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Hydroponic Farming: A Modern Way of Addressing Production Constraints of Tomato Farming

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Abstract

Tomato is one of the highly patronized vegetable crops of choice in Nigeria. It is used for cooking in various recipes. Given the year-round demand for tomatoes, growing them may be a profitable venture that creates jobs. Over the years, the primary factors limiting tomato production have been variable rainfall, elevated temperatures, infestation of pests and diseases, low soil fertility, labor scarcity, and supply seasonality. This research innovation is aimed at developing ebb and flow hydroponic system that can overcome production constraints that limit the potential profit margins associated with tomato farming. Hydroponic farming is the industry term of growing plants without soil in nutrient solutions. Vermiculite, sawdust, coconut coir, perlite, and rockwool are among the artificial media that are frequently used for plant support. Tomatoes are first cultivated in nursery trays before they are moved into the selected hydroponic system (ebb and flow). In milligrams per liter (mg/L) or parts per million (ppm), the concentration of nutrients is changed at different stages of growth. The statistical model employed to comprehend the link between the two assessment variables—the response variable x (EC/pH) and the predictor y (days after transplanting), was linear regression. There is a 95% confidence level that there is a linear relationship between the EC/pH of the nutrient solution and the number of days after tomato transplanting because the significance F and p values are less than 0.05. For electrical conductivity (EC), the model equation from the assessment study is $y = 0.025\,x + 2.0 \pm 0.795$*, and for the pH of the nutrient solution, it is* $y = 0.019\,x + 5.17 \pm 0.175$*. The machine was developed at a reasonable cost of ₦ 212,200, or $141.47. Tomatoes grown in hydroponic systems have an average yield potential of 4.5 kg to 18 kg per stand, which is four times higher than that of conventional farming. Promoting hydroponic tomato farming technology nationwide will boost farmers' income potential, create job opportunities, and boost the local economy in the areas where it is used.*

Keywords: *Hydroponic farming, ebb and flow, growing media, support structure, yield*

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Introduction

An essential member of the Solanaceae family is tomato (Lycopersicon esculentum). This crop is grown for aesthetic and culinary purposes in urban settings as part of food-scaping systems and aquaponics. Tomatoes are grown in greenhouses and on open fields. Increasing the yield potential of tomato farming through emerging innovative approaches is a crucial part of ensuring food security (Gatahi, 2020).

The world is facing a food insecurity problem due to shortage of workforce, conflict, economic shocks, climate extremities, soaring fertilizer prices and a growing world population. The global food crisis has been partially made worse by the growing number of food trade restrictions put in place by countries with the goal of increasing domestic supply and reducing prices. Recently, twenty countries have implemented 27 food export bans, and 10 have implemented 14 export-limiting measures (World Bank, 2023).

The World Food Programme (WFP, 2023) projects that there will be more than 345 million people who will experience severe food insecurity - this assertion was based on data from 79 of the countries where the program is operated. Unmet basic needs of people have heightened the risk of hunger and malnutrition. Unless the necessary resources are made available, loss of lives and reversal of hard-earned development gains **a**re the prices to pay in the near future (WFP, 2023).

Addressing concerns about global food security is a pressing issue in today's world, and hydroponic farming could provide a potential solution. With the projected global population reaching 9.7 billion by 2050, traditional agriculture alone may not be sufficient to meet the growing demand for food. Hydroponics offers the opportunity to grow crops in areas with limited arable land, enabling vertical farming and increasing yield per square feet. Moreover, the controlled environment of hydroponic systems allows for year-round cultivation and eliminates reliance on specific climatic conditions.

The advantage hydroponic farming has over conventional farming methods cannot be over-emphasized - it demonstrates resilience to climate change and extreme weather events. As severe droughts, floods, and temperature fluctuations become more frequent, traditional farming faces greater risks and uncertainties (Karanisa et al., 2021). Hydroponics, being less reliant on external factors, offers a controlled and stable environment that mitigates the impact of climate-related challenges on crop development, securing food production even in adverse conditions (Steenkamp et al., 2021). Hydroponic farming is an essential and revolutionary practice that offers efficiency, sustainability, resource conservation, high crop yields, food security, climate resilience, and adaptability to urban environments.

Moreover, hydroponic farming exhibits great potential for urban agriculture. With the global trend of urbanization, open land availability for traditional farming is diminishing. Hydroponics offers a solution for growing food in urban environments by converting unused spaces, rooftops, and vertical structures into productive farming areas (Wallis, 2023). This distinctive farming method decreases transportation expenses, guaranteeing that fresh fruits and vegetables are easily accessible to city dwellers, thereby improving access to food (Kumari, 2021).

