Performance assessment of automatic pH and Ec monitoring and control system for hydroponically grown lettuce

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Abstract

An experiment was conducted to assess the performance of automatic pH and Ec monitoring and control system for hydroponically grown lettuce (Lactuca sativa), with the objective of creating a precisely controlled nutrient environment with minimum labour cost for achieving high yield.

The experiment had two treatments with four replicates arranged in a complete randomized design. Desired nutrition and pH levels in the automatic system were maintained precisely at set levels throughout the experiment, while the adjustment of Ec and pH of the control experiment was done manually.

Daily air and solution temperature, relative humidity and light intensity in the protected house were measured. Comparison of dry and fresh weight of the yield and subsequent root weights between two treatments were measured 24 days after transplanting.

Plant growth in both treatments was virtually identical and resulted in an average shoot fresh mass of 165.97 g in the automatic system and 156.94 g in manual control system. However, the difference was not significant at alpha level 0.05. The automatic system had the ability to correct pH and Ec levels instantly just after deviation from the set levels.

The results revealed that performance of the automatic system satisfies the requirements to grow lettuce in NFT system and could be recommended as a suitable system for Ec and pH adjustment in hydroponically grown crops.

Keywords: Automatic system, hydroponically grown lettuce, manual system, NFT system

Introduction

Among the different hydroponics systems, Nutrient Film Technique (NFT) (i.e. growing, plants on a thin film of nutrient solution) is considered more economical and environmental friendly. It provides opportunities for maximum use of fertilizer, excellent water conservation, and minimal use of materials and precise control of nutrients. The compact nature of the design helps to develop and implement a high level of automated parameter control system to obtain labour saving and rapid economic return for investment.

One of the major disadvantages of NFT is the difficulty of nutrient management in the nutrient film. It is essential that the relative concentrations of nutrients in the solution are kept approximately equal to the crop uptake ratios, to minimize accumulation or depletion of some nutrients. Regular addition of nutrients to recover the depleted amounts is essential to maintain the proper balance. Many growers find the task of monitoring, analyzing and chemical adjustment undesirable. As a result, only 10% of the world's commercial hydroponic crop producers use this system.

The objective of the present research was to assess the performances of automatic pH and Ec monitoring and control system for hydroponically grown lettuce, in order to cerate precisely control nutrient environment with minimum labour cost for gaining high yield.

Methodology

An automatic system to regulate the pH and Ec of NFT hydroponics systems was designed and constructed in the Department of Agricultural Engineering University of Ruhuna. The system was compared with manually controlled system (the control treatment).

The experiment had two treatments with four replicates arranged in a complete randomized design. Desired nutrition and pH levels in the automatic system were maintained precisely at set levels throughout the experiment, while the adjustment of Ec and pH of the control experiment was done manually.

Daily air and solution temperature, relative humidity and light intensity in the protected house were measured. Comparison of dry and fresh weight of the yield and subsequent root weights between two treatments were measured 24 days after transplanting.

To correct the Ec 20 times concentrated nutrient solution of the working solution was used and delivery lines were connected through solenoid valves directly into a tank which contains working solution. H_3PO_4 acid (25 ppm) was used to correct pH changes in a similar manner.

The pH correction in the manual system was done daily while in the automatic system pH and Ec levels automatically corrected instantly if they deviated from the set levels.

Standard pH and Ec meters were used to measure them in the automatic system. Outputs from the meters were connected to the automatic control system through series of dip switches where the operator could select a desired range of changes and set to "ON and OFF" positions.

The pH valves of the nutrient solution were maintained at 5.8 to 6.2 range and Ec valve of the nutrient solution kept in the range of 1.5 mS/cm to 3.55 mS/cm according to the growth stages. This was done by adjusting the nutrient concentration of the working solution to maintain Ec levels at 1.5, 1.8, and 2.0 during the respective growth stages with the help of the dip switches. The automatic control system has the microprocessor technology. PIC 16F84A* 18-pin 8- bit Microcontroller was introduced to the system and computer program was written using "MP LAB*" software and incorporated in to the chip using an EEPROM* burner.

The controller was mounted in a waterproof healthy environment and electrically earthed to prevent electrical noises to avoid the error readings which may be caused by the plant environment. Ten information line displays were prepared and set on the front panel in the controller to display the ongoing process.

The performance efficiency of the system was checked by observing the growth and development of lettuce grown in the system that with manually operated system.

Results and Discussion

Electrical conductivity

The Fig. 1 shows the variation of Ec levels during the experimental period in manual and automatic systems.

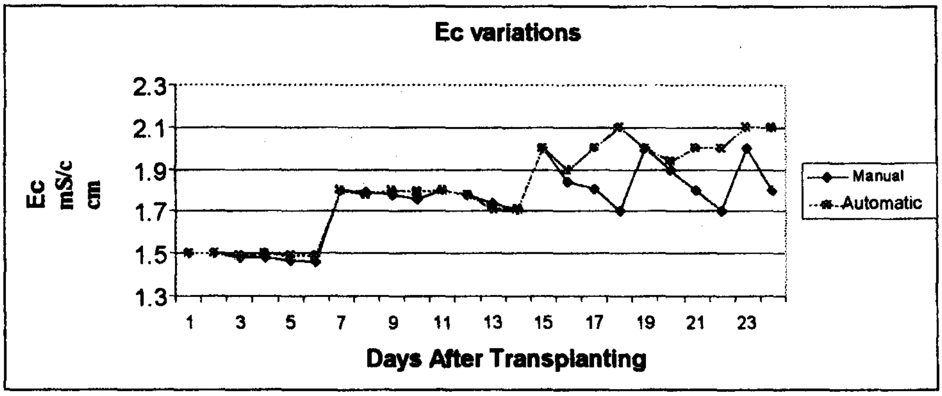

Fig . 1: Ec fluctuations of the manual and automatic control systems

*PIC 16F84A, Peripheral Interface Controller
*MP LAB, Microprocessor Lab
*EEPROM, Electrically Erasable Programmable Read Only Memory

Throughout the experimental period EC of both systems has remained in the range of 1.5-2.0 mS/cm. Lettuce plants grew well and gave a higher quality fresh marketable yield within this range. In manual system pH and Ec were checked daily and adjusted if the deviation was 0.3 m/cm from the set range.

