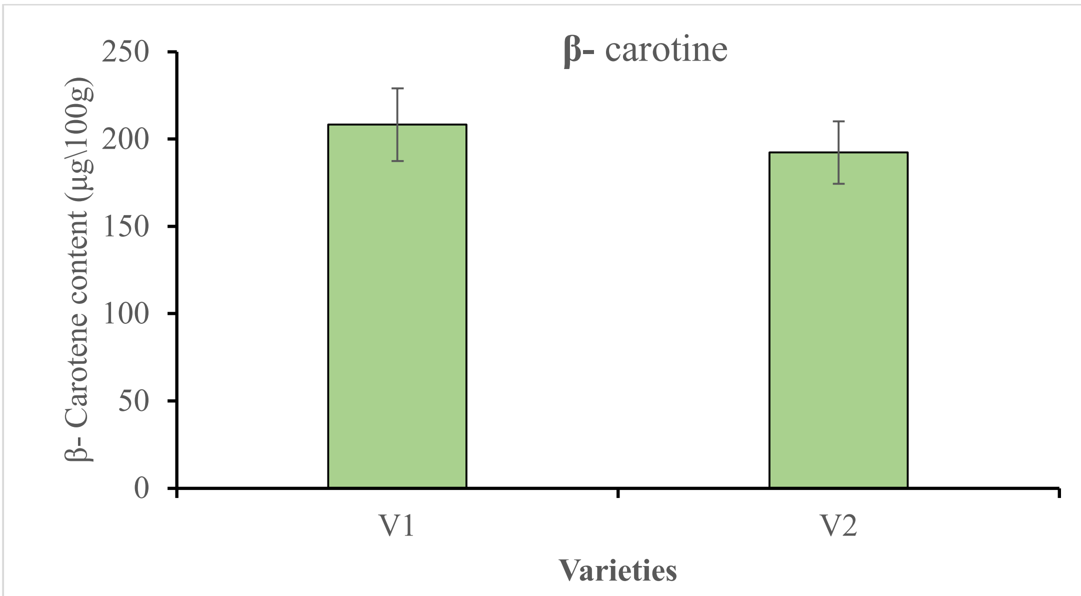
Ascorbic acid content of lettuce was significantly affected by addition of modified electrical conductivity solution (Figure 8). For nutrient solution, the highest ascorbic acid content of lettuce was found in EC_3 (44.00 cc). On the other hand, the lowest ascorbic acid content of lettuce was found in EC_1 (37.17 cc). Saltveit *et al*. (2018) reported that ascorbic acid content of lettuce was increased by the suitability of electrical conductivity in hydroponics system by up taking several nutrient contents like zinc, boron, molybdenum etc. In this experiment, the content of ascorbic acid increased with an increased concentration of nutrient solution treatment of EC_3 (2.5dS/m) that was compatible with these results.



Here, EC_1 = 1.5 dS/m, EC_2 = 2.0 dS/m, EC_3 = 2.5 dS/m, and and EC_4 = 3.0 dS/m.

Figure 8. Effects of electrical conductivity on ascorbic acid content of lettuce

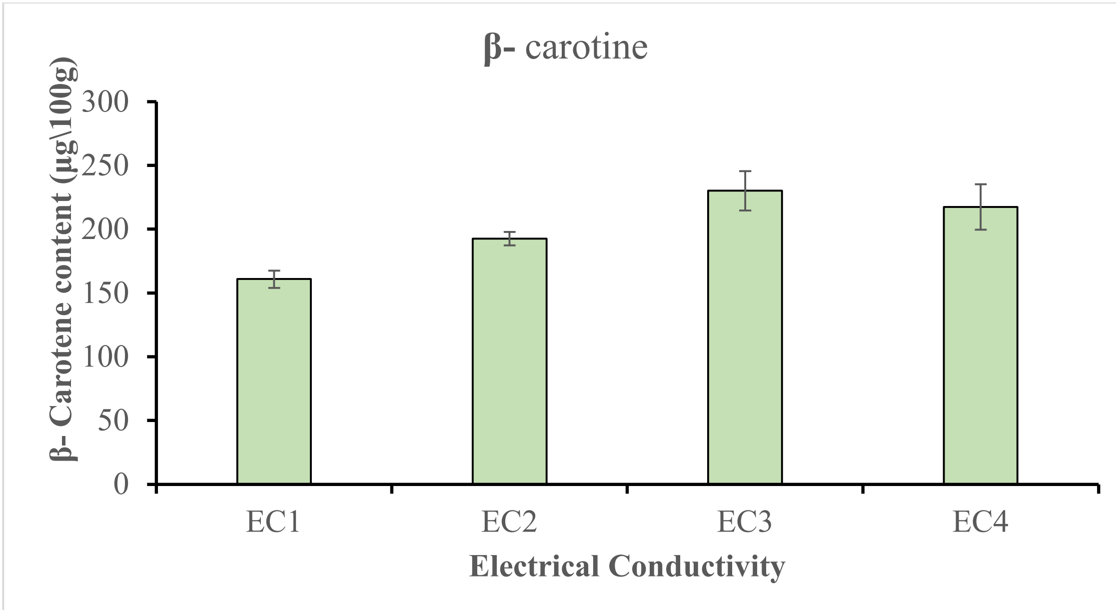
Carotenoids in plant are the key alimentary source of provitamin A content and β- carotene as the most well-known provitamin A carotenoid. β- carotene content in lettuce plant increased with the varieties (Figure 9). β- Carotene content was higher in the plants grown in V_1 (208.25 µg\100g) on the other hand the lowest β- Carotene content of lettuce was estimate in V_2 (192.33 µg\100g). Ismail and Cheah (2003) showed that many organically grown vegetables were higher in vitamins than that conventionally grown and the findings of β- carotene content was 200.6 µg/100 g. In the present study also reported similar findings.