Hydroponic farming also offers a unique advantage in achieving higher crop yields (Vyshnavi et. al, 2023). By closely monitoring and managing nutrient levels and environmental conditions, hydroponic systems create optimal growing conditions for plants. This precise approach eliminates the challenges of unpredictable weather and soil variability, resulting in consistently high-quality crops year-round (Shaker *et. al*, 2023). This increased yield potential can help address food scarcity and ensure food security for growing populations.

Hydroponic farming is more sustainable than traditional agriculture due to its reduced water usage, nutrient runoff prevention, and conservation of land and energy. It requires up to 90% less water compared to conventional farming by recycling and reusing water (BRIO, 2023). This practice also minimizes water pollution and decreases the need for synthetic fertilizers.

Despite the various advantages of hydroponic farming, it is crucial to acknowledge its limitations. Certain crops are more suitable for hydroponics, including leafy greens, tomatoes, herbs, and strawberries, which have shown great success. However, large-rooted plants like trees may face difficulties thriving in hydroponic systems due to limited space and stability. Therefore, careful consideration of crop selection is necessary when opting for hydroponics. In a nutshell, hydroponic farming is a promising and contemporary agricultural method with significant potential for sustainable food production.

This technical brief is in essence geared towards developing a hydroponic system and as well detailing step by step approach to growing tomatoes hydroponically so as to address production constraints limiting the profit potentials of tomato farming.

Materials and Method

Design Consideration

Some relevant factors were considered in the design and construction of the hydroponic system for tomato farming. They include the type of hydroponic system, capacity, water distribution mechanism, efficiency, effectiveness, safety of use, weather consideration, etc. four inches PVC pipes were used for the construction to prevent corrosion and provide a longer lifespan compared to metal pipes. All these serve to reduce replacement costs. Two-inches square pipes and some metal bars were used as support frames for the entire assembly.

Among other things, efficiency, adaptability, and simplicity of use were given top priority in the hydroponic system design. In order to minimize the possibility of over-supplying some regions and under supplying others with nutrient solution, the design is expected to optimize ebb and flow supply pattern to provide uniform coverage with the help of a submersible pump. The hydroponic system is also expected to have an easy-to-understand and intuitive design that makes it simple for operators to use. Easy-to-use parts and other electronic instruments with little downtime will assist in making maintenance and cleaning straightforward.

Design Philosophy

Using the ebb and flow principle, the machine distributes liquid fertilizer. When the submersible pump is engaged or switched on, the piping is linked to convey water solution to the roots of tomato plants under consideration. The water solution is then conveyed back into a reservoir provided by gravity. This operation continues on and on until the experiment is eventually terminated.

Parts of the Machine

The parts of the ebb and flow hydroponic system include the following: growing tray, submersible pump, timer, nutrient reservoir, overflow tube/drain pipe, growing medium, air pump and air stones, float valve, pH and electrical conductivity meter, growing lights, support frame, castor wheels, PVC pipes, etc.

i. Growing Tray: This is where the plants are placed and supported. It is usually a flat or slopping tray with holes or cups to hold the plants or growing medium.

ii. Submersible Pump: This pump is responsible for pumping water from the nutrient reservoir into the growing tray periodically.

iii. Support Frame: the piping is mounted on a support frame with castor wheels, allowing the entire assembly to be pushed, pulled, or towed behind a vehicle. The design of the frame may vary depending on the intended use and capacity of the hydroponic system.

iv. Timer: A timer is used to control the frequency and duration of the flooding and draining cycles in the system.

v. Nutrient Reservoir: This is a container that holds the nutrient solution, which is a mixture of water and essential nutrients required for plant growth.

vi. Overflow Tube/Drain Pipe: This allows excess water to drain out of the growing tray and back into the nutrient reservoir when the flooding cycle ends.

vii Growing Medium: Ebb and flow systems can use various growing mediums such as clay pebbles, perlite, coco coir, or even Rockwool cubes to provide support to the plant's root system.

viii. Air Pump and Air Stones: oxygenation is crucial for the plant roots in a hydroponic system. An air pump and air stones are used to introduce oxygen into the nutrient solution, ensuring adequate oxygen supply to the plant roots.

ix. Float Valve: a float valve can be included to automatically refill the nutrient reservoir when the water level drops below a certain point.

x. pH and EC (Electrical Conductivity) Meter: These meters are used to monitor and adjust the pH level and nutrient concentration in the nutrient solution, ensuring optimal conditions for plant growth.

xi. Growing Lights: If the ebb and flow system is set up indoors or in a location with insufficient natural light, artificial grow lights may be necessary to provide the plants with the required light spectrum for photosynthesis.

