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The Effect of Internet of Things Based Drip Fertilization System with Cultivation Model on Harvest Results and Quality of Red Lettuce (*Lactuca sativa* L. var. Crispa)

Eko Noerhayati[1*], Siti Asmaniyah Mardiyani[2], Soraya Norma Mustika[3]

[1] Departement of Civil Engineering, Universitas Islam Malang, Malang, East Java, Indonesia

[2] Departement of Agricultural, Universitas Islam Malang, Malang, East Java, Indonesia

[3] Faculty of Applied Science and Technology, Universitas Negeri Malang, Jalan. Semarang 5 Malang, Malang, Indonesia

* Corresponding author's e-mail: eko.noerhayati@unisma.ac.id

ABSTRACT

Plants on the land quickly wilt and perish due to the extended dry season, severe temperatures, heat, and glaring sunlight. This issue has impacted red lettuce, which has commercial value and high marketing prospects. Providing plants with water and fertilizer during the dry season must be efficient and exact. Excess fertilizer application pollutes the environment. In the dry season, drip irrigation with IoT-based liquid fertilizer distribution is projected to save water and fertilizer due to low discharge and high frequency. The study's goal is to provide effective autonomous distribution of water and fertilizer to red lettuce plants in order to achieve precision environmentally friendly agriculture. A split-plot design with a main plot and subplots was used to structure the research. Each treatment in one replication contained 5 plant samples, for a total of 60 plants in this study, with weekly watering and fertilization. The findings show that an IoT-based automatic water supply and drip fertilization system can precisely regulate the distribution of water and fertilizer to red lettuce plants, thereby improving water efficiency, farmer energy efficiency, and environmental friendliness.

Keywords: drip irrigation, IoT, *Lactuca sativa*.

INTRODUCTION

Plants on land quickly wilt and die as a result of prolonged dry seasons, extreme temperatures, heat, and blazing sunlight (Dietz et al., 2021; Chen et al., 2021). If the soil conditions for plants cannot hold water for an extended period of time, an irrigation system is required to provide water continuously over a long period of time and on a regular basis. Drip irrigation is a method of irrigation that saves water and fertilizer by allowing water to drip slowly to plant roots through the soil surface or directly to the roots, providing water with low discharge and high frequency around plant roots, and maintaining soil moisture levels (Barman et al., 2020). In comparison to manual irrigation, automatic drip irrigation integrated with solar energy to optimize water use has worked well. Ananda et al. (2021) in his Internet of Things-based research on automatic irrigation of ornamental plants. This demonstrates that the automatic irrigation system performed well with small sensor errors and high accuracy. Red lettuce, which has commercial value and good marketing prospects, is one of the plants affected by the dry season (Alkadri et al., 2023). Providing water and fertilizer to plants during the dry season must be efficient and precise. Excessive fertilizer application pollutes the environment, whereas lettuce plants require regular watering and fertilization.

Fertilizing plants adds nutrients to the soil (root fertilizer) and plants (Zhaoxiang et al., 2020; Kizito et al., 2019). The amount of fertilizer given to plants affects the growth of weeds on the land. (Murtilaksono et al., 2022; Akol and Hamed 2023), Synthetic fertilizers and herbicides play an important role in managing nutrients and weeds in food crops, both of which cause serious environmental issues. An integrated nutrient and non-chemical weed management approach can help reduce the chemical load in the environment while maintaining efficiency and yields. Ghosh et al. (2022) stated that using sensors from Internet of Things technology, farmers can monitor soil water levels around plants and temperature conditions to use water more efficiently and effectively. Data will be collected, exchanged, and analyzed in Hryhoriv et al. (2023) to gain valuable information about the relationship between these things (Nalendra & Mujiono, 2020; Namana et al. 2022; Usha Rani and Burthi 2022). However, there is still little discussion about the amount of water, fertilizer, temperature, and soil moisture for IoT-based plants, which impact environmentally friendly agriculture.

The research aims to achieve efficient automatic water and fertilizer distribution to red lettuce plants in order to realize precision environmentally friendly agriculture. Drip irrigation with IoT-based liquid fertilizer distribution is expected to save water and fertilizer with low discharge and high frequency. So that farmers can meet their water needs during the dry season.