Here, V_1 = Hybrid (Glossa) Lettuce, V_2= Loose-leaf Lettuce.

Figure 9. Effects of varieties on β- Carotene content of lettuce

β- Carotene content of lettuce was significantly affected by addition of modified strength of nutrient solution (Figure 10). In the present experiment, β- carotene content increased with increased concentration of Rahman and Inden (2012) solution. For electrical conductivity, the highest β- carotene content of lettuce was estimate in EC_3 (230.17 µg\100g). On the other hand, the lowest ascorbic acid content of lettuce was found in EC_1 (160.83 µg\100g).



Here, EC_1 = 1.5 dS/m, EC_2 = 2.0 dS/m, EC_3 = 2.5 dS/m, and and EC_4 = 3.0 dS/m.

Figure 10. Effects of electrical conductivity on β- Carotene content of lettuce

There was a significant interaction between varieties and nutrient solution in case of ascorbic acid and β- Carotene content concentration on lettuce (Table 10). The lowest ascorbic acid content of lettuce was found in V_2EC_1 (32 cc). On the other hand, the highest ascorbic acid content of lettuce was found in V_1EC_3 (49.67 cc) and the relatively similar ascorbic acid concentration in V_1EC_4 (47.33 cc). The results of present study revealed ascorbic acid content increased markedly with the increasing levels of nutrient solution with varieties. The lowest β- Carotene content observed in V_2EC_1 and the highest value was observed in V_1EC_1. In V_1EC_3 (245.67 µg\100g) maximum β- Carotene content was determined which is relatively similar with the treatments V_1EC_4 (235.33 µg\100g). However, it was significant that β- Carotene content increased in the same treatment with higher yield. Electrical conductivity of nutrient solution dramatically affected the uptake of several minerals which are influence the β- Carotene accumulation in lettuce (Sublett *et al*., 2018).

Table 10. Interaction of varieties and electrical conductivity on ascorbic acid and β-carotene content of lettuce

Treatments	Ascorbic acid content (cc)	β- carotine (μg\100g)
V_1EC_1	42.33 c	154.00 g
V_1EC_2	46.00 b	198.00 d
V_1EC_3	49.67 a	245.67 a
V_1EC_4	47.33 b	235.33 b
V_2EC_1	32.00 g	167.67 f
V_2EC_2	35.67 f	187.33 e
V_2EC_3	38.33 d	214.67 c
V_2EC_4	37.00 e	199.67 d
p-value	0.041	0.039

Here, V_1 = Hybrid (Glossa) Lettuce, V_2= Loose-leaf Lettuce. EC_1 = 1.5 dS/m, EC_2 = 2.0 dS/m, EC_3 = 2.5 dS/m, and and EC_4 = 3.0 dS/m.

CHAPTER 4

SUMMARY AND CONCLUSION

This study was conducted at a semi-green house at the Horticulture Farm of Sher-e - Bangla Agricultural University, Bangladesh during September 2019 to February 2020 for optimal and safe cultivation of hydroponic lettuce. The aim of this study was to assess lettuce production, using two types of lettuce varieties (Hybrid (Glossa) Lettuce and Loose-leaf Lettuce) and four different electrical conductivity (1.5, 2.0, 2.5 and 3.0 dS/m) of standard nutrient solution ratios. Morphological, physiological growth and yield were measured in the experiment.