Materials Selection

Table 1 below shows the materials used for the construction of various subcomponents of the hydroponic machine assembly. The dimensions, remarks and the criteria for selection of those components were also presented in the table.

Table 1: Materials Selection

Machine component	Criteria for material selection	Machine selected	Dimension	Remark
Submersible Pump (15 Watt)	Must be strong and able to pump water to overcome gravity barriers	Made of plastic of 5 mm thickness with impeller blade incorporated	Top Section: 70 mm x 60 mm x 5 mm thickness	It does not corrode (bought readymade)
Castor wheel	Ability to bear weight of the machine assembly and as well aid in the mobility of the entire assembly.	Made of Teflon with high load capacity	$\emptyset$ 100 mm 10 mm thickness	Durable (bought readymade)
Piping Frame Work (Ebb & Flow)	Must be strong and able to support plant growth	Made of Poly-Vienne Chloride (PVC) plastic	3290mm long and ɸ 50mm	PVC pipe was bought and constructed based on dimensions provided
Water pipe & hoses	Must be strong and able to allow free flow of water	PVC pipe of ɸ 101.6 mm	101.6 mm 2,438.4 mm long	Bought and constructed to specification
Scaffold	Ability to support water reservoir	Galvanized pipe of $\emptyset$ 26.9 mm and 3.2 mm thickness	1016 mm x 1016 mm x 2,438 mm	Available (constructed)
Support frame for the machine assembly	Must have strong member frame sufficiently long enough to support the wait of the hydroponic structure. It must be able to give allowance for	Square pipe 25 mm x 25 mm x 6 mm	609.6 mm long at every level	Stable (constructed to specification)

	compact movement of the assembly.			
Nutrient reservoir	This is a container that holds the nutrient solution. It must be resistant to corrosion.	Plastic container	Ø1100 mm x 1220 mm height	Bought readymade
Growing Tray/Cup	Must be able to support the growth of transplanted seedlings.	Plastic cup or plastic tray with hollow section at the middle	Uniform sizes cups with Ø 50 mm	Bought readymade
Growing Medium	Must be able to provide support for plant roots.	Sawdust with trace of humus was used as growing medium inside the PVC pipes		Sourced locally

Machine Principle of Operation

One way to grow plants without soil is with an ebb-and-flow hydroponic system. In this method, plants are arranged in a cup-shaped support structure that is filled with sawdust, perlite, or coconut coir as a growing medium. Periodically, the roots of the plants within the support structure are flooded with a solution of water and nutrients. The roots can absorb the water and nutrients necessary for growth during this inundation, sometimes referred to as the "ebb" period. The water returns to the reservoir after the pump stops working after a predetermined period. The roots are kept from becoming waterlogged by this draining, also known as the "flow" phase, which gives them access to oxygen. The cycle of operation continues repeatedly till maturation and harvest date. Figure 1 shows the autographic projection of the hydroponic system.

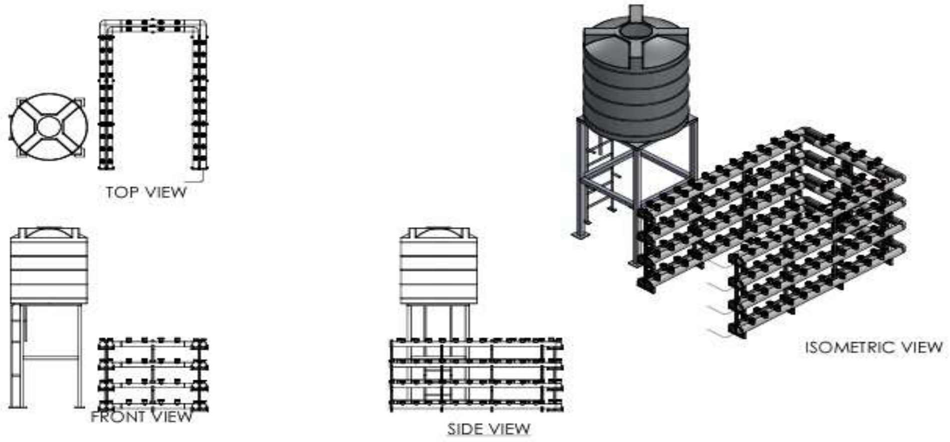

Figure 1: Autographic Projection of the Hydroponic System

Design of the Hydroponic System with Design Calculations

Several criteria, including system size, desired plant density, fertilizer requirements, and desired flood and drain cycle, must be taken into account while designing an ebb-and-flow hydroponic system.