Smart irigation system

Smart irrigation is a modern technology design that allows for the practical monitoring and control of irrigation systems. The integrated sensors will send data for monitoring in the irrigation system environment via the internet network, including temperature, humidity, flowing water flow, and water level in irrigation system channels. Smart Irrigation is expected to reduce the amount of time required for humans to monitor and control an irrigation flow system (Sakthivel & Radhakrishnan, 2022; Marline Joys Kumari et al., 2023; Subrahmanyam et al., 2023). The Soil Moisture Sensor works by reading the amount of water content in the soil around it. Although this sensor is low-tech, it is ideal for monitoring plant soil moisture. This sensor works by passing current through two conductors and then reading the resistance value to determine the water content (Zhu et al., 2022). Water flow sensors are used in measurements that produce water discharge and volume values as the water flows through the sensor. (Salam & Salam, 2020). The novelty of this research, analysis enviromental and quality harvest plant Smart irrigation system and water fertilizer system using organic fertilizer for red lettuce (*Lactuca sativa* L. var. Crispa). The hypotheses of this research use of water efficiency and water optimization using IoT makes crop yields better. The impact on the environment is the efficiency of water resources. Apart from that, the use of organic fertilizer keeps the soil from being damaged.

RESEARCH METHODS

Materials preparation

Drip irrigation, 1550 L water tank, embedded system, water solenoid valve, IoT module, outcell PLC, 12 inch and 1 inch PVC pipe, water pump, humidity sensor (Soil Moisture), automatic faucet with modified 2-piece solenoid valve, microcontroller equipment with NodeMCU, and microcontroller connecting cable with AC/DC electricity are the tools used in the design and microcontroller circuit. Meanwhile, laboratory equipment is used for plant analysis. The materials used are red lettuce, plant seeds, and fertilizer.

Plot design

Split plot design consisting of a main plot and subplots. The main plot of the fertilization model consists of two levels, namely:

- P1 – fertilization using conventional tools;
- P2 – fertilization uses microcontroller-based automatic drops and IoT.

Research procedure

Drip irrigation design using a microcontroller

This irrigation design is the result of a case study from previous research with several additional components and additional technology (Noerhayati et al., 2022; Mustika et al., 2022). This drip irrigation design incorporates sensors in each component deemed important to monitor. An ultrasonic tank is installed in the tank to measure the water level. When the water level reaches 90 cm, the pump automatically shuts off. The soil moisture sensor detects moisture in the soil, whereas the automatic faucet uses a solenoid valve. Figure 1 shows a design drawing of an automatic drip irrigation (IoT) model with fertilizer.

Observation parameters

Sensors and the condition of the plants in the field are used to make direct observations. Water and fertilizer volume, soil moisture, temperature, relative growth rate, plant fresh weight, plant economic weight, and plant quality components (total dissolved solids, chlorophyll, vitamin C) are among the parameters used.

Direct observations and measurements on test grounds

Direct observations and measurements on the ground are used to determine the actual value of IoT-based drip irrigation tools in experimental fields. The provision of water and fertilizer is observed 5 times per week, with a dose of 2.5 liters of liquid fertilizer and 50 liters of water per the needs of red lettuce plants, which is 1:20. Soil moisture is measured to determine how much water is in the soil. Humidity measurements were taken before and after watering on seven consecutive days. Moisture testing for manual (P1) and automatic processes (P2).

RESULTS AND DISCUSSION

Soil temperature

Soil temperature is measured using temperature sensors. Planting a temperature sensor in the ground and adding water to the soil yields the temperature value. The temperature value will then appear automatically (Rakuasa et al., 2023). If the previous conditions were dry or the plants required water, the DS18B20 temperature sensor microcontroller will send a signal. The LCD layer and application can be used to monitor it. The sensor value range varies in number (15–40°) based on the sensor data values, indicating the environmental temperature. The higher the sensor reading, the hotter the environmental temperature conditions are, causing the soil to dry out, and the lower the sensor reading value, the cooler the environmental temperature, causing the ground to become damp, as seen quickly on the screen.

