International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 15, No. 4, p. 401-407, 2019

INNSPUB

RESEARCH PAPER OPEN ACCESS

Comparative performance of static and re-circulating close hydroponic system for lettuce production

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Key words: Lettuce, Hydroponic system, Yield

http://dx.doi.org/10.12692/ijb/15.4.401-407 Article published on October 30, 2019

Abstract

Lettuce (*Lactuca sativa*) is commonly used as salads although it is also seen in different kinds of foods; soups, sandwiches and wraps. In Pakistan conventional lettuce production techniques are unable to meet market requirements during offseason while consumers demands for regular year-round supply. In this scenario, alternative farming practices; nutrient film technique (NFT) a liquid hydroponic system was developed. NFT is an innovative food production system having a high yield promise. Keeping in view the market demand of lettuce an experiment was conducted at Hydroponic Research Station Rawat, Institute of Hydroponic Agriculture, Pir Mehr Ali Shah Arid Agriculture University Rawalpindi. Experiment was performed for the testing of static and re-circulating close hydroponic system and the comparison of different treatments was made in greenhouse conditions. Growth and yield parameters was recorded regularly throughout the life cycle of crop. Crop parameters include plant height, number of leaves per plant, length of leaf, breadth of leaf, and yield per plant in eight treatments (T_1, T_2,T_3.....T_8) were measured. To take the average data five plants were selected from each treatment. The data was statistically analyzed by using Completely Randomized Design (CRD) at 5% level of probability. Comparatively better yield was observed in re-circulating nutrient film technique.

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Introduction

Recently close re-circulating hydroponic system is becoming popular because this is clean and relatively easy method and no chances of soil borne diseases, insects or pest infection to the crops by decreasing use of pesticides. Besides, plants require less growing time than the crop grown in static hydroponic system and plant growth is faster because of no mechanical hindrance to the roots and the other nutrients are abundantly available for plants. This technique is very useful for the area where environmental stress (cold, heat, dessert etc.) is a major problem. There is no effect of climate change on the crops grown in greenhouse hydroponic system therefore horticultural crops can be cultivated around the year and considered as off season (Sharma *et al.*, 2018).

As water becomes short, there is much need of water conservation techniques for crop production. In static hydroponic system there is no re-circulation of water and water has been provided to the channels after every week for growth of lettuce crop. Therefore, close re-circulating hydroponic system is the best method because it conserve more water and nutrients as compared to static hydroponic system.

In nutrient film technique (NFT) a shallow stream of nutrient enrich water required for plant growth is re-circulated and past to the bare roots of plants in a channel. A major problem facing world agriculture is the variation in crop yields every year due to climate changes like droughts, floods, high wind velocities and high or low temperature. Plant damage due to stresses can also resulted in physiological disorders in crop plants. Tip burn in lettuce crop is occur due to high temperature. Cat face is another disease caused by poor pollination resulting from low temperatures (Xu *et al.*, 2015). The main principle of the NFT is the principle by which nutrient solutions are continuously recirculated for growth of crop. The system is widely adjusted for a different crops production and is most suitable for short term crops like lettuce, leafy crops and herbs. Larger NFT systems are suitable for long term crops such as cucumbers and tomatoes. This technique makes hydroponics economically more attractive and due to their outstanding advantages. NFT is ideal for protecting the degradation of natural resources and it makes the culture more efficient to countries (Mohammed & Sookoo, 2017).

NFT design provides all requirements for better plant growth. NFT provides higher yields of high quality over the whole season of crop. A drawback of NFT is that it has a very little buffering against interruptions in the flow e.g. power outages but overall this is one of the more productive techniques in hydroponic system (Nelson, 2012). In the present experiment, close hydroponic system was developed by using two types of channels, PVC pipes (7.6 and 10.1 cm dia) and trays (8.8 and 12.5 cm) made by galvanized steel. Comparison between static and re-circulating close hydroponic system was made for the production of Lettuce. A water pump was used in each re-circulating hydroponic system for the continuous re-circulation of water and an air pump was used to provide oxygen in the plants.

