J. Patuakhali Sci. and Tech. Uni. 2018, 9 (1&2): 239-250 ISSN 1996-4501

EFFECT OF ELECTRICAL CONDUCTIVITY ON GROWTH AND YIELD OF STRAWBERRY CULTIVATED IN AEROPONIC SYSTEM

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Abstract

An experiment was conducted to evaluate the effect of different levels of electrical conductivity (EC) on growth and yield-related attributes of strawberry cultivated in the aeroponic system. The single factor experiment was conducted using a Completely Randomized Design with three replications. The factor in the experiment was three electrical conductivity level of nutrient solution (EC 1.5, EC 2.0 and EC 2.5 ds m^{-1}). Among the three EC levels, the effect of EC 1.5 ds m^{-1} was found to be the best for vegetative and yield contributing characteristics. The significant effect of EC 1.5 ds m^{-1} was observed on vegetative growth parameters of strawberries like leaf number, plant height, fresh, and dry weight of the plant and on yield-related characteristics like fruit weight, marketable fruit numbers, individual fruit weight, total fruit yield, etc. The highest total fruit yield (271.9g) was obtained from the electrical conductivity of nutrient solution 1.5 ds m^{-1}. Therefore, electrical conductivity in nutrient solution 1.5 ds m^{-1} could be followed to increase the fruit production of strawberry cultivation in the aeroponic system.

Key Words: Aeroponic, EC, Growth, Yield, Strawberry.

Introduction

Strawberry (*Fragaria ananassa*) belongs to the family Rosaceae is a perennial plant which sprouts in every year (Taylor, 2002); (Bowling, 2000). It is an important high-value horticultural crop and one of the most delicious fruits in the world. It is widely appreciated for its bright red color, juicy texture, sweetness, a higher percentage of phenolics, flavonoids, aroma and vitamin contents (Hakkinen & Torronen, 2000); (Power *et al*., 2008). However, providing clean and fresh food for the next generation is our main concerns, especially for the growing global population (Alexandratos & Bruinsma, 2012).

Consumers are becoming more aware of nutritious and sustainable food options. Soilless grown fruits and vegetables have been gaining momentum and have caught the attention of many producers, consumers, and scientists, because of the plethora of benefits offered by soilless growing methods (Resh 2013). Soilless culture, including aeroponics, aquaponics, and hydroponics, is considered one of the more innovative agricultural strategies to produce more product from less input, in order to feed the estimated 11 billion people in the world by 2100 (Lal, 2016). Soilless growing systems in protected environments are said to be the trend for the cultivation of the strawberry. When cultivation is carried out on benches above ground level, the

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job is easier and less unhealthy, the use of fumigant soil products is eliminated and there is a reduction in the occurrence of leaf diseases and consequently in the application of pesticides. Furthermore, there is an improvement in fruit quality, both sensory and from the point of view of chemical and microbiological contaminants. Aeroponic is the process of growing plants in an air or mist environment without the use of soil or an aggregate medium. The basic principle of aeroponic growing is to grow plants suspended in a closed or semi-closed environment by spraying the plant's dangling roots and lower stem with an atomized or sprayed, nutrient-rich water solution (Mithunesh *et al.,* 2015).

Outcomes of using aeroponics system over their counterparts are a more efficient use of water. Almost 99 percent of the water is used. No pesticides and soil compatible fertilizers are used. So, fruit and vegetables obtained are pure and do not need to be washed before use and delivers nutrients directly to the plant roots, which results in faster growth of crops. Fruits and vegetables obtained from an aeroponics-based greenhouse are healthy, nutritious, pure, rich, fresh, and tasteful. Uniform growth observed among all crops (Mithunesh *et al.,* 2015). Many studies have clearly shown that aeroponics promotes plant growth rates through optimization of root aeration because the plant is totally suspended in air giving the plant stem and root systems access to 100% of the available oxygen in the air (Buckseth *et al.,* 2016). Soon after its development, aeroponics took hold as a valuable research tool. Aeroponics offered researchers a non-invasive way to examine roots under development. This new technology also allowed researchers a larger number and a wider range of experimental parameters to use in their work (Mithunesh *et al.,* 2015).