Soil moisture

A soil moisture sensor is a sensor for monitoring soil moisture for automatic plant watering. The results of the sensor performance are humidity values in percentage (%) displayed on the LCD or smartphone (Mohamed et al., 2021; Ronny et al., 2021; Sarmphim et al., 2022). The test results are primary data from field observations, which the researcher then processes. Table 1 displays soil moisture data collected during manual treatment, while Table 2 shows the results of monitoring soil moisture with a smartphone app. The sensor value range varies from 0 to 100% based on the sensor data values, indicating soil moisture. The higher the sensor reading, the drier the soil moisture conditions, and the lower the sensor reading, the wetter the soil moisture. Moisture testing for manual (P1) and automatic (P2) processes. Table 3 shows the average humidity results with different watering treatments that do not significantly affect soil moisture conditions.

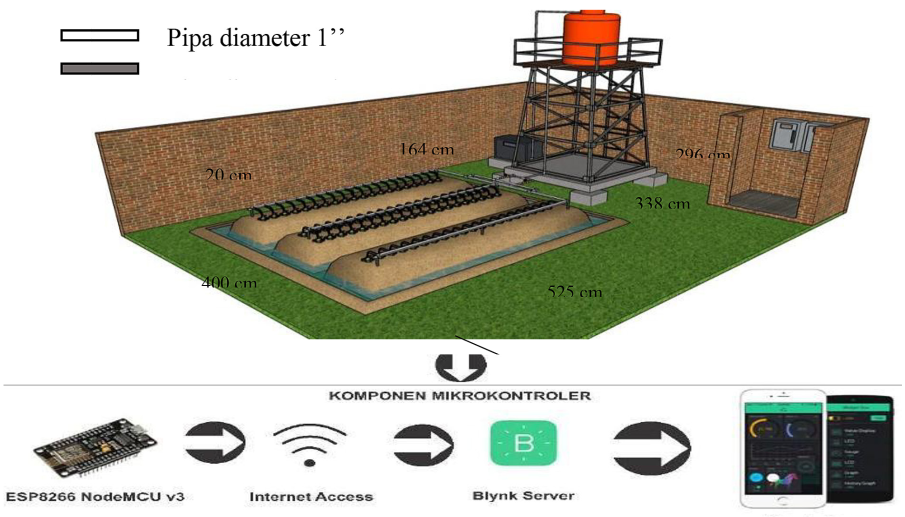

Fig. 1. IoT-based drip irrigation system design

Table 1. Soil moisture in manual treatment P1

Treatment	Day	Humidity (%)		
		Before watering	After watering	At 16.00 WIB
P_1	1	49	96	72
	2	48	95	74
	3	47	95	71
	4	49	97	73
	5	48	94	76
	6	47	94	74
	7	49	95	75
Average		48.14	95.14	73.57

Table 2. Soil moisture in IoT treatment P2

Treatment	Day	Humidity (%)		
		Minimum limit	Maximum limit	At 16.00 WIB
P_2	1	48	95	72
	2			74
	3			71
	4			73
	5			76
	6			74
	7			75
Average		48	95	73.57

Table 3. Average soil moisture

Treatment	Average soil moisture at 16.00 WIB	
	Humidity (%)	Soil conditions
P_1	73.57	Wet
P_2	73.57	Wet

Volume of water and fertilizer

The watering treatment was carried out using two separate methods, namely manual watering and automatic watering, both of which were carried out with the help of an IoT-enabled smartphone. Dripping is used for watering. The panel or smartphone can be used to refill the reservoir. The water flow value per minute and volume value are water flow sensor values that can be presented on the LCD panel (Reddy et al., 2020; Noerhayati et al., 2020). Fertilization is done once a week using both Internet of Things and traditional drip irrigation. Fertilization based on the Internet of Things employs a small water pump linked to a microcontroller, which acts as an automatic faucet to help increase fertilization pressure. Organic fertilization is done in 2.5 liters of water mixed with 50 liters of fertilizer. The results of monitoring the liquid fertilizer discharge to red lettuce using IoT are shown in Table 4.

