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Research Article

Development and testing of re-circulating nutrient film technique

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Abstract

Nutrient film technique is an innovative food production system in which nutrients are circulated through bare roots to meet nutritional requirements of plants, as circulating nutrients solution is important for optimum growth. Experiment for development and testing of NFT and its comparison with geoponics was carried out at Hydroponic Research Station Rawat, Institute of Hydroponic Agriculture, PMAS-Arid Agriculture University Rawalpindi. Development of nutrient film technique was completed during first six month, and then planned experiment was executed in the green house conditions. Crop growth parameters were measured weekly throughout the cropping season, sum up all weekly data, while yield was recorded after harvesting. Crop parameters include plant height, number of leaves per plant, length of leaf, breadth of leaf, and yield per plant in five treatments T_1 (re-circulating pipe with 7.6 cm dia.), T_2 (re-circulating pipe with 10.1 cm dia.), T_3 (re-circulating tray with 8.8 cm width), T_4 (re-circulating tray with 12.5 cm width) and T_5 (Geoponics) were measured. Five plants were selected from each treatment and average data were measured. The data were statistically analyzed by following Completely Randomized Design (CRD) at 5% level of probability. Comparatively better production was observed in nutrient film technique as compared to geoponics. The highest yield per plant (321.40) was recorded in T_2 while the least yield per plant (150.80) observed in treatment T_5. Yield in treatment T_2 (321.40) is significantly differ with all other treatments T_1 (241.00), T_3 (214.20), T_4 (288.80) and T_5 (150.80) respectively at 5 % level of probability.

Keywords: Geoponics; Lettuce; Nutrient film technique; Yield

Introduction

Per capita surface water availability declined from 5260 cubic meter per year in 1951 to around 1000 cubic meter in 2016. Hydroponics utilizes relatively little water in contrast to the soil farming. In conventional soil method, most of the water provided to the crops is leached deep into the soil and is inaccessible to the roots of the crops, whereas in hydroponics, plant roots are either filled with water or a film of nutrients mixed in water constantly comprises the root zone, maintaining it hydrated and nourished. As water is recovered, filtered, replenished and recycled and is not wasted in this process. Waste nutrient solution can be used in hydroponic systems as an alternative water resource for growing crops [1]. 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 field 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 [2].

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 [3].Plant spacing for the cultivation of lettuce is a significant criterion for maximum vegetative development and a significant aspect of crop growth in order to maximize yield. Optimum plant spacing guarantees that natural resources are used sensibly and facilitates intercultural activities. It helps to boost leaves, branches, and productive foliage. Densely planted crops are effecting proper development and growth. On the other side, wider spacing guarantees important nutritional demands but lowers overall plant numbers as well as overall yield. Using optimum spacing in leafy vegetables, growth rates can be improved to 25% for any crop [4]. 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 also been analyzed with multiple nutrient solutions for lettuce yield optimization [5].

Conventional agricultural (geoponics) methods may cause many negative impacts on the environment. “Conventional has been historically defined as the practice of growing crops in soil, in the open air, with irrigation, and the active application of nutrients”. Some of the negative impacts of traditional agriculture contain the more and incompetent use of water, more land requirements, higher amount of nutrients requirement, and soil erosion. The increase in growth of the world population require higher rate in the production of the food. To feed the world’s growing population in a better way, innovative techniques for producing food have to be used [6]. Hydroponics derived from Latin word which means, “working water”. In this soilless culture and modern agriculture techniques, the plants are cultivated in water. However, simple water is not used in this system and this water contains different nutrients. Some of the important nutrients for hydroponics are: Nitrogen N, Potassium K, Phosphorus P, Calcium Ca, Magnesium Mg, Sulphur S, Iron Fe, Manganese Mn, Copper Cu, Zinc Zn, Boron B and Chlorine Cl. Moreover, hydroponic system is seen to be in the forefront in terms of commercial prospects. Keeping in mind both the commercial and environmental perspectives the paper aims to weigh hydroponics against geoponics [7]. This study was focus on introducing close hydroponic lettuce production system in indigenous developed re-circulating nutrient film technique and its comparison was made with geoponics.

Materials and methods

Study area

The study for development of close re-circulating hydroponic system and its comparison with the geoponics was carried out at Hydroponic Research Station-Rawat Institute of Hydroponic Agriculture PMAS-Arid Agriculture University Rawalpindi during 2018-19. Experimental area falls 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

Five treatments were designed in the experiment; T_1 (re-circulating pipe with 7.6 cm dia.), T_2 (re-circulating pipe with 10.1 cm dia.), T_3 (re-circulating tray with 8.8 cm width), T_4 (re-circulating tray with 12.5 cm width) and T_5 Geoponics. For comparative study of the different shapes of channels volume of water for T_1 was kept equal to $T_3$and volume of water for T_2 were kept equal to T_4.

