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Optimizing Crop Yield using Hydroponic Farming on Tomato Plants by applying Deep Neural Networks

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ABSTRACT

Deep learning constitutes a recent, modern technique for new variants in agriculture with quality yield, minimal resources, and large potential. As deep learning has been successfully applied in various domains, it has recently entered also the domain of agriculture. In this paper, hydroponic farming is employed using deep learning techniques for tomato plant production addressing major challenges for increasing the production using a small area for cultivation and also in a short span of time. By examining the production and agricultural problems understudy the novel technology of smart farming techniques can be implemented for overall performance. Hydroponic system, multi-planned air flow, moisture, amount of nutrients thresholds of carbon dioxide and nitrogen can be controlled and operated using deep learning techniques. IoT sensors and use of UAVs assist in controlling the other aspects of production. The study evaluates the application of deep learning methods on tomato plants for optimizing high quality yields of production. In this research study 1500 sq. ft. land was used for cultivating the hydroponic farming of tomato plants automating supply of nutrients, water and use of controlled environment with low cost. This study was conducted for about six months from March 2020 to September 2020. The results show that 27% production was increased yielding best quality tomatoes with minimum investment and time span.

Key Words: Smart Farming, Hydroponics, Deep Neural Networks, Sensors, Tomatoes, Vertical Farming.

INTRODUCTION

The agriculture sector is experiencing several challenges such as increasing population, scarcity of water and insufficient farming lands in generating adequate yields to meet the requirements. Water is the main resource for agriculture, but groundwater is depleting in many areas due to global warming. Besides, agriculture lands are occupied with high rise constructions, infrastructure development, road widening, and industrial expansion, hypothetically leading to a shortage of farmlands. Conventional techniques in agriculture prove to be inefficient for achieving larger yields with smaller farm areas. There is a necessitate for a smart food production system that increases the crop yield, uses less period, requires less water, stacked area, and fewer human power.

Smart farming using hydroponics is a sustainable method for feeding the global population and to conserve fast depleting land and water resources (Van, 2017). In the present scenario soil, free conservation is gathering momentum. Using hydroponics cultivation, crop yield can be increased, the use of land is minimized and less requirement of water is accomplished. Several viable and specialized crops can be cultivated using hydroponics including peppermint, lettuce, tomatoes, green peas, capsicum, peppers, chilies, cucumbers, strawberries and many more(Zuchi *et al,* 2009). Anti-soil Agriculture includes different types – Hydroponics, Aquaponics, and Aeroponics. Among these Hydroponics farming attains high recognition due to its efficient resource management and crop production (Wang *et al,* 2016).

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Artificial intelligence, Machine Learning, and Deep Learning techniques are advanced computational techniques addressing many realistic problems. These techniques can be collaborated with the agriculture sector for unique research to improve the speed, type, new variety and protection should be employed. Increasing the yield, maintaining the quality crop,monitoring the pH value, nutrient proportion, amount of water required, humidity and oxygen components can be automatically monitored using Deep Learning and AI. Many countries are using mini-bots to analyze ripeness and crop quality in the agriculture sector. Mini-bots are employed to pluck ripen fruits and vegetables without harming the delicate skin of tomatoes and strawberries.

The main objective of this article was to introduce a smart model for solving the issues of Hydroponic systems. Smart Hydroponic system uses sensors – temperature, Humidity, Heat and water-level, timers and mineral components to screen the system in an efficient and optimized manner(Harper *et al,* 2015). Deep learning techniques are applied to the monitored datasets to improve the quality and quantity of the crop yields. Farmers can easily adjust the component measurements by using the proposed model. This method is efficient because it guides in an optimized way of increasing quality-based crop yield and low usage of fertilizers (Karamjit*et al*, 2020).

MATERIALS AND METHODS

Tomato plants convert light energy into chemical energy. Micronutrients and Macronutrients are evenly distributed by stimulating with the pH level and aerators(Maucieri*et al,* 2018). Tomatoes absorb oxygen needed for complete registration. The system is customized for different plants and environments needed for the cultivator.

For cultivating 88 tomato plants we use 120 parts of nitrogen to 19 litersof water for irrigating 7 times in a day. The nutrient solution is fed to plants using the dripping technique. The system is monitored at regular intervals using Deep Neural networks. Next day's input is predicted from the DNNs values for improving the quality and quantity of tomatoes. Using the automatic system, installed time buzzers feed the tomatoes at regular intervals taking the inputs from the DNN technique.