Lettuce (*Lactuca sativa*) is one of the hydroponic vegetables most frequently cultivated. Hydroponics is plant growing technique without using soil. Plants can only be cultivated in a nutrient solution (liquid culture) or grow by an inert medium (culture of aggregates). In both systems, the irrigation water supplies all the nutritional needs of the crops (Kaiser & Ernst, 2016). Compared to traditionally cultivated lettuce, the life cycle of hydroponic lettuce is of short duration. After 35 to 40 days of growth, hydroponic lettuce may be harvested. Lettuce can be successfully grown in the NFT system and in this system it is possible to grow more than 8 crops per year efficiently. Horizontal and vertical hydroponic systems have been analyzed with multiple nutrient solutions for lettuce yield optimization (Touliatos *et al.*, 2016).

Lettuce (*Lactuca sativa L.*) is an appetizing plant. This leafy vegetable is consumed in Brazil and also used in other parts of world due to a good source of vitamins and minerals. Lettuce growth in NFT involves modern growing techniques and resulted in good quality and high value lettuce.

These growing methods are performed in greenhouses. Leafy type lettuce and semi-head cultivars are produced and mostly planted at a density of about two plants per square feet. One to three weeks old seedlings are transplanted and the duration from transplanting to harvesting ranges from four to seven weeks. Nutrient solution is recirculated continuously and nutrient solution is maintained properly. From the nutritional point of view, Lettuce is a more important crop from the socio-economic aspect as it is a great source of profit for farmers (Souza *et al.*, 2017). In Nutrient film technique close systems re-use the nutrient solution through recirculation for 24 hours. In this system the nutrient solution are regularly monitored and adjusted to maintain nutrient ratios properly. Common techniques are used to maintain nutrient solution volume are through water addition and nutrient concentration level are maintained through the mixing of nutrient solution. In comparison with open systems, close systems conserve more water and nutrients, which suddenly reduces waste. Generally close systems uses 20-40% less water and nutrients as compared to open systems, but this system is more difficult to monitor and maintain. This difficulty is due to ion accumulation as the nutrient solution recirculated continuously. Recirculation of nutrient solution required a complete infrastructure of reservoirs and pumping systems that should be monitored and maintained continuously to perform optimally for crop growth (Christie, 2014).

The study is unique in the sense that it developed and introduced a new close re-circulating hydroponic greenhouse lettuce production system for relatively higher yield and its comparison was made with static hydroponic system. Further, this is first such type of research work which have been done with significant research narrative for adoption strategies of close re-circulating hydroponic system with reuse of nutrient solution as compared to static hydroponic system. This study was mainly focused on introducing indigenously developed close re-circulating hydroponic system and its comparison was made with static hydroponic system in greenhouse condition for lettuce production.

Materials and methods

Study Area

Experiment was carried out at Hydroponic Research Station Rawat, Institute of Hydroponic Agriculture, PMAS-Arid Agriculture University Rawalpindi during 2018-19. Experimental area fall in the jurisdiction of district Rawalpindi, Pothwar region of North Punjab, Pakistan. For year round supply of lettuce experiment was conducted in greenhouse condition.

Treatments

Eight treatments were design in the experiment; T_1 (Static pipe with 7.6 cm dia.), T_2 (Static pipe with 10.1 cm dia.), T_3 (Static tray with 8.8 cm width), T_4 (Static tray with 12.5 cm width), T_5 (Recirculating pipe with 7.6 cm dia.), T_6 (Recirculating pipe with 10.1 cm dia.), T_7 (Recirculating tray with 8.8 cm width), T_8 (Recirculating tray with 12.5 cm width).

Static and Re-Circulating Close Hydroponic System

To achieve research objectives, static and re-circulating close hydroponic system with different sizes of PVC pipes and galvanized steel trays were developed. Diameter of PVC pipes were 7.6 & 10.1 cm while width of galvanized steel trays were 8.8 & 12.5 cm. The length of each water channel was 3.6 m feet for both static and re-circulating close hydroponic system. Plants grown in these water channels (PVC pipes & galvanized steel trays) were fed with nutrient enrich solution. A bucket of 25 liter size was selected as a container in which a submersible pump with required discharge rate (1.5liter/min) was installed for recirculation of nutrient solution. Air pumps were used in both re-circulating and static hydroponic system with discharge of 1.5 and 2.5L/min respectively. Submersible pump is put into a container of nutrient solution to deliver water to the top of channels for re-circulation. The water channels were placed at 2% slope for proper operation of recirculating hydroponic system. Recommended irrigation water with pH (6-7) and EC (1.2-1.8) dS/m respectively for lettuce (Singh & Bruce, 2016) was provided to system. Performance of re-circulating close hydroponic system and its comparison with static hydroponic system was made for lettuce production.