There are limitations when cultivating strawberries in the soil related to the prohibition of chemical fumigants for the control of phytopathogens and to the ergonomic difficulties of cultivating the plants on the ground surface, both of which have hampered the recruitment of manpower (Godoi *et al.,* 2009). (Darghouth *et al.,* 2005) reported that water is another critical resource. The scarcity of water is the most important and crucial issue to perform agricultural activities and inflicting insecurity on social problems.

The electrical conductivity of any nutrient solution is the indication of the strength of the nutrients in that nutrient solution (Anonymous, 2002). The nutrients are dissolved in water and provided to the plants. Various kinds of nutrients are used for different types of plants, all nutrients being essentially salts containing a positively charged cation part as well as a negatively charged anion part. The fertilizer salt breaks into cation and anion into the nutrient solution given to the plant, and hence capable of conducting electricity; hence a higher nutrient content signifies a greater magnitude of electrical ions and a greater electrical conductivity (EC). Most of the solutions have EC less than 3.0 (Jr, 1982). Vegetative growth of the plant generally restricted with the increase in the application of salt (EC) (Yilmaz & Kina, 2008). A very few research works were evident on the effect of electrical conductivity on growth and yield of strawberry cultivated in the aeroponic system. Results of this study would be helpful to identify suitable EC level for strawberry cultivation using the aeroponic system.

The aim of this work was to evaluate variables of phenology; yield and fruit quality of strawberry as affected by different EC levels cultivated in the aeroponic system.

Materials and Methods

The experiment was carried out in the Germplasm Center and laboratories of the Department of Horticulture, Patuakhali Science and Technology University, Patuakhali from October 2017 to April 2018. The maximum daily temperatures at the site vary from 25^0C to 26^0C, while the minimum range from 5^0C to 20 ^{0}C. The single factor experiment was laid out in a completely randomized design with three replications. The treatments of the experiment were three levels of nutrient solution EC (EC 1.5, EC 2.0 and EC 2.5 ds m^{-1}).

The experiment was carried out in a net house. The aeroponics units were built in plastic pots (0.5 m wide, 0.5 m high, and 1 m long). Six plants were planted in each pot at 20 × 20 cm^2 spacing. The aeroponic system used had three beds with 0.25 m^3 air volumes and an area of 0.5 m^2 each. The nutrient solution was prepared in one tank with 100 liters for every bed. In every bed, there were six nozzles (AEROJSUMAX-6SS, Spraying Systems, Shanghai Co., Shanghai, China) placed horizontally at the end and middle of the pots with a capacity of 2 liters per hour. The sprayers were working from 7:00am till 7:00pm for 25 seconds at five minutes interval. The amount of water supply was, on average, 1.4 l/m^2 per day. Plantlets of the strawberry cultivar (Festival) were collected from the Tissue Culture Laboratory of BRAC nursery and transplanted to the aeroponics culture system. Plants were supplied with full strength Cooper's (1979) hydroponic nutrients solution. The Cooper solution consisted of the nutrients concentration of 200, 60, 300, 170, 50, 68, 1, 0.1, 0.1, 2, 0.3, and 0.2 mg L^{-1} of N, P, K, Ca, Mg, S, Fe, Cu, Zn, Mn, B, and Mo, respectively (Asao, 2012). Nine aeroponic units were used for the experiment. In the experiment, the influence of different ECs of nutrient solution (EC 1.5, EC 2.0 and EC 2.5 ds m^{-1}) on growth, yield and quality of strawberry was tested. The whole system was controlled by the electronic timer. EC level was maintained throughout the experimental period using portable Hanna EC/TDS meter (Japan). The p^H of the nutrient solution was maintained at 6.0 by adding H_3PO_3.