The size of the hydroponic system

More than 120 tomato seedlings can be grown in the hydroponic system. With their corresponding support structures, the assembly contains 120 holes. One line of flow to another is connected by the way the piping was designed. The flow section is accomplished by gravity, while the ebb section is accomplished by a submersible water pump in a nutrient solution. The desired plant density was determined based on number of flood trays and holes designed for the assembly. The plant density was estimated as 200 plant stands. The dimension is 2.44 m by 1.22 m by 2.44 m. The portion of land used is 2.977 m^2.

Nutrient requirements

The nutrient requirements of the plants involve determining the ideal pH level, electrical conductivity (EC) value, and nutrient concentration (ppm). A pH sensor for monitoring the level of acidity or alkalinity was used for the nutrient solution before and after flooding. The values for the pH sensor reading scale range from 4 to 10. The electrical conductivity (EC) of the nutrient solution is of great importance for plant development. It is an indicator of the total concentration of ions in a solution (Nikolov et al, 2023). The reading scale for EC is from 0 to 5.0 mS cm^{-1}. The nutrient solution sensor measures nutrient concentration in part per million.

Flood and drain requirements

The flood drain cycle refers to the timing of how often the nutrient solution floods the table and drains back into the reservoir. The frequency depends on the plants' water requirements and their stage of growth. As a starting point, aim for a flood and drain cycle of 3 to 6 times per day, with each flooding lasting around 15 to 30 minutes is required for the hydroponic system.

Pump flow rate estimation

The flow rate is the amount of water that should be pumped into the flood tray during each flood event. The flow rate was calculated by dividing the volume of nutrient solution needed per flood by the desired flood duration. For example, if one needs to flood 50 liters of nutrient solution in 20 minute, the flow rate should be around 50 liter / 20 minutes or 2.5 liters per minutes. The pump that can deliver the estimated flow rate was therefore chosen. Other factors such as pump head difference and power requirements were also considered. The timer was set to activate the pump during flood event and turn it off during the drain event.

Parameters adjustment

Once the system was set up, nutrients solution pH / EC, nutrient concentration (ppm), RH, and temperature levels were monitored for appropriate adjustment where necessary for optimum plant growth.

Materials for Evaluation and Variables Considered

Materials used for evaluation of the ebb and flow hydroponic system are nutrients solution, pump, pH sensor, EC sensor, nutrient concentration sensor, temperature sensor, humidity sensor, sensitive measuring scale, stop watch and recording materials. Variables considered during evaluation are pH, EC and time.

Performance Evaluation

The hydroponic system performance was assessed using both a pH meter and EC sensor at various time rates of flooding, retention and draining. Using a stopwatch, the flooding time and draining time were determined.

Procedure:

- A seedbed of the exact size of the hydroponic equipment system was made
- Seeds of tomato were planted on the seed bed.
- After 3 weeks, the seeds were transplanted into the hydroponic system
- The hydroponic system was partly filled with sawdust in the plastic pipes which helped to hold firm the roots of the tomato seedlings.
- A reservoir was set up to ensure the availability of water through the PVC pipes for the tomato seedlings.
- An air pump was also made available to ensure oxygen was provided in the water for the tomato seedlings.
- The tomato seedlings were placed in disposable cups with holes to hold and direct the growth of the tomato seedlings.
- pH sensor, CE sensor and temperature sensors were periodically used to determine the pH and electro-conductivity of the solution.

Method of Analysis of Results

For the variables under consideration, the alternative hypothesis is H1: $r < 0.5$, and the null hypothesis is Ho: $0.5 \leq r \leq 1$ for the two variable. The statistical model employed to ascertain the correlation between the predictor and the response variable was linear regression. X1 / Xn is the predictor, β1 / β n is the regression coefficient, ε is the model error, Y is the response variable, and βo is the intercept on the y-axis. The nutrient solution pH and EC are variables y, the response variable, while variable X, the predictor, is the time rate of flooding and draining. Microsoft Excel's Analysis Tool-Pak was utilized to examine the correlation between the response variable and the predictor. Equation 1 presents the generic model for linear regression analysis for both bivariate and multivariate data.

$$y = \beta o + \beta 1X1 + \beta nXn \pm \varepsilon \qquad \textbf{(1)}$$

(Zach, 2020, Statology)

Cost Estimation of Broadcaster Fertilizer

Direct costs and indirect costs are the two main categories into which the cost of technical goods, such as the freshly constructed ebb and flow hydroponic equipment, falls (Hasiehurst, 1981). "Direct cost" refers, for example, to the cost of components that are directly involved in the manufacturing of a certain component (labor and material expenses). On the other hand, indirect costs are those that are unintentionally associated with the manufacturing of a certain machine; for instance, overhead expenses are sometimes expressed as a percentage of the direct labor cost (Ajav et al, 2018). To calculate the cost of the newly designed and built hydroponic equipment, the comprehensive factorial estimate approach (Sinnot, 1993) was employed. This is so that it is possible to estimate and dissect each individual component part in depth because the machine has been fully built. Table 2 shows the machine's cost analysis.