Yields

Figure 2 depicts the condition of the land after using IoT-based drip irrigation for greater water efficiency. Wild plants (weeds) do not grow around the red lettuce plants, whereas with manual watering, wild plants grow because a large amount of water wets the soil around the plants, resulting in water waste. The rice field environment requires cleaning, which adds to farmer workload.

Observation of relative growth rate (RGR)

The analysis of variance revealed that the fertilization system treatment with the cultivation

Table 4. Results of IoT-based liquid fertilizer discharge monitoring

No.	Time	Week	Discharge (m^3/second)
1	04:30:34 PM	1	0.082
2	04:15:17 PM	2	0.080
3	04:35:45 PM	3	0.089
4	05:00:03 PM	4	0.082
5	04:53:13 PM	5	0.081

Fig. 2. Red lettuce plants with IoT watering and manual watering

model did not have a significantly different interaction effect, whereas the conventional fertilization system treatment and the IOT-based automatic drip system did not have a significant effect separately between treatments. The cultivation model treatment, on the other hand, had a real effect only at the RGR observation age of 20-30 HST. Table 5 shows the average RGR value of *Lactuca sativa* plants. The fertilization system treatment did not have a significantly different effect, the cultivation model treatment at the age of 20-30 HST, the M2 treatment (inorganic cultivation) was the best compared to the organic cultivation model, according to the results of the 5% BNT follow-up test on the RGR observation variable of *Lactuca sativa* plants.

Plant fresh weight

Table 6 shows that the fertilizer system treatment and plant cultivation model have no interaction effect but have a significant effect on the fertilizer system treatment and plant cultivation model. The average fresh weight of *Lactuca sativa* plants can be seen in Table 7.

Table 6 shows that the IOT-based automatic drip fertilization system treatment (P2) is the best treatment, with a fresh plant weight of 1460.83 grams versus 963.83 grams for the conventional equipment system treatment (P1). Meanwhile, in the cultivation model, treatment M2 (inorganic cultivation) outperformed treatment M1 (organic model) by providing a fresh weight of 1837.50 grams.

Economic weight of plants

The analysis of variance revealed that the fertilization system and plant cultivation model had no significant interaction effect on the economic weight of *Lactuca sativa* plants. Meanwhile, there is a real impact on the fertilization system and the plant cultivation model. Table 8

Table 5. Average RGR of *Lactuca sativa* separately on fertilization system treatment and cultivation model

Treatment fertilization	Average relative growth rate of *Lactuca sativa* plant (g/day)	
	10-20 HST	20-30 HST
Conventional	0.023	0.064
Yacht	0.015	0.078
BNT 5%	TN	TN
Organic	0.023	0.014 a
Inorganic	0.015	0.128 b
BNT 5%	TN	0.025

Note: Numbers followed by the same letter in each of the same columns show no real difference based on the 5% BNT test. HST: day after planting. TN – unreal.

Table 6. Results of analysis of various variables of economic weight of *Lactuca sativa* plants

CS	db	JK	Others	F_{hitung}	F_{tabel} 5%
Deuteronomy	2	82686,5	41343.3	0.75	6.94
PU	1	649140	649140	11.72*	7.71
Error	2	110802	55401.1		
AP	1	4024050	4024050	27.69*	7.71
PUxAP	1	247969	247969	1.71	7.71
Error	4	581311	145328		
total	11	5447990			

Note: * real effect.

Table 7. Average fresh weight of red lettuce plants plants separately on fertilization system treatment and cultivation model

Treatment fertilization	Average fresh weight of *Lactuca sativa* plant (grams)
Conventional	963.83 a
Yacht	1460.83 b
BNT 5%	422.32
Organic	587.17 a
Inorganic	1837.50 b
BNT 5%	648.35

Note: numbers followed by the same letter in each of the same columns show no real difference based on the 5% BNT test. HST – day after planting. TN – unreal.

shows the average economic weight of *Lactuca sativa* plants. Based on the results of the 5% BNT follow-up test, the IOT-based automatic drip fertilization system treatment (P2) has a weight of 1355.83 grams, while the conventional tool fertilization system treatment (P1) has a weight of 890.67 grams. Meanwhile, the M2 cultivation model (inorganic cultivation) was the best treatment, with an average value of 1702.33 grams, compared to the M1 cultivation model (organic cultivation), which had an average value of 544.17 grams.