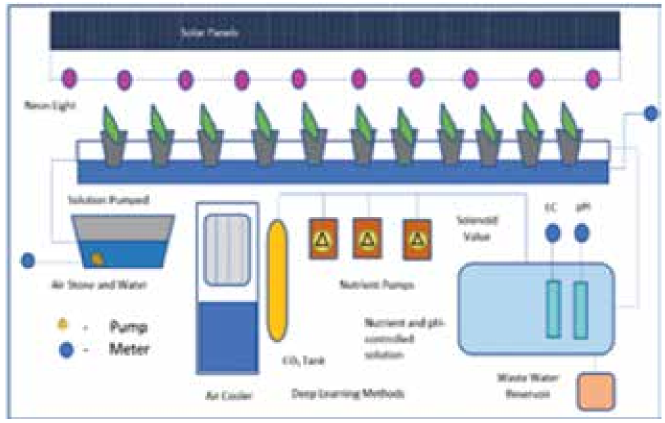

Fig: 1. Model of Hydroponic farming using Deep Neural Networks

Steps involved in the implementation of hydroponic tomatoes using DNNs

1. Fill the reservoir with water double the minimum requirement.
2. Close the reservoirs to avoid algae growth.
3. Use fountain pumps to supply water for the tomato plant channels.
4. Install filters for both inflow and outflow units to discourage clogging
5. Place the individual saplings or the tomato plants in meshed coconut coir net pots containing growing channels
6. Recommended pH, EC, Manure and CO_2 are automatically adjusted from the inputs of the DNN algorithm and this gradually updates when the plants start ripening.
7. Neon lights are used for 18-20 hrs a day this gradually increases when the plants bear fruits.
8. Sap using pollen-covered sticks for flowers to be pollinated.

9. Recording the plant height, leaf count, health and stem width are tracked daily in the cloud system.
10. Pruning takes place for removing the undesirable stems and to keep the tomato plants erect.
11. To bear fruit the plant takes approximately 92-110 days.
12. Each plant's fruit count is monitored and stored in the cloud systems.

Basic metrics for each component such as pH, EC (electrical conductivity) (Zekki *et al,* 2019), Humidity and Temperature are given in table 1. Air showers are released with the help of air cooler to maintain the moisture in the controlled environment. This is tunned by the outer climatic conditions. Air stone in the proposed model in figure 1 helps to prevent from forming algae. It's important to properly set up the soil for plant growth (Max, 2019).

Soil to grow tomatoes should be at least a foot deep, rich in organic matter, and slightly acidic in pH. If pH is not ideal, it can be altered using various additives, including Advanced Nutrients pH Up or Down using DNN inputs. Maintaining a proper pH is essential for plant health. The pH of root zone media greatly affects the way plants can intake nutrients, which of course greatly affects growth.

Among the dataset of 88 plants for the experiment, the following is the table 3 representing the metrics of a tomato plant chosen randomly. 6th plant statistics are given as a reference sample metrics from the cloud monitoring units. This data is taken from the plantation of seedlings to a plant starts bearing the fruits, this has taken approximately 15-18 weeks of complete growth.

Tomatoes can be cultivated using bush (determinate) or Vining (indeterminate) techniques. For the current proposed model, we applied vining technique that use8 rows of PVC tubing systems.

Table 1. Component requirements for tomato plants.

Components	Metrics
pH	2.0-5.0
EC	5.5-6.5
Temperature (DAY)	12-18C
Temperature (NIGHT)	15-20C
Air Showers	12-15C

In each row 11 tomato plants were kept in net pots. Vining varieties were preferable used by most growers since the plants can be pruned using a lean-and-lower system. This makes plants more accessible and much faster to harvest. For growing media, we are using coconut coir and perlite. Minerals such as nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur are mixed in the nutrient solution for the quality crop(Neocleous *et al,* 2016).

Potassium reduces the plant stress from abnormalities and Sulphur deprives the nutrients of water. Common deficiencies for tomato plants are phosphorus (which shows up as stunted/slow growth and necrotic spots) and magnesium (which appears as interveinal chlorosis then necrosis around the edges of the leaf and puckering of leaf surfaces) (Cho *et al,* 2017). Required measurements of the minerals are given in table 2.

Table 2. Minerals requirement for tomato plant.

Minerals	Limit range(%)
Nitrogen	20-25
Phosphorous	21-27
Potassium	19-27
Calcium	19-25
Magnesium	21-27
Sulphur	13-22

RESULTS AND DISCUSSION

Various components are required for the adequate growth of a plant. EC, pH, temperature and humidity parameters are tuned according to the computational metrics from DNNs. Calculated measurement ratios are listed for about 110 days on plant 6 in figure 2.