Table 2: Bill of Engineering Quantity and Measurement (BEME)

S/N	**Materials**	**Specification**	**Quantity**	**Unit Price (N)**	**Total Amount (N)**
1	Pipe	2″	8	4,500.00	36,000.00
2	Pipe	1″	5	2,200.00	11,000.00
3	Castor Wheel	Ø30 mm	5	12,000.00	60,000.00
4	Angle Iron	5 mm	1	2,5000.00	2,500.00
5	Iron Rod	8 mm thick	1	5,400.00	5,400.00
6	Transportation		1	5,000.00	5,000.00
7	Electrode	Gauge 12	1 Packet	5,000.00	5.000.00
8	Paint	-	-	6,000.00	6,000.00
9	Bolt & Nut	-	-	3,000.00	3,000.00
10	Transport	-	-	7,000.00	7,000.00
11	Miscellaneous	-			12,500.00
12	Pump	10 Watt			15,000.00
	TOTAL				**168,500.00**

i. Materials Cost = ₦ **168,500.00**
ii. Direct Labour Cost: (Cutting , Bending, painting, gumming, pump installation, etc.) = **₦ 10,000.00**
iii. Indirect/Overhead Cost: = 20% of ₦ **168,500.00** = **₦ 33,700.00**

Grand-total = Material cost + Labour cost + Overhead cost **= ₦ 168,500.00+ ₦ 10,000.00 +**

₦ 33,700.00 = ₦ 212,200

At $ 1.00 = ₦ 1500

₦ 212,200 = $ 141.47

Results and Discussion

The condition of the nutrient solution in relation to plant growth was evaluated using an EC probe and a pH meter. Every hour, the two parameters were measured for the batch that was being studied. This helps to check for nutritional deficiencies, pH levels that are unfavorable for plant growth, and EC levels. The findings are displayed in table 3, 4, 5 and 6 below. The duration measured was kept constant for all the parameters measured. The statistical analyses of the results of evaluation are presented in Tables 7 and 8 for electrical conductivity and pH level respectively. The pictures of the machine assembly during nursery and transplanting stage of tomato plants are as shown in Figures 1, 2 and 3.

Nutrients are the main factors that influence a plant's ability to grow and develop. Tomato plants require a lot of fertilizer since they grow in tandem during vegetative and reproductive phases. Controlling the nutrient solution content has a major effect on crop development in soilless cultivation. A low concentration of the nutrient solution will impede the growth and development of the plants due to a lack of nutrients, while a high concentration will interfere with the root's capacity to absorb nutrients and water (Dennis et al, 2015; Sang et al 2018; Xing et al, 2015). The charts for tomato growth days after transplanting, pH of the nutrient solution, electrical conductivity, and tomato production per stand/square meter are displayed in Figures 4, 5, 6, and 7, respectively.

Table 3: Number of Plats per Stand Days after Transplanting

S/N	**Number of leaves per plant**	**Days after Transplanting**
1	6	15
2	10	30
3	16	45
4	21	60
5	25	75

Table 4: Electrical Conductivity Days after Transplanting

S/N	**Electrical Conductivity (** $mScm^{-1}$)	**Days after Transplanting**
1	3.0	7
2	2.9	14
3	2.7	21
4	2.4	28
5	2.0	35
6	1.5	42
7	3.0	49
8	3.5	56
9	4.2	70
10	4.6	75

Table 5: pH Level Days after Transplanting

S/N	pH Level	Days after Transplanting
1	5.5	7
2	5.6	14
3	5.5	21
4	5.7	28
5	5.6	35
6	5.8	42
7	5.9	49
8	6.2	56
9	6.6	70
10	6.8	75

Table 6: Tomato Yield per Stand Randomly Picked

Tomato Yield (Kg)	Numbered Plant Stand Randomly Picked
8.6	10
7.5	16
8.2	25
6.9	40
5.6	41
5.8	60
5.9	85
4.5	95
4.9	87
5.2	116

Table 7: Regression Statistics for Electrical -Conductivity

Regression Statistics	*Electrical Conductivity*

Multiple R	0.603476853
R Square	0.364184312
Adjusted R Square	0.284707351
Standard Error	0.795184696
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2.89745	2.89745	4.5822627	0.064713682
Residual	8	5.05855	0.632319		