QUALITY COMPONENTS

Chlorophyll

The analysis of variance results revealed that there was no natural interaction effect between the fertilization system treatment and the *Lactuca sativa* cultivation model on the chlorophyll observation variable tested using the SPAD tool separately. There was also no natural effect on the treatment of the conventional fertilization system with the automatic drop IOT system, as well as on the treatment of organic and inorganic cultivation models. Figures 3 and 4 show the average chlorophyll value of red lettuce plants. The plant chlorophyll observation variable has no significant effect, as shown in Figures 3 and 4. The combination of treatments used had no significant effect on plant chlorophyll.

Total dissolved solids (TDS)

The variance analysis results show that the fertilization system treatment with the *Lactuca sativa* L. var. Crispa cultivation model has no significant interaction effect on total dissolved solids. Separately, both the fertilization system treatment and the *Lactuca sativa* cultivation model had a significant impact. Table 9 shows the average TDS of plants. According to Table 8, the IOT-based automatic drip fertilization system treatment (P2) outperforms the conventional system treatment (P1) with an average value of 1.99 °Brix. In comparison to the organic cultivation model treatment, the inorganic cultivation model treatment (M2) performs best, with an average value of 2.35 °Brix.

Table 8. Average economic weight of *Lactuca sativa* plants separately on fertilization system treatment and cultivation model

Treatment fertilization	Average economic weight of *Lactuca sativa* plant (grams)
Conventional	890.67 a
Yacht	1355.83 b
BNT 5%	377.24
Organic	544.17 a
Inorganic	1702.33 b
BNT 5%	610.99

Note: Numbers followed by the same letter in each of the same columns show no real difference based on the 5% BNT test. HST – day after planting. TN – unreal.

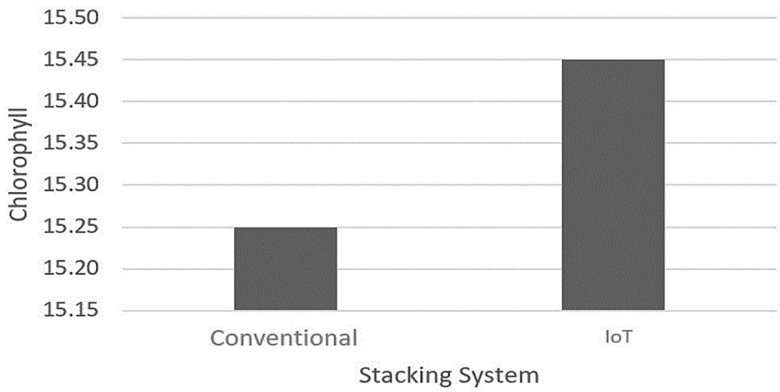

Fig. 3. Average chlorophyll *of Lactuca sativa* in the fertilization system treatment; remarks: TN – unreal

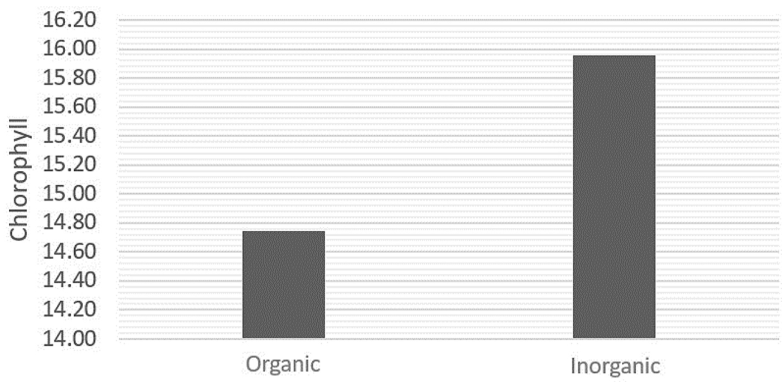

Fig. 4. Average chlorophyll of *Lactuca sativa* in the cultivation model; Remarks: TN – unreal

Table 9. Average TDS *Lactuca sativa* separately in fertilization system treatment and cultivation model

Treatment fertilization	Average total *Lactuca sativa* plant dissolved solids (°Brix)
Conventional	1.53 a
Yacht	1.99 b
BNT 5%	0.26
Organic	1.17 a
Inorganic	2.35 b
BNT 5%	0.86

Note: Numbers followed by the same letter in each of the same columns show no real difference based on the 5% BNT test. HST: day after planting. TN – unreal.