The results revealed that use of varieties had significant effect on growth and quality yield of lettuce. In case of growth parameters of lettuce, such as plant height and leaf number, tallest plant (22.95 cm) and the maximum number leaves plant^{-1} (18.38) were recorded from plant grown in V_1 while the shortest plant height (18.93 cm) and the minimum number leaves plant^{-1} (15.29) were recorded from V_2. Additionally, highest leaf breath (13.57 cm) was observed in V_1 and lowest (11.14 cm) in V_2. In case of fresh weight, maximum total fresh weight (210.90 g/plant) was recorded from the plant grown in V_1 and minimum total fresh weight (186.83 g/plant) recorded from V_2. In case of dry weight maximum total dry weight (12.29 g/plant) was recorded from the plant grown in V_1 and minimum (10.99 g/plant) from the plant grown in V_2. Different physiological variables; viz. in case of leaf mass ratio (LMR), higher leaf mass ratio was recorded from the plant grown in V_2 and lower leaf mass ratio was recorded from the plant grown in V_1; in case of leaf area ratio (LAR) statistically higher result found in V_2. In case of root weight ratio (RWR), net assimilation ratio NAR, and relative growth rate (RGR), highest value found in V_1.

The increase of plant height was more or less incremental up to harvest, highest plant height (23.26 cm) was accounted for EC_3 and the lowest (17.90 cm) one for EC_1. The maximum number of leaves plant^{-1} (17.83), higher leaf breadth (14.35) was recorded from EC_3 while the minimum leaves plant^{-1} (15.92) and lower leaf breadth (9.60 cm) from EC_1 at harvest. In case of hydroponic nutrient solution, maximum total fresh weight (218.48 g/plant) was recorded from EC_3 and minimum (177.07 g/plant) recorded from the plant grown in EC_1. For dry weight, the maximum total dry weight (12.50 g / plant) of the plant grown in EC_3 and the minimum total dry weight (10.72 g / plant) of the plant grown in EC_1 were recorded. In case of almost all growth parameters the best results were found for plants grown in V_1EC_3 where the lowest were found in V_2EC_1. The combination of V_1 with EC_3 (2.5 dS/m) would be most favorable for growth performance of leaf lettuce.

Conclusions:

According to the findings of this study, the following conclusions were drawn.

i. Higher yield with other vegetative growth parameters and physiological traits of lettuce were found in Hybrid lettuce variety.

ii. Medium level (2.5 dS/m) of electrical conductivity treated plants showed the best performance for production as well as physiological traits with accumulation of ascorbic acid and β- carotene content in lettuce.

Therefore, it could be concluded that in hydroponics system production, Hybrid lettuce with 2.5 dS/m electrical conductivity of nutrient solution performed best result for achieving higher yield and quality comparative to other treatments combination in hydroponics system.

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APPENDICES

Appendix 1. Analysis of variances of total and leaf fresh weight at harvesting time of lettuce

Source of variation	Degrees of freedom (df)	Sum squares for fresh weight of lettuce at harvesting time		Means squares for dry weight of lettuce at harvesting time		F -value	
		Total	Leaf	Total	Leaf	Total	Leaf
Varieties (V)	1	8750.2	6859.5	2390.6	1159.5	949.6	480.9
Electrical Conductivity (EC)	3	9269.4	3849.1	2355.5	1756.7	1443.1	549.9
V X S	3	846.1	397.1	79.3	45.1	36.2	23.5
Error	20	61.2	42.4	1.68	1.31		

Appendix 2. Analysis of variances of ascorbic acid content in edible part of lettuce

Source of variation	Degrees of freedom (df)	Sum squares for ascorbic acid content	Mean squares for ascorbic acid content	F -value
Varieties (V)	1	972.6	328.4	534.1
Electrical Conductivity (EC)	3	4017.5	1389.1	129.3
V X S	3	138.9	15.6	6.61
Error	20	71.1	2.4	

Appendix 3. Analysis of variances of β- carotene content in edible part of lettuce

Source of variation	Degrees of freedom (df)	Sum squares for β- carotene content	Mean squares for β- carotene content	F -value
Varieties (V)	1	19289.1	731.6	16.2
Electrical Conductivity (EC)	3	51589.2	201.4	13.4
V X S	3	898.4	11.4	0.748
Error	20	435.2	13.7	

PLATES

Plate 4. Seedling of lettuce in seedling trays (Before transplanting)

Plate 5. Seedling transplanting to the hydroponics system

(A)

(B)

Plate 6. Growing lettuce in hydroponic system (A: 14 days after transplanting; B: 21 days after transplanting)