The number of leaves per plant was recorded by counting all the leaves from each plant and the mean was calculated at 60 days after transplanting (DAT). After 40 days of transplanting, newly emerged runners were removed for better yield and quality fruits. Plant height of each plant was measured in centimeter (cm) by using a meter scale. Fresh weight of plant was measured in gram by weighing the whole plant. Plant samples were oven-dried at 70 ^{0}C for 72 h. and weighed for dry weight on a scale accurate to 0.0001g. Flowering, fruiting, and harvesting were counted by visual observation from the date of strawberry plantlets transplanting. The number of marketable fruit per plant was obtained by measuring the total number of fruits in a plant. Individual fruit weight was obtained by measuring the average weight of fruit. Total fruit yield of each plot was obtained by summation of the weight of the total marketable fruits. Fruit weight was measured by Electronic Precision Balance (Ek 600i) in gram. Fruit length and diameter were measured using Digital Caliper-515 (DC-515) in millimeter (mm). Brix percent were measured by portable Refractometer (ERMA, Japan). Every single fruit was blend and juice was collected to measure Brix percent. Brix percent of fruits was measured at room temperature.

All results were subjected to a one-way analysis of variance (ANOVA) using Minitab statistical software version 17 (Minitab Inc., State College, PA, USA); and the means were separated using Tukey at $p = 0.01$.

Results

The supply of different EC levels of nutrient solution affected the production of leaves per plant (Figure 1A) and the effect was statistically different, hence the number of leaves produced by the plant were significant ($p<0.01$). The plants grown in EC 1.5 ds m^{-1} produced the highest number of leaves (35.33) and EC 2.5 ds m^{-1} gave the lowest number of leaves (20.67).

The plant height was statistically affected by the application of different EC treatments ($p<0.01$) (Figure 1B). The plants that were grown in EC 1.5 ds m^{-1} gave the highest plant height and it was statistically different and superior over that of EC 2.0 ds $m^{-1}$and EC 2.5 ds m^{-1} level. The tallest (18.5 cm) plant was marked in EC 1.5 ds m^{-1} treated plants, whereas the smallest (14.8 cm) from 2.5 ds m^{-1}. There was a gradual decrease in plant height with the increase in EC level.

The EC levels had a significant effect on the total fresh weight of plant parts ($p< 0.01$) (Figure 1C). The plants that were grown in EC 1.5 ds m-1 gave the highest fresh weight (125.67g) of plant parts and the lowest (112.67g) fresh weight was found at EC 2.5 ds m-1. There was a gradual decrease in fresh weight of plant parts with the increase in EC level.

The uneven supply of different EC levels of nutrient solution affected the dry weight of the plant (Figure 1D) but the effect was statistically non-significant ($P= 0.069$). The highest (11.33 g) dry weight was observed in EC 1.5 ds m^{-1} and the lowest (10.83 g) was in EC 2.5 ds m^{-1}.

The days to flowering was significantly affected by the EC of nutrient solution ($p<0.01$) (Figure 2A). Flowering was earliest in EC 2.5 ds m^{-1} (62.33 days) and delayed in EC 1.5 ds m^{-1} (75.67 days).