Close re-circulating hydroponic

To achieve research objectives, re-circulating close hydroponic system with different sizes of PVC pipes and galvanized steel trays were developed. Diameter of PVC pipes were 7.6 cm & 10.1 cm while width of galvanized steel trays were 8.8 cm & 12.5 cm respectively. The length of each water channel was 3.6 meter for re-circulating close hydroponic system. Plants grown in the water channels (PVC pipes & galvanized steel trays) were fed with nutrient enriched solution. A bucket of 25 liter size was selected as a container in which a submersible pump of required discharge rate (1.5 liter/min) was installed for re-circulation of nutrient solution.

Air pumps were used in re-circulating hydroponic system having discharge rate of 1.5 L/min. The water channels were placed at 2% slope for proper operation of re-circulating hydroponic system. Recommended irrigation water with pH (6-7) and EC (1.2-1.8) dS/m for lettuce was provided to system **[8]**. Performance of close re-circulating hydroponic system and its comparison was made with geoponics for lettuce production.

Sowing of lettuce

Seeds were placed on rock-wool plug fitted into the net-pots. Rock-wool were moist using reverse osmosis (RO) water. After washing of rock-wool lettuce seeds were placed on the rock-wool with the help of a stick. Coco peat powder was used to cover the seed surface which is helpful in keeping the rock-wool surface wet. Net-pots used for sowing of lettuce plants were the plastic transparent cups. 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 attained at least two leaves. At two leaves stage, the nursery was shifted in the close re-circulating hydroponic system under greenhouse environment.

Geoponics

To compare the performance of re-circulating hydroponic system with geoponics in green house conditions lettuce was also sown in border soil. Holes were drilled at the bottom of each pots with the help of drill machine for proper drainage of water. The sowing of lettuce in border soil and in net-pots using rock-wool as a supporting media completed on the same day to evaluate the performance of lettuce in both growing system.

Plant growth parameters

Lettuce crop was grown in re-circulating hydroponic system and in geoponics, crop parameters including plant height, number of leaves per plant, length of leaf, breadth of leaf, and yield per plant for five treatments (T_1, T_2…..T_5) were measured.

Statistical analysis

Data recorded in different treatments for various crop growth parameters were statistically analyzed using software (Statistix 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 to compare re-circulating close hydroponic system and geoponics. Various crop growth parameters measured during experiment were statistically analyzed by using Completely Randomize Design in Statistix 8.1 software. Mean values for 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 greenhouse conditions so the external factors; sunlight, wind, rain, hail storm were not much adversely effective.

Plant height (cm)

Plant height (Table 1) of each lettuce plant was measured in re-circulating hydroponic system and in geoponics. Average plant height in treatment T_1, T_2, T_3, T_4, and T_5, was recorded 20.40, 22.50, 19.46, 21.72 and 17.38cm respectively. In all treatments the optimum plant height (22.50) was observed in treatment T_2 while the lowest plant height (17.38) was observed in treatment T_5. Plant height in treatment T_2 (22.50) is non-significantly different with T_4 (21.72) and significantly differed with all other treatments T_1 (20.40), T_3(19.46) and T_5 (17.38)respectively at 5 % level of probability.

Treatment T_5 (17.38) is significantly different with other treatments T_1 (20.40), T_2 (22.50), T_3 (19.46) and T_4(21.72)at 5 % level of probability which is in accordance with the finding of scientist who stated that plants that are grown in soil tended to be less vigorous than those plants grown in nutrient film technique **[9]**.

Table 1. Effect of various treatments on plant height

Treatments	Plant Height (cm)
T_1 Re-circulating pipe with 7.6 cm dia.	20.40 bc
T_2 Re-circulating pipe with 10.1 cm dia.	22.50 a
T_3 Re-circulating tray with 8.8 cm width	19.46 c
T_4 Re-circulating tray with 12.5 cm width	21.72 ab
T_5 Geoponics	17.38 d
LSD	**1.3424**

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 treatments T_1, T_2, T_3, T_4 and T_5 were observed 10.6, 12.2, 10.4, 11.2 and 8.4 respectively. Average number of leaves per plant in treatment T_2 (12.2) differed non-significantly with treatment T_4 (11.2) and significantly different with other treatments T_1 (10.6), T_3 (10.4) and T_5 (8.4) respectively at 5 % level of probability.