Vitamin C

According to the results of the analysis of variance in Table 10, the fertilization system treatment with the plant cultivation model has no natural interaction effect on the observation variable for vitamin C in red sod plants, nor do the results of separate analysis of each treatment give a natural effect. Figures 5 and 6 show the average vitamin C value of *Lactuca sativa* plants. Figures 5 and 6 show that the treatment had no significant effect on vitamin C in red lettuce plants after being tested by ANOVA at the 5% level.

The effect of IOT-Based conventional and automatic drip fertilization systems with organic and inorganic cultivation models

Separate treatments had a significant effect on the growth of *Lactuca sativa* L. var. Crispa plants, as did several observations on plant yields. Meanwhile, the interaction had no effect on the yield of red lettuce plants. The fertilization system and plant cultivation model are thought to influence the yield of *Lactuca sativa* plants. The fresh weight of plants and roots is the weight of plants and roots immediately following harvest before they wilt and lose water. The fresh weight of plants also refers to the total weight, which reflects the plant's metabolic activity (Hussein et al., 2022). The larger the plant organs that develop, the more water the plant can bind (Zhang et al., 2020). Other parameters, such as plant height, number of leaves, roots, and chlorophyll levels, all influence the increase in fresh weight. Cell division and tissue formation occur at a rate proportional to the growth of stems, leaves, and root systems (Lynch et al., 2021). This is consistent with the findings of this study, which show that in the fertilizer system, treatment P2 is superior to treatment P1, and the inorganic cultivation model (M2) is superior to the results of other parameters related to the fresh weight of *Lactuca sativa* L. var. Crispa plants. Using an IoT-based automatic drip system for fertilization has many advantages over traditional ones because it saves farmers water and time when fertilizing. Aside from that, spending time caring for plants is more effective when controlled by an IoT-based microcontroller device. Meanwhile, inorganic fertilizers can stimulate overall growth, particularly of branches, stems, and leaves, and play an important role in photosynthesis, which produces photosynthate for plants (Sondang et al., 2023). Plant growth and production are influenced by the availability of complete and balanced nutrients that plants can absorb (Vocciante et al., 2022).

A plant's economic weight is the portion of the plant that has economic value and can be consumed by humans. The fresh consumption weight is identical to that of plants, but without the roots to distinguish them. In terms of the economic fresh weight of *Lactuca sativa* L. var. Crispa plants, the IoT-based automatic drip fertilization system outperforms conventional tools. When liquid fertilizer is applied conventionally or manually, it is unmeasured and uneven throughout, hampered plant growth and production (Mukhopadhyay et al., 2021). According to (Grant & Flaten, 2019; Li et al., 2021) stated that it was possible to increase crop yields by improving fertilization system technology.

The relative growth rate of *Lactuca sativa* L. var. Crispa plants in the cultivation model treatment had a significant impact, with the inorganic cultivation model outperforming the organic model. According to Maaya Igarashi (Igarashi et al., 2021), the assumption used in the quantitative equation of relative growth rate is that the increase in plant biomass per unit time is not constant depending on the plant's initial weight. The amount of chlorophyll and vitamin C in the

Table 10. Results of analysis of various variables of Vitamin C in red lettuce plant

CS	db	JK	Others	F_{hitung}	F_{tabel} 5%
Deuteronomy	2	51.6267	25.8133	0.33	6.94
PU	1	0.0075	0.0075	0.000097	7.71
Error	2	154.88	77.44		
AP	1	102.667	102.667	2.00	7.71
PUxAP	1	0.00083	0.00083	0.000016	7.71
Error	4	205.348	51.3369		
Total	11	514.529			

Note: * real effect.