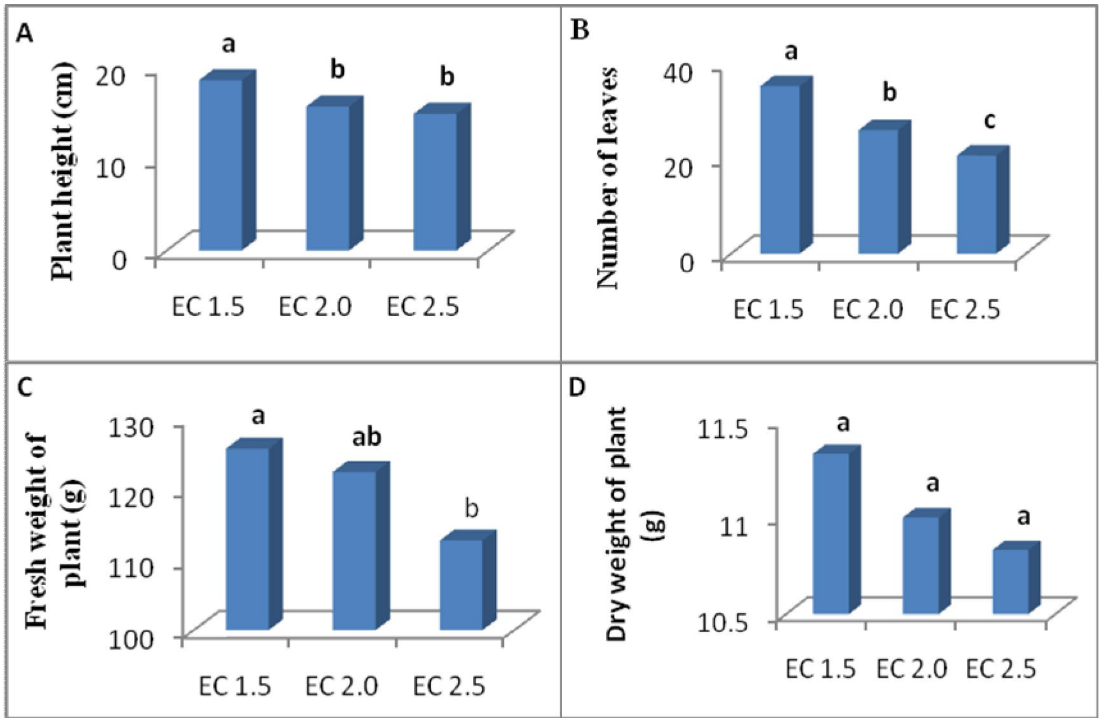

Figure 1. **Effect of different EC levels onplant height (A), the number of leaves (B), fresh weight of plant (C) and dry weight of plant (D). In the column, values havinga similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly at 1% level of probability analyzed by Tukey.**

The application of different EC treatments significantly affected days to fruit setting ($p< 0.01$) (Figure 2B). The plants grown with EC treatment 2.5 ds m^{-1} showed early fruiting (66.67 days) and delayed in EC 1.5 ds m^{-1} (81.0 days). There was a gradual decrease in fruit setting time with the increase in EC level.

The provision of the uneven supply of the different concentrations of nutrient solution significantly affected the fruit harvesting time ($p< 0.01$) (Figure 2C). The plants that were grown in EC 2.5 ds m^{-1} had attended early harvesting of fruits (91.0 days) and delayed (115.0 days) in EC 1.5 ds m^{-1}. Fruit harvesting time was gradually decreased with the increase in nutrient concentration.

The different concentrations of nutrient solution affected the total number of marketable fruits /plant (Figure 2D). There was a significant effect of EC levels on marketable fruits number per plant ($p< 0.01$). The highest (16.0) number of marketable fruit was produced in plant treated with EC 1.5 ds m^{-1} while the lowest (7.67) was obtained from EC 2.5 ds m^{-1}. The number of marketable fruits per plant was decreased gradually with the increase of EC level.

The different concentrations of nutrient solution affected the total number of marketable fruits per plant (Figure 2D). There was a significant effect of EC levels on marketable number of fruits per plant ($p< 0.01$). The highest (16.0) number of marketable fruits was produced in plant treated with EC 1.5 ds m^{-1}.The lowest (7.67) number of marketable fruits was obtained from EC 2.5 ds $m^{-1,}$ which was statistically similar to the number of marketable fruits (10.67) produced in EC 2.0 ds m^{-1}.The number of marketable fruits per plant was decreased gradually with the increase of EC level.

The provision of uneven electrical concentration affected the fruit weight of strawberries in the absolute terms and results were statistically significant ($p= 0.001$). The different levels of EC affected fruit weight and it was highest (12.97g) in EC level of 1.5 ds m^{-1}. It was gradually decreased with the increase in EC level of 2.0 ds m^{-1} and 2.5 ds m^{-1} respectively, (Figure 2E).