Regression Equation Parameters	*Coefficients*	*Standard Error*	*t Stat*	*P-value*
Intercept	2.000531501	0.522106663	3.831653	0.0050062
Days after Transplanting	0.024671751	0.011525505	2.140622	0.0647137

Table 8: Regression Statistics for pH Level

Regression Statistics	pH Level
Multiple R	0.933980953
R Square	0.872320421
Adjusted R Square	0.856360474
Standard Error	0.175779572
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.688812	1.688812	54.65685	7.67055E-05
Residual	8	0.247188	0.030898		

Total	9	1.936

Model Equation Parameters	*Coefficients*	*Standard Error*	*t Stat*	*P-value*
Intercept	5.172221172	0.115414301	44.81439	6.787E-11
Days after Transplanting	0.018835739	0.002547771	7.393027	7.671E-05

Figure 1: The Ebb and Flow Hydroponic Machine Assembly

Figure 2: Transplanting Stage of the Tomato Seedlings from Nursery

Figure 3: Nursery Stage of the Tomato Seedlings at 3 weeks

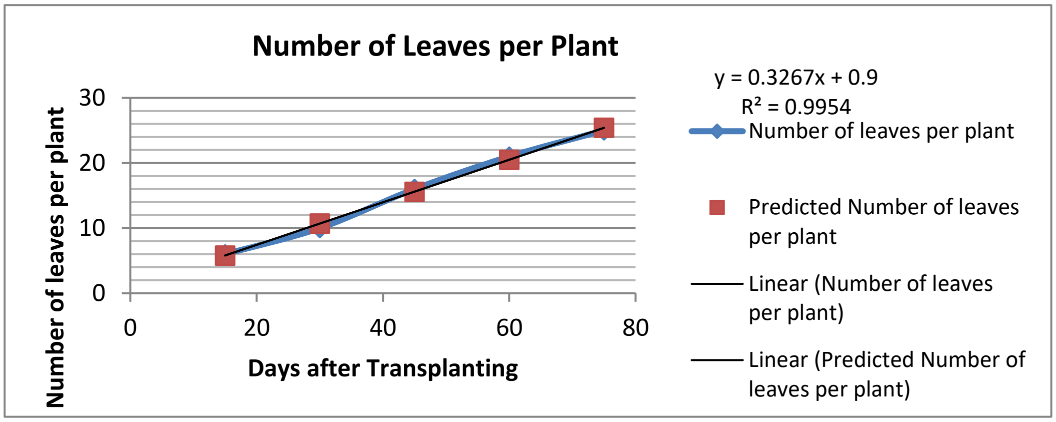

Figure 4: Tomato's growth days after transplanting