Sowing of Lettuce

Seeds were placed on rock-wool plug fitted into the net-pots. Rock-wool were moist using RO water. After washing of rock-wool lettuce seed placed on the rock-wool with the help of a stick. Coco peat powder used to cover the seed surface which is helpful in keeping the rock-wool surface wet. Net-pots used for sowing of lettuce plants are the plastic transparent cups. Plastic cups were used as net-pots. Using these cups as a net-pots it was necessary to drill holes on all side wall and on the bottom of cup to provide proper ventilation and plant roots penetration.

The rock-wool was shaped as the shape and size of plastic cup so that rock-wool easily adjusted in the net-pots and used for the initial seedling growth of lettuce. After three days of sowing almost all the seed starts growing. Plastic sheet was removed from the net-pots and seedlings were irrigated with RO water daily until each plant attain at least two leaves. After achieving desire height about 2-3 leaves the nursery was shifted in the nutrient film technique under greenhouse environment.

Plant Growth Parameters

Lettuce crop was grown in static and re-circulating hydroponic system, crop parameters which include plant height, number of leaves per plant, length of leaf, breadth of leaf, and yield per plant for eight treatments (T_1, T_2.....T_8) were measured.

Statistical Analysis

Data recorded in different treatments for various crop growth parameters was statistically analyzed using suitable software (Statistics 8.1) by selecting Completely Randomized Design (CRD). Results were compared using Least Significance Difference (LSD) at 5% level of Probability.

Results and discussion

The research was carried out for the comparison of static and re-circulating close hydroponic system. Various crop growth parameters measured during experiment were statistically analyzed by using Completely Randomize Design in Statistics 8.1 software. Mean tables including plant height, number of leaves per plant, leaf length, leaf breadth and yield per plant are represented in Table 1 to 5. The experiment was conducted under controlled environment so the external factors; sunlight, wind, rain, hail storm were not much adversely effective.

Plant height (cm)

Plant height (Table 1) of each plant was measured in re-circulating and static hydroponic system throughout the cropping cycle of lettuce. Average plant height in treatment T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8, was observed 18.58, 20.64, 18.22, 19.24, 20.40, 22.50, 19.46 and 21.72cm respectively. In all treatments the maximum plant height (22.50) was observed in treatment T_6 while the minimum plant height (18.22) was observed in treatment T_3. Plant height in treatment T_6 (22.5) is non-significantly different with T_8 (21.72) and significantly different with all other treatments T_1 (18.58), T_2 (20.64), T_3 (18.22), T_4 (19.24), T_5 (20.40) and T_7 (19.46) respectively at 5% level of probability. Treatments T_2 (20.64), T_5 (20.40) and T_8 (21.72) are non-significantly different with each other at 5% level of probability.

Plant height was greater in re-circulating hydroponic system than static hydroponic system which is similar with the finding of Kratky (2015) who reported that plant height for the recirculating system was greater than the static method in close hydroponic system.

Table 1. Effect of various treatments on plant height.

Treatments	Plant Height (cm)
T1 Static pipe with 7.6 cm dia.	18.58 ef
T2 Static pipe with 10.1 cm dia.	20.64 bc
T3 Static tray with 8.8 cm width	18.22 ef
T4 Static tray with 12.5 cm width	19.24 de
T5 Re-circulating pipe with 7.6 cm dia.	20.40 bcd
T6 Re-circulating pipe with 10.1 cm dia.	22.50 a
T7 Re-circulating tray with 8.8 cm width	19.46 cde
T8 Re-circulating tray with 12.5 cm width	21.72 ab
LSD	1.4568

Mean having same lettering are non-significantly differ from one another at 5% level of probability.