Average number of leaves in treatment T_5 (8.4) geoponic is significantly different from all other treatments T_1 (10.6), T_2 (12.2), T_3 (10.4) and T_4 (11.2) which is in accordance with the finding of scientist who studied that there are greater number of leaves per plant in nutrient film technique than those plants that are grown in soil [9].

Table 2. Effect of various treatments on No. of leaves per plant

Treatments	Number of Leaves per Plant
T_1 Re-circulating pipe with 7.6 cm dia.	10.6 b
T_2 Re-circulating pipe with 10.1 cm dia.	12.2 a
T_3 Re-circulating tray with 8.8 cm width	10.4 b
T_4 Re-circulating tray with 12.5 cm width	11.2 ab
T_5 Geoponics	8.4 c
LSD	**1.1501**

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 re-circulating hydroponic system and geoponics was measured. Leaf length in treatments T_1, T_2, T_3, T_4 and $T_5$was observed 8.50, 9.46, 8.12, 8.88 and 7.50 respectively. Optimum leaf length (9.46) was recorded in treatment T_2 while the lowest leaf length (7.50) was observed in treatment T_5. Leaf Length in treatment T_2 (9.46) is significantly different from its all competitors; treatments T_1 (8.50), T_3 (8.12), T_4 (8.88) and T_5 (7.50) respectively at 5 % level of probability.

Leaf length in treatment T_5 (7.50) geoponic is significantly different from all other treatments T_1 (8.50), T_2 (9.46), T_3 (8.12) and T_4 (8.88) which is in accordance with the finding of scientist who stated that there is more growth in close re-circulating hydroponic system than geoponics [10].

Table 3. Effect of various treatments on leaf length

Treatments	Leaf Length (cm)
T_1 Re-circulating pipe with 7.6 cm dia.	8.50 bc
T_2 Re-circulating pipe with 10.1 cm dia.	9.46 a
T_3 Re-circulating tray with 8.8 cm width	8.12 c
T_4 Re-circulating tray with 12.5 cm width	8.88 b
T_5 Geoponics	7.50 d
LSD	**0.4597**

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

Leaf breadth (cm)

Leaf breadth (Table 4) of lettuce was measured in all treatments of re-circulating hydroponic system and geoponics. Leaf breadth in treatment T_1, T_2, T_3, $T_4$and $T_5$was measured 4.78, 5.10, 4.68, 5.02 and 4.12cm respectively. The greater leaf breadth (5.10) was observed in treatment T_2 while the lowest leaf breadth (4.12) was observed in treatment T_5. Leaf breadth in treatment T_2 (5.1) is non-significantly differ with the treatments T_1(4.78), T_3(4.68)and T_4(5.02) respectively and significantly differ with treatmentT_5(4.12) at 5 % level of probability.

Leaf breadth in treatment T_5 (4.12) geoponic is significantly different with all other treatments T_1 (4.78), T_2 (5.10), T_3 (4.68) and T_4 (5.02) which is in line with the finding of researcher who stated there is more growth in close re-circulating hydroponic system than geoponics [10].

Table 4. Effect of various treatments on leaf breadth

Treatments	Leaf Breadth (cm)
T_1 Re-circulating pipe with 7.6 cm dia.	4.78 a
T_2 Re-circulating pipe with 10.1 cm dia.	5.10 a
T_3 Re-circulating tray with 8.8 cm width	4.68 a
T_4 Re-circulating tray with 12.5 cm width	5.02 a
T_5 Geoponics	4.12 b
LSD	**0.5051**

Mean having same lettering are non-significantly different 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 re-circulating hydroponic system and in geoponics at the end of cropping season. Yield per plant in treatments T_1, T_2, T_3, T_4, T_5 was observed 241, 321.40, 214.20, 288.80 and 150.80 respectively. The greater yield per plant (321.40) was recorded in T_2 while the least yield per plant (150.80) observed in treatment T_5. Yield in treatment T_2 (321.40) is significantly differ with all other treatments T_1 (241.00), T_3 (214.20), T_4 (288.80) and T_5 (150.80) respectively at 5 % level of probability.

Yield per plant in treatment T_5 (150.80) geoponic is significantly different fromother treatments T_1 (241), T_2 (321.40), T_3 (214.20) and T_4 (288.80) Average yield of lettuce was highest in treatment T_2. The yield reduction in other treatments may be associated with space limitations for root growth, density, porosity, water holding capacity and drainage, which is in accordance with the finding of researcher who studied that there is more production in close re-circulating hydroponic system than geoponics **[10]**.