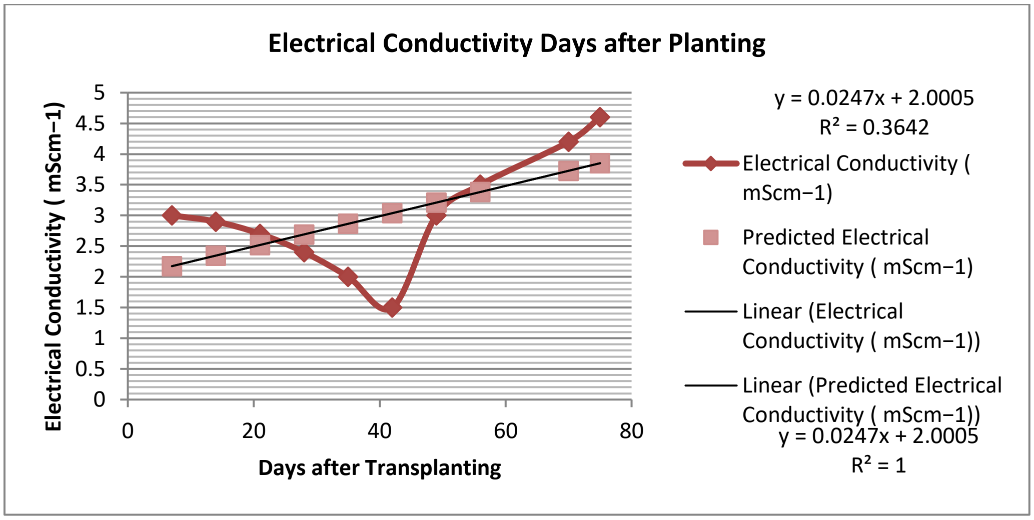

Figure 5: Electrical Conductivity Days after Planting

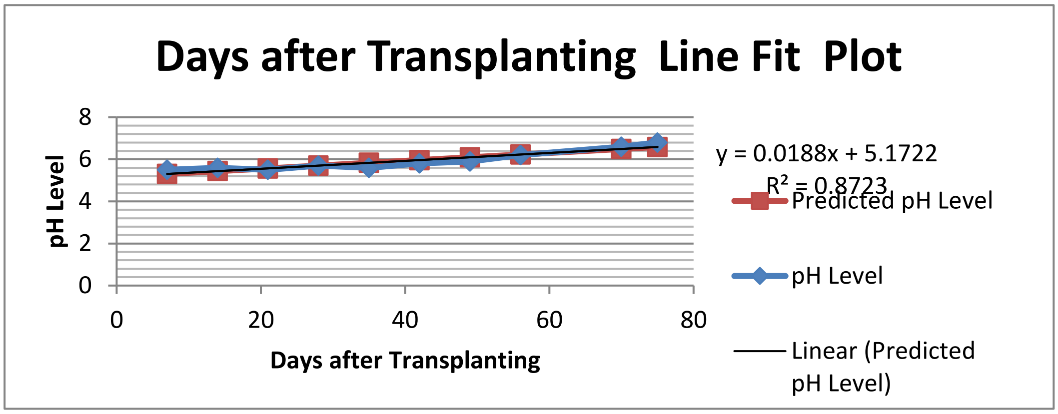

Figure 6: pH Level Days after Planting

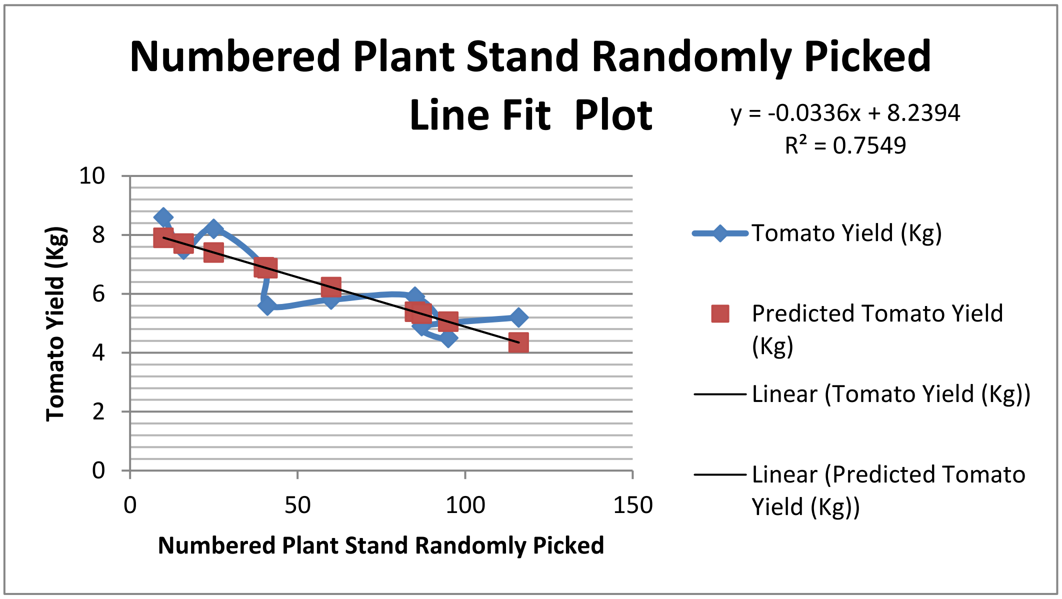

Figure 7: Tomato Yield Randomly Picked

Discussion

Depending on their stage of growth, plants have distinct dietary requirements (Fageria, and Baligar, 2005). Variations in nutrient solution content have been shown to alter both plant development features and fruit quality (Dittakit and Thongket, 2014; Maruyama, et al, 2010). It is anticipated that tomato plants in the seedling and flowering growth phases will grow less when their EC increases from 1.5 ms•cm^{-1} to 3.0 ms•cm^{-1}. During the fruiting stage, the plant's exceptional capacity to assimilate carbon through photosynthesis will be maintained in the nutrient solution at an EC range of 3.0 ms•cm^{-1} to 4.5 ms•cm^{-1}. When tomato fruit is at the harvesting stage, a higher EC will help it form with better quality (Lu and colleagues, 2022).