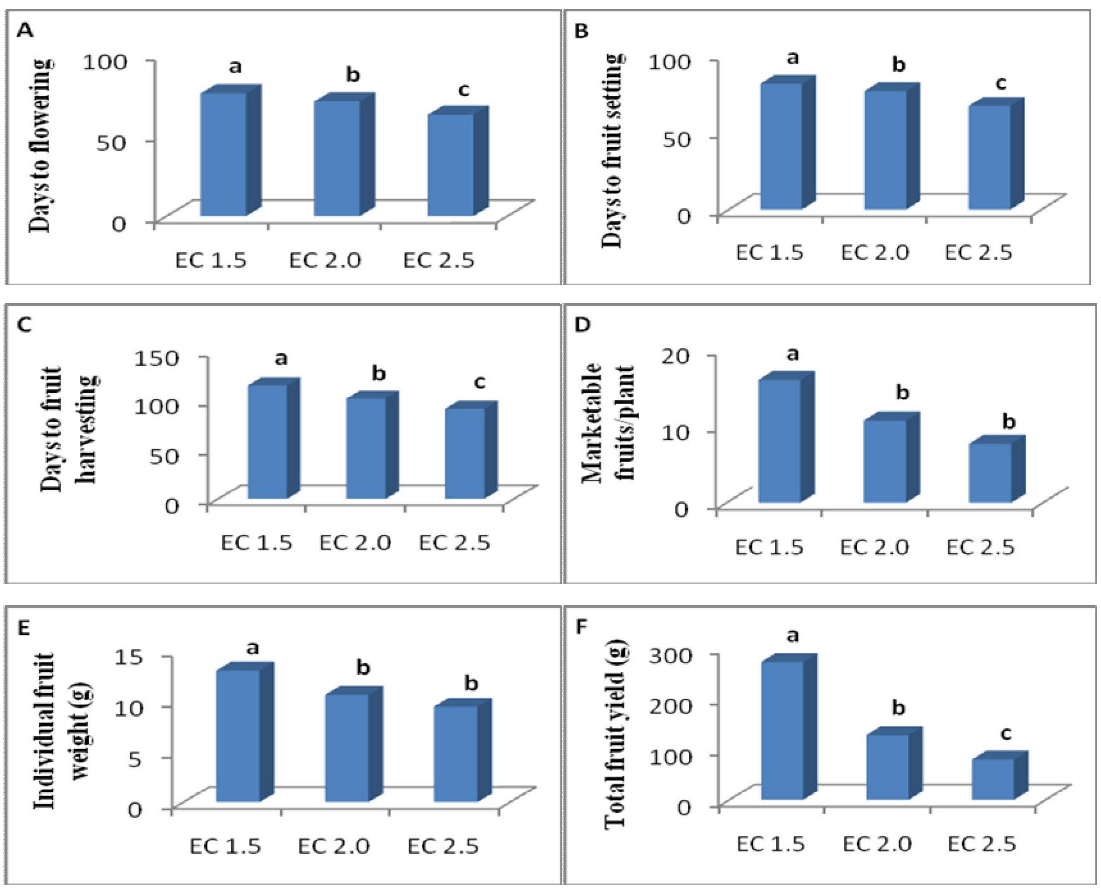

Figure 2: Effect of different EC levels on days to flowering (A), days to fruit setting (B), days to fruit harvesting(C), marketable fruits per plant (D), individual fruit weight (E) and total fruit yield (F). In the column, values having similar letter (s) are statistically identical and those having the dissimilar letter (s) differ significantly at 1%level of probability analyzed by Tukey.