Number of Leaves/plant (No.)

Average number of leaves (Table 2) per plant in treatment T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 were observed 9.6, 10.8, 9.2, 10.2, 10.6, 12.2, 10.4, 11.2 respectively. Average number of leaves per plant in treatment T_6 (12.2) were non-significantly differ with treatment T_8 (11.2) and significantly different with all other treatments T_1 (9.6), T_2 (10.8), T_3 (9.2), T_4 (10.2), T_5 (10.6) and T_7 (10.4) respectively at 5% level of probability. Number of leaves per plant in Treatments T_2 (10.8) were non-significantly differ with T_4 (10.2), T_5 (10.6), T_7 (10.4) and T_8 (11.2) while it is significantly differ with other treatments T_1 (9.6), T_3 (9.2) and T_6 (12.2) respectively at 5% level of probability.

Number of leaves per plant was greater in re-circulating hydroponic system than static hydroponic system which is similar with the finding of Kratky (2015) who reported that number of leaves per plant for the recirculating system was greater than the static method in close hydroponic system.

Table 2. Effect of various treatments on number of leaves per plant.

Treatments	Number of Leaves per Plant
T1 Static pipe with 7.6 cm dia.	9.6 cd
T2 Static pipe with 10.1 cm dia.	10.8 b
T3 Static tray with 8.8 cm width	9.2 de
T4 Static tray with 12.5 cm width	10.2 bcd
T5 Re-circulating pipe with 7.6 cm dia.	10.6 bc
T6 Re-circulating pipe with 10.1 cm dia.	12.2 a
T7 Re-circulating tray with 8.8 cm width	10.4 bc
T8 Re-circulating tray with 12.5 cm width	11.2 ab
LSD	1.0082

Mean having same lettering are non-significantly differ from one another at 5% level of probability.

Leaf Length (cm)

Leaf length (Table 3) of lettuce in all treatments of static and re-circulating hydroponic system was measured. Leaf length in treatment T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 was observed 7.76, 8.64, 7.62, 7.96, 8.50, 9.46, 8.12 and 8.88 respectively. Maximum leaf length (9.46) was observed in treatment T_6 while the minimum leaf length (7.62) was observed in treatment T_3. Leaf Length in treatment T_6 (9.46) is significantly differ with its all competitors; treatments T_1 (7.76), T_2 (8.64), T_3 (7.62), T_4 (7.96), T_5 (8.5), T_7 (8.12) and T_8 (8.88) respectively at 5% level of probability. Leaf length in treatments T_2 (8.64) is non-significant with T_5 (8.50) and T_8 (8.88) while it is significantly differ with other treatments T_1 (7.76), T_3 (7.62), T_4 (7.96), T_6 (9.46) and T_7 (8.12) respectively at 5% level of probability.

Leaf length was greater in re-circulating hydroponic system than static hydroponic system which is in line with the findings of Kratky (2015) who reported that leaf length in recirculating system was comparatively better than the static system in close hydroponic system.

Table 3. Effect of various treatments on leaf length.

Treatments	Leaf Length (cm)
T1 Static pipe with 7.6 cm dia.	7.76 de
T2 Static pipe with 10.1 cm dia.	8.64 b
T3 Static tray with 8.8 cm width	7.62 e
T4 Static tray with 12.5 cm width	7.96 de
T5 Re-circulating pipe with 7.6 cm dia.	8.50 bc
T6 Re-circulating pipe with 10.1 cm dia.	9.46 a
T7 Re-circulating tray with 8.8 cm width	8.12 cd
T8 Re-circulating tray with 12.5 cm width	8.88 b
LSD	0.4751

Mean having same lettering are non-significantly differ from one another at 5% level of probability.