Table 5. Effect of various treatments on yield per plant

Treatments	Yield per plant (g)
T_1 Re-circulating pipe with 7.6 cm dia.	241.00 c
T_2 Re-circulating pipe with 10.1 cm dia.	321.40 a
T_3 Re-circulating tray with 8.8 cm width	214.20 d
T_4 Re-circulating tray with 12.5 cm width	288.80 b
T_5 Geoponics	150.80 e
LSD	**8.4660**

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

Conclusion and recommendations

The highest mean yield (321.4g) was recorded in treatment T_2 in re-circulating pipe with 10.1 cm dia. while yield in equal volume of water re-circulating tray with 12.5 cm width was observed (288.8g). Average production in treatment T_1 re-circulating pipe with 7.6 cm dia. was (241g) which is comparatively better than the equal volume of water re-circulating galvanized steel tray (214.20g) with 8.8 cm width. Minimum lettuce production was observed in geoponics (150.80g) as compared to re-circulating hydroponic system. For greenhouse lettuce production, it is therefore concluded that, circular shaped re-circulating hydroponic system was a comparatively better choice as compared to geoponics. Yield reduction in geoponic is due to positive and negative ions of silt and clay particles of soil. Nutrient react with these positive and negative ions of soil, form chemical bonding, as result salts unavailable to plants for their proper growth. While in hydroponic all nutrient supplied were available to plant roots. To get better yield, pipe is recommended to use as a carrier in re-circulating hydroponic. Research on automation of nutrient film technique should be carried out to develop indigenously automation model. Consultancy services should be initiated by the Institute of Hydroponic Agriculture and Faculty of Agricultural Engineering for the interested framers, to design and install nutrient film technique. The study is unique in the sense that it developed and introduced a new greenhouse lettuce production technique. This is first such type of research work which have been done with significant research narrative for adoption strategies of close re-circulating nutrient film technique most feasible in protected environment with re-use of nutrient solution by maintaining its EC & pH.

Authors' contributions

Conducted research and wrote first draft of manuscript: A Qadeer, Supervised the research and helped in technical writing: ZU Haq, Technical guidance throughout research: SJ Butt, Corrected manuscript: HM Asam & MK Nawaz, Helped in data collection: SR Haidree, Helped in statistical analysis and formatting: T Mehmood.

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References

1. Choi B, Lee SS & Sik Ok Y(2012). Effects of waste nutrient solution on growth of chinese cabbage (*Brassica campestris* L.) in Korea. *Korean JEnvir Agri* 30(2): 125-131.
2. Sharma A, Kumar S & Chaurasia (2018). Hydroponics as an advanced technique for vegetable production: An overview. *J Soil Water Conserv*17(4): 364-371.
3. Kaiser C & Ernst M(2016). Hydroponic lettuce. CCD- CP-63. Lexington, KY: Center for Crop Diversification, University of Kentucky College of Agriculture, Food and Environment.
4. Hasan MR, Tahsin AKMM, Islam MN, Ali MA & Uddain J(2017). Growth and yield of lettuce (*Lactuca Sativa* L.) influenced as nitrogen fertilizer and plant spacing. *J Agri Vet Sci* 19(6): 7-62.
5. Touliatos D, Dodd IC & Mcainsh M(2016). Vertical farming increases lettuce yield per unit area compared to conventional horizontal hydroponics. *Food Energy Secu* 5(3): 184-191.
6. Alshrouf A(2017). Hydroponics, aeroponic and aquaponic as compared with conventional farming. *Amer Sci Res J Engg Tech Sci* 27(1): 247-255.
7. Goenka A(2018). Hydroponics v/s geoponics. *Intl J Emerg Res Dev* 1(5): 41-44.
8. Singh H & Bruce D(2016). Electrial conductivity and pH guide for hydroponics. Oklahoma Cooperative Extension Fact Sheets, HLA-6722. Oklahoma State University, Division of Agricultural Sciences and Natural Resources pp 5.
9. Abou-Hadid AF, Zayed AM, EI-Behairy UA & EI-Beltagy AS(1989). A comparison between Nutrient Film Technique (NFT) and Soil for Tomato Production under Protected Cultivation in Egypt. *Ejypt J Horti* 16(2): 111-118.
10. Barbosa GL, Daiane F, Gadelha A, Kublik N, Proctor A, Reichelm L & Halden RU(2015). Comparison of land, water, and energy requirements of lettuce grown using hydroponic vs conventional agricultural methods. *Intl J Envir Res Pub H*12: 6879-6891.