The supply of different EC levels affected the total fruit yield significantly ($p<0.01$). Plants grown with the EC treatment 1.5 ds m^{-1} had the highest (271.9g) fruit weight with a significant difference with the EC treatment 2.0 ds m^{-1} and 2.5 ds m^{-1}. The increase in the EC concentration reduced the fruit weight per plant, but fruit yield was statistically similar in EC treatment 2.0 ds m^{-1} and 2.5 ds m^{-1}. The lowest (79.73g) total fruit yield was found in EC treatment 2.5 ds m^{-1}(Figure 2F).

The fruit length of strawberry was affected by the application of different EC treatments (Table 1). The statistical test of the fruit length showed a significant effect by different concentrations of nutrient solutions ($p=0.01$). The EC level 1.5 ds m^{-1} gave statistically highest (29.07mm) length of fruit. It was followed by the EC level 2.0 and 2.5 ds m^{-1}. The effects of EC level 2.0 and 2.5 ds m^{-1} on fruit length was statistically similar.

The provision of the uneven supply of the different concentrations of nutrient solution significantly affected the fruit diameter ($p<0.01$) (Table 1). The plants grown in EC 1.5 dsm-^{1} gave the highest (25.4 mm) fruit diameter and the lowest (18.47 mm) was observed in EC 2.5 ds m-^{1}. The effects of EC level 2.0 and 2.5 ds m-^{1} on fruit diameter was statistically similar. There was a gradual decrease of fruit diameter with the increase of EC level.

Brix percent was affected by the application of different EC treatments (Table 1). The statistical test showed a significant effect by different concentrations of nutrient solutions ($p<0.01$) on Brix percent. Maximum (9.57%) Brix percent was found in EC1.5 ds m^{-1} treated strawberry plants while minimum (3.6%) was found in EC 2.5 ds m^{-1}. The effects of EC level 2.0 and 2.5 ds m^{-1} on Brix percent was statistically similar.

Table1. Effect of different EC levels on strawberry related to quality attributes

Treatments (ds m^{-1})	Fruit Length (mm)	Fruit Diameter (mm)	Brix %
EC 1.5	29.07 ^{a}	25.40 ^{a}	9.57 ^{a}
EC 2.0	22.97 ^{b}	20.17 ^{b}	6.03 ^{b}
EC 2.5	21.53 ^{b}	18.47 ^{b}	3.60 ^{b}
Level of Sig.	**	**	**

In the column, values having a similar letter (s) are statistically identical and those having the dissimilar letter (s) differ significantly at 1% level of probability analyzed by Tukey. ** = Significant at 1% level of probability