Figures 5 and 6 display charts that illustrate the link between electrical conductivity (EC) and pH of the nutrient solution and the number of days following transplanting. The graph indicates that up to the sixth or seventh week of transplanting, the pH level was high. The pH level dropped to nearly neutral during the fruiting and maturity stages. This is because if the pH is higher or lower than the advised range, some minerals from the hydroponic nutrition solution won't be absorbed by the plant. In the first five to seven weeks following planting, the pH range between 5.5 and 5.8 is excellent for plant uptake. Every mineral is currently completely accessible. The pH during the final three weeks was observed to be between 6.1 and 6.8.

In contrast to providing a nutrient solution at a consistent concentration of 5.0 ms·cm^{-1} for the duration of tomato growth cycle, a reduction in nutrient solution concentration from 5.0 ms·cm^{-1} to 2.5 ms·cm^{-1} during the seedling and flowering phases successfully encouraged tomato plant growth and improved leaf photosynthetic capacity. The tomato fruit quality and quantity were enhanced by an increase in EC from 3.2 ms·cm^{-1} to 4.9 ms·cm^{-1} during the fruiting or harvesting phase. Moreover, fertilizer productivity can be raised by using this management technique for nutrient solution concentration.

Variable **X_1** in the model is "***days after transplanting***"; βo is intercept on y-axis, ε is the model error and variable **Y** is the nutrient solution pH or electrical conductivity. The results presented in tables 7 and 8 show that 10 observations were used for the model of the predictor and response variable. The coefficient of determination, R square in table 7 (0.872) implies that 87.2 % of ***days after transplanting*** can be explained by the pH/EC. The multiple R-value, 0.993/0.603 reveals there is strong level of correlation or relationship between the explanatory variable (***days after transplanting***) and response variable (pH//EC). It also implies that the null hypothesis defined is within acceptable limit. The standard error, 0.176/0.795 is larger than the coefficient of the predictor (***days after transplanting***) which is 0.019/0.025. On average, the observed value of predictor falls 0.019/0.025 from the regression line.

Tables 7 and 8 also show the analysis of variance (ANOVA) of the regression statistics. From the Tables, it can also be inferred that the number of independent variables in the model is 1 as the regression degree of freedom (df) is 1 while total df is 9. F values in the tables are respectively 0.064 and 7.67055E^{-05}. The Significance F for the two tables are respectively 4.58 and 54.65685. The F-value assists in testing the hypothesis if the slope of the independent variable is zero or not. Since the p-value is below 0.05, it implies there is 95% confidence that the slope of the regression line is **not zero**. Hence, there is a significant linear relationship between ***days after transplanting*** and pH/EC of nutrient solution. For individual p-values in Table 7 or 8, it can be inferred that the predictor is statistically significant – meaning the predictor is applicable for the model. The model equations are respectively $\boldsymbol{y} = 0.025\,\boldsymbol{x} + 2.0 \pm 0.795$ and $\boldsymbol{y} = 0.019\,\boldsymbol{x} + 5.17 \pm 0.175$

Several variables, including the kind of hydroponic system used, the tomato variety planted, the environment, the way nutrients are managed, and the general upkeep of the plants, can affect the production of tomato plants grown hydroponically. Nevertheless, during the growing season, tomato plants cultivated in hydroponic systems can produce anywhere from 4.5 to 18.0 kg per plant on average.

Conclusion

Hydroponic farming is a promising modern agricultural technique that holds immense potential for sustainable food production. It offers benefits such as increased crop yields, water use efficiency, early maturity, etc. Through continued research and development, hydroponics has the potential to greatly enhance global food security, particularly in regions with limited fertile land or difficult weather conditions. The integration of technology and agriculture in hydroponics presents a promising direction for the agricultural industry and inventive solutions to future challenges.

However, the initial outlay for purchasing hydroponic equipment and supplies, such as gutters, pumps, solar panels, batteries, etc., is significantly high. This makes it unattractive to poor farmers in the industry to embrace for adoption. By economy of scale, a group of farmer can team up for the ebb and flow system for commercial hydroponic operations. Seed, fertilizer, and growing media are the only ongoing expenses after the first investment is made. Promoting hydroponic tomato farming technology across the nation will benefit farmers' revenue potential, create job possibilities, and guarantee the economic prosperity of the communities where it is used.

Recommendations

The following recommendations are given about the hydroponic equipment:

i. The equipment can be adopted for use by farmers at all levels to promote high yield at harvest.

ii. More evaluation exercises should be carried out on the hydroponic for process optimization.

iii. More research works should be done to develop other machines/equipment involved in ensuring improved yield of tomato.

iv. It would be beneficial to do additional research to supply a few references for future investigations into adjusting the concentration of nutrient solutions to enhance fertilizer usage rates and fruit quality.

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