Figure 3 illustrates the nutrient component mix ratios for plant growth. This component nitrogen, phosphorus, potassium are given for 110 days whereas calcium, sulphur, and magnesium are given for the initial 90 days.

Deep Neural networks were used to determine the optimal crop yield by tuning the EC and pH values at various stages. The weight values from DNN training were used as input for next hidden layers to predict the optimum harvest.

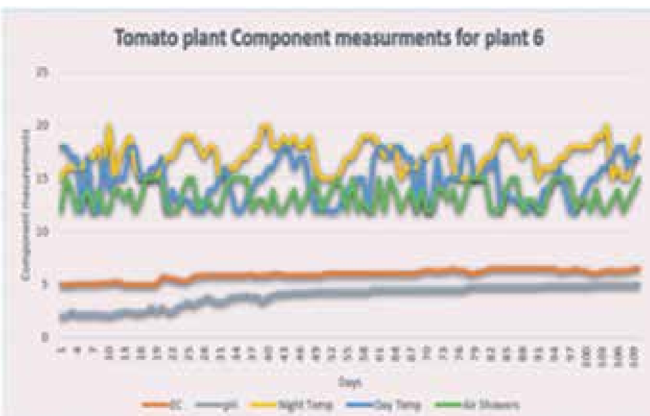

Fig. 2: Component ratios for the plant growth

Weights for the nutrient mix and component ratios are computed by using the following activation function notation for various hidden layers in Deep Neural Networks. Overall sum for k neurons is represented as for j^{th} neuron and l^{th} layer. W represents the weight and b represents the baises.

In figure 4 average deviations are computed by considering four parameters plant height, stem size, leaf count and fruits ripen. Plant height was gradually increasing, Stem size was deviating from the average as shown by the error bars. Leaf count was growing with respect to the plant height between week 10 to week 17. Initially from week 3 to week 10 there was no progress in fruits ripen. In later weeks there was an increase of fruits grown from week 11 to 17.

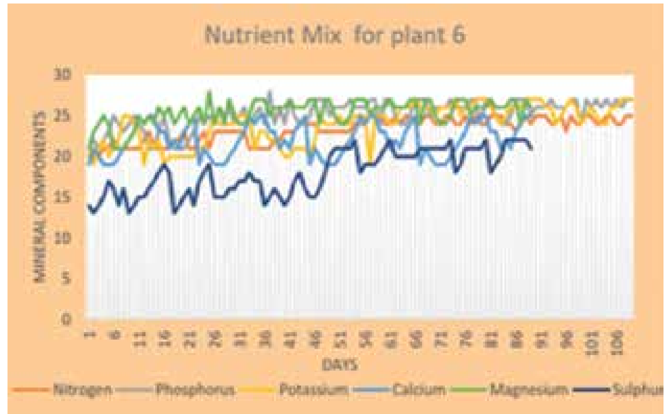

Fig. 3: Nutrient mix on various days for plant yield

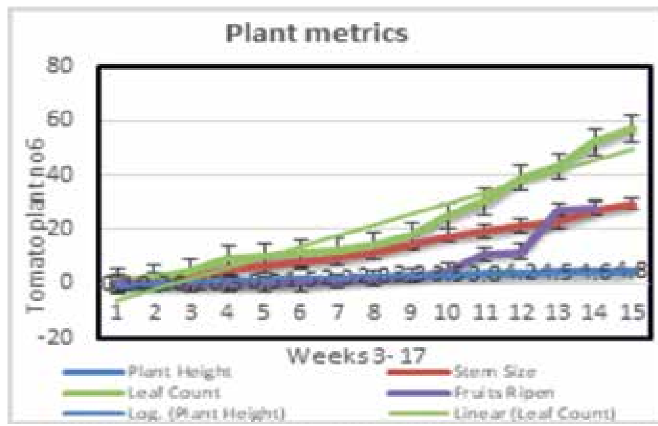

Fig. 4: Error bars show the linear deviations from the average of plant height and leaf count

88 tomato plants for 17 weeks were supervised under a controlled environment using hydroponics. DNNs method provided the necessary reliable metrics for the consequent days component requirements. From the experiment conducted the plants were cultivated with minimal power, water, and nutrient resources. Figure 5 represents the spike lines of plants 6, 21, 33, 45, 61, 70 and 85. Graphs signify the highest and lowest point with respect to parameters considered. Column graphs 13, 26, 37, 56, 65, 76 and 88 indicate the quality of the crop yield from week 1 to week 17.