In the automatic system the pH and Ec parameters could be set with higher accuracy to correct it at the deviation of 0.1 mS/cm. During first two weeks the optimum range was 1.5 mS/cm and 1.8 mS/cm and Ec variation was very narrow. But after the second week the set value was 2 mS/cm. However the fluctuation of Ec was high in the latter periods due to high consumption of plant nutrients. Accordingly, nutrient level around the root zone in the automated system has closely followed the favorable range, compared to manual system.

pH Variations

The pH fluctuation in manual & automatic systems during the experiment is illustrated in the Fig. 2

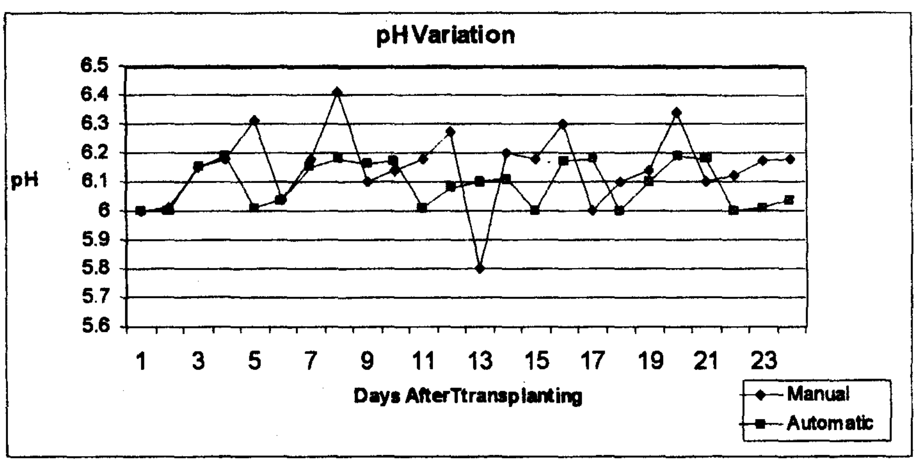

Fig. 2: pH of the nutrient solutions in manual and automatic control systems

The recommended pH range for Lettuce is 5.8-6.2. with the optimum of 6. In the manual system pH has been checked daily and corrected if it deviates by 0.2 of the optimum. It was evident from Fig. 2 that the automatic system has frequently adjusted the pH level to reach the set levels. Whenever the pH value in the working solution exceeds 6.2 the automatic system had released the required volume of acid from the feeder tank which helped to maintain pH more closer to optimum in the automatic system compared to manual system.

Table 1. Performance assessment of Lettuce grown in two systems

Treatments	Mean with T grouping			
	Fresh weight (g/plant)		Dry weight (g/plant)	
	Leaves	Root	Leaves	Root
Automatic	165.97 a	7.03 a	7.42 a	1.16 a
Manual	156.94 a	7.35 a	7.61 a	1.18 a

Means with the same letters are not significantly different at alpha=0.05.

Fresh and dry weights of Lettuce plant grown in two systems are given in the Table.1. There was no significant difference in fresh and dry weights of leaves and root in the two systems. It was evident that fresh weight of the Lettuce plants varied from 178.87g to 135.46g in different treatments.

Plant fresh weight was slightly increased (5.7%) in the automatic system but was not significant. Analogical observation could be made for dry weights of leaves and roots of the Lettuce plants, grown in two systems.

Length and width of the seventh leaf

Average length and width of the 7[th] leaf of plants grown in two systems just before harvesting is given in Table 2.

Table 2. Leaf growth and production of Lettuce grown in two systems

Treatment	Length (cm)	Width (cm)	Number of leaves/plant (average)
1. Automatic	18.78[a]	13.38[a]	29.25
2. Manual	18.35[a]	13.29[a]	28.5

* Means with same letter are not significantly different at alpha = 0.05

As indicated in Table 2, there was no significant difference between two treatments at 0.05 alpha level. But individual mean values showed a slight increase in length and width of the seventh leaf of the Lettuce plant in auto monitoring system.

At transplanting stage, there were three leaves in a plant and it increased up to average of 29.25 and 28.5 in automatic and manual system, respectively after 24 days. There was no significant difference, among the treatments. However increased number of leaves was observed when it was grown in automatic system, though the difference was not significant.

Performance of lettuce in the automatic system was better and as such automatic system can be used to replace manual labour which is vitally important in large scale year round continuous production. In the case of lettuce only pH and Ec control and solution circulation are the major tasks to perform as it has small crop duration of less than 30 days. Improvement of even and better appearance, avoiding bitter taste could be easily controlled with in the system for the competitive market.

Conclusions

1. Lettuce could be successfully grown using the Albert's solution in the automatic system where pH & EC adjustment could be regulated precisely.

2. The growth, development and yield of lettuce grown in the automatic system were comparatively high (165.97g/plant) compared to manual system (156.54g/plant).

3. The automation of solution circulation & maintenance of pH & EC of the solution using proposed electronic system could be recommended for the future automation of the lettuce cultivation in NFT systems. The system could be used to grow long duration crops such as Tomato, Bellpepper, etc after field validation of the system.

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