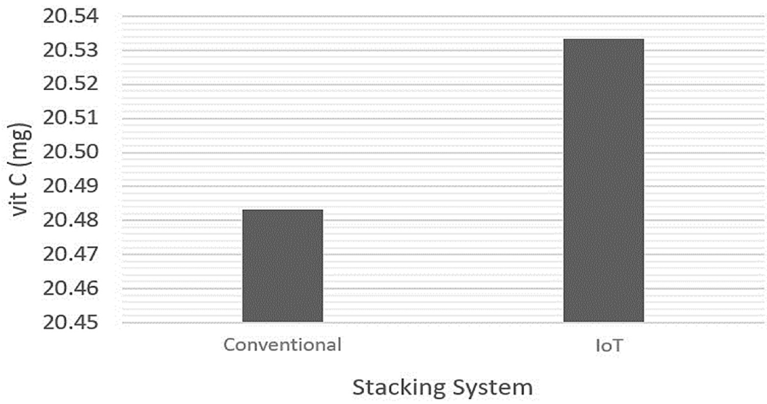

Fig. 5. Average vitamin C for *Lactuca sativa* in fertilization system treatments and cultivation models; remarks: TN – unreal

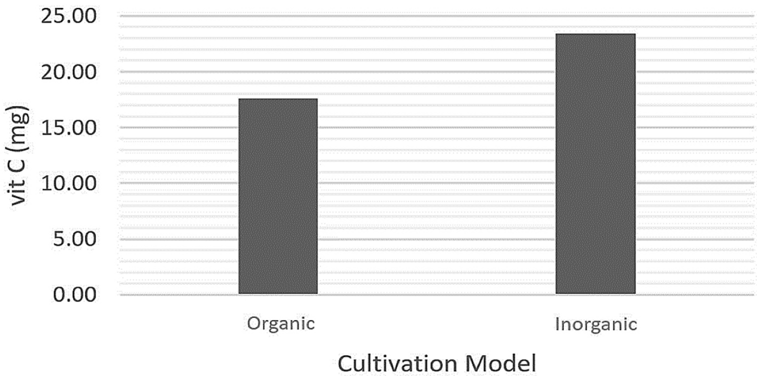

Fig. 6. Average vitamin C for *Lactuca sativa* in the cultivation model; remarks: TN – unreal

Lactuca sativa plants' yield had no effect on the fertilizer system or cultivation model (Turan et al., 2022). It is believed that none of the treatments used had a significant impact on the plant's chlorophyll and vitamin C content. Light, carbohydrates, water, temperature, genetic factors, and nutrients such as N, Mg, Fe, Mn, Cu, Zn, and S all have an impact on chlorophyll synthesis (Latifa et al., 2019). Temperature, salt and sugar concentration, pH, oxygen, enzymes, catalysts, metals, initial concentration, and the ratio of ascorbic acid and dehydroascorbic acid concentrations are all factors that influence vitamin C content in food (Sondang et al., 2023). Total dissolved solids (TDS) is the concentration of water-soluble materials such as glucose, sucrose, fructose, and peptin (Utami et al., 2023). A refractometer is one tool for measuring TDS. The treatment of the IoT-based automatic drip fertilization system (P2) and the inorganic cultivation model (M2) had a more significant influence on the TDS results of *Lactuca sativa* plants in this study's TDS results. TDS results are related to plant photosynthesis results because they are related to the carbohydrate content of the plant. Nitrogen and phosphorus nutrients for plants can increase seed development and metabolic processes, thereby increasing total dissolved solids in seeds (Dixit, 2020).

CONCLUSIONS

Sensors for moisture. Discharge and temperature sensors can read soil moisture, temperature, water discharge, and fertilizer conditions to send commands and execute solenoid valves to open the plant watering irrigation system's tap stop. The observed variables of relative growth rate, total dissolved solids, plant fresh weight, economic weight, fresh weight of plant roots, and land that does not grow clay plants (weeds) are influenced by plant yields. The IoT-based water and fertilizer application system for red lettuce demonstrates an efficient and precise irrigation system in terms of the amount of water and fertilizer that is both environmentally friendly and energy efficient for farmers.

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