Leaf Breadth (cm)

Leaf breadth (Table 4) of lettuce was measured in all treatments of static and re-circulating hydroponic system. Leaf breadth in treatment T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 was observed 4.38, 4.88, 4.20, 4.60, 4.78, 5.10, 4.68 and 5.02cm respectively. The maximum leaf breadth (5.10) was observed in treatment T_6 while the minimum leaf breadth (4.20) was observed in treatment T_3. Leaf breadth in treatment T_6 (5.1) is non-significantly differ with the treatments T_2 (4.88), T_4 (4.60), T_5 (4.78), T_7 (4.68) and T_8 (5.02) respectively and significantly differ with treatments T_1 (4.38) and T_3 (4.20) at 5% level of probability. Leaf breadth was greater in re-circulating hydroponic system than static hydroponic system which is in accordance with the finding of Kratky (2015) who reported that leaf breadth in recirculating method was greater than the static method in close hydroponic system.

Table 4. Effect of various treatments on Leaf breadth.

Treatments	Leaf Breadth (cm)
T1 Static pipe with 7.6 cm dia.	4.38 bcd
T2 Static pipe with 10.1 cm dia.	4.88 ab
T3 Static tray with 8.8 cm width	4.20 cd
T4 Static tray with 12.5 cm width	4.60 abcd
T5 Re-circulating pipe with 7.6 cm dia.	4.78 ab
T6 Re-circulating pipe with 10.1 cm dia.	5.10 a
T7 Re-circulating tray with 8.8 cm width	4.68 abc
T8 Re-circulating tray with 12.5 cm width	5.02 a
LSD	0.5447

Mean having same lettering are non-significantly differ from one another at 5% level of probability.

Yield per Plant (g)

Yield per plant (Table 5) of lettuce was measured in all treatments of static and re-circulating hydroponic system at the end of cropping season. Yield per plant in treatment T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 was observed 190.80, 245.80, 176.00, 213.40, 241.00, 321.40, 214.20 and 288.80 respectively. The maximum yield per plant (321.40) was observed in T_6 while the minimum yield per plant (176) perceived in treatment T_3. Yield in treatment T_6 is significantly differ with all other treatments. Yield per plant of treatment T_2 (245.8) is non-significant with T_5 (241) and significant with T_1 (190.8), T_3 (176), T_4 (213.4), T_6 (321.4), T_7 (214.20) and T_8 (288.8) respectively at 5% level of probability. Yield per plant in treatments T_4 (213.4) is non-significant with T_7 (214) and significant with T_1 (190.8), T_2 (245.8), T_3 (176), T_5 (241), T_6 (321.40) and T_8 (288.8) respectively at 5% level of probability.

The present results are similar with the findings of Kratky (2015) who reported that yield for the recirculating method was greater than the static method in close hydroponic system. Barbosa *et al.* (2015) also reported that there is more production of lettuce in close re-circulating hydroponics.

Table 5. Effect of various treatments on yield per plant.

Treatments	Yield per Plant (g)
T1 Static pipe with 7.6 cm dia.	190.80 e
T2 Static pipe with 10.1 cm dia.	245.80 c
T3 Static tray with 8.8 cm width	176.00 f
T4 Static tray with 12.5 cm width	213.40 d
T5 Re-circulating pipe with 7.6 cm dia	241.00 c
T6 Re-circulating pipe with 10.1 cm dia.	321.40 a
T7 Re-circulating tray with 8.8 cm width	214.20 d
T8 Re-circulating tray with 12.5 cm width	288.80 b
LSD	7.4341

Mean having same lettering are non-significantly differ from one another at 5% level of probability.

Conclusions

Highest mean yield (321.4g) was recorded in treatment T_6 in re-circulating pipe with 10.1 cm dia. while in equal volume of re-circulating tray with 12.5 cm width was observed (288.8g). Yield in static pipe 10.1 cm dia. (245.85g) was comparatively better than equal volume of static tray with 12.5 cm width. Average production in re-circulating pipe with 7.6 cm dia. was (241g) which is comparatively better than the equal volume of re-circulating galvanized steel tray (214.20g) with 8.8 cm width. For greenhouse lettuce production, it is therefore concluded that, circular shaped re-circulating hydroponic system was a comparatively better choice as compared to static hydroponic.

Acknowledgments

I am highly thankful to Dean, Faculty of Agricultural Engineering & Technology and Director, Institute of Hydroponic Agriculture for providing me facilities and infrastructure required during this research.

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