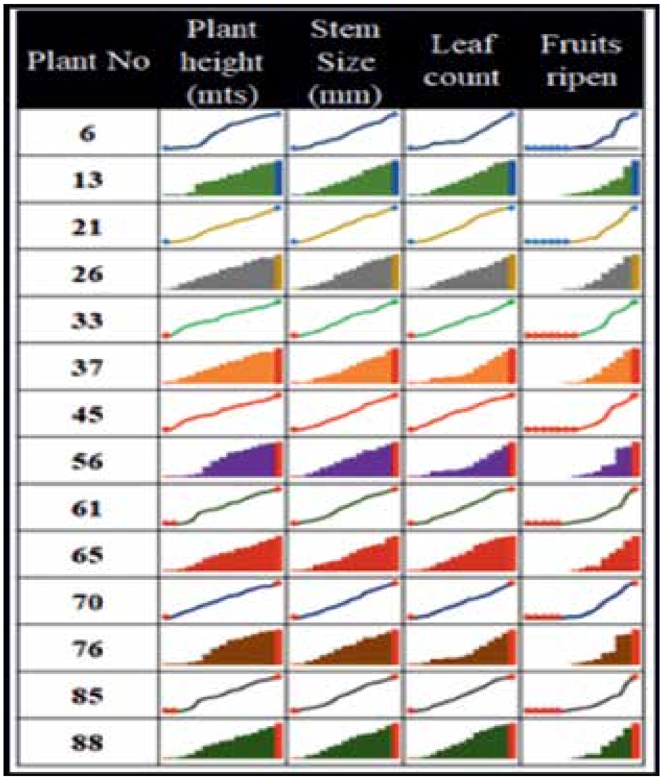

Fig. 5: Spike lines and columns for various plants under observation

Cherry tomatoes' average production in a short period of 15-16 weeks was 3.68 kg for a plantas specified in table 3. The good yield in figure 8 was influenced due to various parameters such as nutrient film technique, higher levels of moisture in the substrates, uninterrupted supply of nutrients, irrigation frequency and hydraulic conductivity. EC values were adjusted to an increase of 40% from the regularity at root level for obtaining higher yield.

This purely depends on the cultivation parameters and previous computations from DNNs. Transit of assimilated and nutrient absorption can be hindered at the root level due to salinity; this reduces the leaf area development. Intake of nutrients, water and competing for minerals will gradually increase after 58 days of plantations. So, certainly different treatments are maintained for different permutations of climatic environments.

CONCLUSION

The indeterminant hydroponic technique for cultivating tomatoes resulted in high-quality crop yield and huge production. Application of DeepNeural Networks in the model delivers accurate EC and NS values to a greater extent. As EC level at roots will increase the crop yield production.

The targeted management saves water and nutrients for improving the quality of the tomato berries. Using the vining hydroponic system resulted in the excessive saving of water, eco-

Table 3. Plant no: 6 Statistics about plant height, Stem size, leaf count and fruits ripen.

Weeks	Plant height (mts)	Stem Size (mm)	Leaf count	Fruits ripen	Weeks	Plant height (mts)	Stem Size (mm)	Leaf count	Fruits ripen
Week 1	0.0	0	0	0	Week 10	2.8	11.8	14	2
Week 2	0.0	0	0	0	Week 11	3.3	14.9	18	3
Week 3	0.1	1.1	1	0	Week 12	3.5	17.8	25	5
Week 4	0.2	1.5	2	0	Week 13	3.8	19.4	30	11
Week 5	0.2	2.4	4	0	Week 14	4.2	21.5	39	12
Week 6	0.3	5.8	9	0	Week 15	4.5	22.8	43	27
Week 7	0.5	6.9	10	0	Week 16	4.6	27.4	52	28
Week 8	1.5	8.2	11	0	Week 17	4.8	29.4	57	32
Week 9	2.3	9.5	12	1					

friendly cultivation, lower economic investments, and triplicated harvest. Appropriate nutrient supply for tomato plants consequences a maximum growth in the crop yield for about 27%. With this proposed model harvest was doubled with high quality. This plants require high nitrogen, low phosphorus, minimal potassium, and frequent feedings during the initial six weeks.

Deep Neural Networks provides weights for various parameters by fine-tuning the component requirements. Specialized additives give plants key growth and high yield. If the yield is increased it can be further exported by maintaining foreign reserves. This farming increases the quality and per capita of the product.

This technique can be applied to various other veggies and fruits. Tuning certain parameters will result in a high-quality harvest. The tuning of the parameters varies upon the type of leafy vegetables or fruits like strawberries under farming.

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