Discussion

The different EC levels of the nutrient solution had a significant effect on various vegetative and growth characteristics of the strawberry. It was observed that the plants grown with various EC levels differed in the production of biomass and the result was significant. Most of the vegetative parameters mentioned above had shown significance over the higher concentration of the EC. The highest number of leaves and plant height were observed in EC 1.5 ds m^{-1}.Overall plant biomass viz., fresh and dry weight of the plant, the number of leaves, and plant height were decreased with the increase in the EC concentration, and therefore, water stress would have caused such reduction. The increase in the nutrient solution concentration, the plant roots were forced to uptake the maximum minerals but at the same time, increase in mineral concentration, restricted roots from water absorption and ultimately caused water stress. This was forced physiological stress on the plants which resulted in a reduction of vegetative characteristics at higher concentration and vice versa. The water deficit caused numerous changes in the physiological and biological process of the plant (Klamkowski & Treder, 2008). The leaves of strawberry are large and the plant has a shallow deep root system, the water requirement of strawberry was more but was subjected to stress-causing water deficits (Keutgen & Pawelzik, 2008). The lowest EC level was found to be the best for most of the characteristics than the highest treatments. (D'Anna *et al.*, 2003), (Romero-Aranda & Soria, 2001);(Saied *et al.*, 2005); (Yilmaz & Kina, 2008) reported that the increase in EC exceeding to (6.5) resulted in the restricted vegetative growth of plant, reduction in leaf number and individual leaf area. (Klamkowski & Treder, 2008) reported that the water stress in Elsanta variety caused the reduction in the leaf area. There was a significant effect of different EC levels on fresh weight of the plant. The highest fresh weight was observed in the EC level of 1.5 ds m^{-1} followed by EC level of 2.0 ds m^{-1} and 2.5 ds m^{-1}. It was with a scientific basis that the roots always respond best to optimum EC level. The EC level of 1.5 ds m^{-1} being lowest among all was proved to be suitable for root growth than the other two treatments. The dry weight of the plant was also higher in the EC level of 1.5 ds m^{-1}. Similar results were reported by Bisko *et al*., 2010.. The fresh biomass yield and dry matter of shoots and roots of the variety Elsanta were reduced significantly with the increase in the application of NaCl. The uneven supply of nutrient concentrations considerably affected the physiological process of plants grown in them. The yield contributing characters of the strawberry have significance due to different EC levels. The yield of any crop is the most economical and qualitative aspect and is of paramount importance. The present study revealed that there was a very good result due to the EC level of 1.5 ds m^{-1}. In this treatment, the characteristics like individual fruit weight and total fruit yield were highest than EC levels of 2.0 ds m^{-1} and 2.5 ds m^{-1}. This was due to the suitable EC level for plants. The plants had comparatively less physiological stress. The strawberry plants grow well in the lower level of EC. This was supported by Caruso *et al*.,2011and it was observed that the lowest EC (1.3 ds m^{-1}) was effective for the fruit production in the spring season of strawberry. There was a gradual decrease in the yield level due to higher EC as the plant face stress conditions which ultimately affected the yield of strawberry. The similar result was reported by (Mavrogianopoulos *et al.*, 1999) and it was seen that the addition of NaCl in the nutrient solution caused the significant effect on the total yield of melon.

The total yield of Melon was reduced with the increase of NaCl in the nutrient solution. The increase in the EC concentration caused the fruit quantity reduction hence maximum non-marketable yield was obtained from the plants grown 2.5 ds m^{-1} EC than the lowest concentration. The fruit quality was directly related to the EC level which confirmed the research work of Cruso *et al*., 2011.The weight of the fruits harvested from the plants grown in EC level 1.5 ds m^{-1} was better than 2.0 and 2.5 ds m^{-1} EC levels, respectively. The average fruit weight and total fruit yield of the strawberry were significantly affected by the EC levels. The EC level of 1.5 ds m^{-1} was proved to be the best in recording more individual fruit weight and total fruit yield than EC level of 2.0 and 2.5 ds m^{-1}. Both the characteristics were yield contributing characteristics and have a positive effect on increasing the fruit. It also indicated that biggest sized fruits were produced on the plants grown in EC 1.5 ds m^{-1} than other two concentrations (2.0 and 2.5 ds m^{-1}).

Conclusion

Based on the findings of the present investigation, it can be concluded that among the three concentrations of EC levels studied for strawberry production under the aeroponic system, the EC level of 1.5 ds m^{-1} was the best than EC level of 2.0 and 2.5. Most of the growth parameters, biomass production, and yield contributing components gave a better response at the EC level of 1.5 ds m^{-1} than EC level of 2.0 and 2.5 ds m^{-1}. The EC level of 1.5 significantly induced best yield contributing characteristics of the number of marketable fruits, the individual weight of fruit, and total fruit yield followed by EC level 2.0 and 2.5. All the parameters studied was significantly affected by EC level except the dry weight of the plant. The EC level of 1.5 ds m^{-1} was found best for most of the characteristics and affected the vegetative growth of plants. The maximum number of leaves, plant height, fresh and dry weight of plant was the highest in EC treatment 1.5 ds m^{-1}. The highest supply of EC level caused the reduction in the reproductive as well as the vegetative yield of plants grown in them. The quality fruits with respect to size and weight can be harvested by growing them in 1.5 ds m^{-1} EC.

Acknowledgments

Authors would like to acknowledge Patuakhali Science and Technology University (PSTU), Research and Training Center and Department of Horticulture, PSTU for financial support and other facilities during the study period.

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