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Design of Automatic Citrus Fertilizer Irrigation System Based on Photocell Timer

Yusuf Hariandi [1], Dianta Ginting
[1] Master of Mechanical Engineering Program, Faculty of Engineering, Mercu Buana University Jakarta, 11650, Indonesia

E-mail: dianta.ginting@mercubuana.ac.id

Abstract-- *Climate change has a significant impact on citrus growth, which relies on water and nutrients for the development of stems, leaves, flowers, and fruits. To spray citrus to overcome the uncertain climate, a good irrigation system is needed in the citrus garden, with optimization through an irrigation system that will be carried out automatically. The engineering plants, farmers in the Simalungun region, still employ conventional methods, which are time-consuming and weather-dependent. Meanwhile, drip irrigation is widely used for low-pressure irrigation, and implementing modern Internet of Things (IoT)-based irrigation systems is challenging due to limited internet connectivity, a lack of electricity in orchards, and high costs. This study aims to design a photocell timer and PVC valve-based irrigation system that does not require internet connectivity or electricity, utilizing locally available components. The research method involved engineering a system on approximately 1 hectare of citrus orchard land, using a 6.5 HP gasoline engine, a Tanika TWN-22 sprayer pump, a 300-liter tank, 3/4-inch PVC pipes, and a photocell timer device to control each group of plants. The results showed a time efficiency of 89.2%. For a 1-hectare plot, the average conventional spraying time of 8 hours was reduced to 52 minutes. This system is easy to implement, energy and labor-efficient, and provides more even spraying across all citrus plants. In conclusion, given the limited infrastructure, using a photocell timer-based citrus irrigation and fertilization system can be an efficient, practical, and sustainable solution for citrus farmers in the Simalungun district..*

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1. INTRODUCTION

Indonesia is known as an agricultural country, and most of its population works in the agricultural sector, so the majority of this population has a source of income derived from agricultural products. One of them is Simalungun Regency, where most of the population works as farmers. However, the way and pattern of work of farmers in this area still tend to be conventional by pulling the hose when spraying each orange tree and still relying on a rain-fed system that will affect planting and fertilization patterns, so that it will later affect the harvest [1].

Climate has a significant influence on almost all aspects of plant growth, including citrus [2],[3]. As one of the crops produced in the agricultural sector in the Simalungun region, North Sumatra, citrus is a green plant that requires water throughout the year, and sometimes a lack or excess of water can trigger a physiological response that allows the plant to adapt to the overall reduction in water availability [4].

Fruit size and net weight are greatly influenced by water volume. Reduced water volume tends to produce thinner skin than usual, and this may occur due to the lack of water supply that inhibits the growth of fruit skin tissue [5]. Therefore, producing optimal citrus production technology requires involvement between climate aspects, soil management, irrigation techniques, selection of plant variety seeds, and appropriate post-harvest technology on an ongoing basis [6].

Previous research from several journals related to irrigation systems, among others, includes:
Optimization of irrigation and fertigation in smart agriculture involves an internet-based automatic irrigation system, whereby farmers monitor the system via a mobile application and twin digital technology to manage water and fertilizer consumption. The system operates via the internet and

pushes and pulls between the IoT and cloud services. It consists of a piezometer, temperature, soil moisture, and weather sensors [7],[8], [9], [10].

This system has weaknesses because it requires a good internet connection and infrastructure at the plantation site to operate properly. However, in the Simalungun region of North Sumatra, internet coverage is not yet widespread or comprehensive in farmers' plantations. In addition to a reliable internet connection, specialized labor and human resources with expertise in the technology of the system to be operated are required, as this system is internet-based (Internet of Things/IoT), and implementing such technology involves significant costs.

Therefore, in the automated irrigation and fertilization system for orange plantations, the technology to be developed is a system based on the use of sunlight, employing solar-powered timers. To operate it, farmers only need to ensure the availability of water and fertilizer in the mixing tank, which will be sprayed onto the orange trees in groups.

Validation of the FERTI-drip model for the evaluation and simulation of fertigation events in drip irrigation, which uses a method of water reserves entering irrigation pipes and reaching plants through several drippers. This method is used to evaluate drip irrigation fertigation systems that characterize fertilizer distribution and dynamics during irrigation activities. This drip irrigation model predicts fertilizer dosage, application time, and cleaning at the dripper level, thereby improving application efficiency and reducing issues and time management challenges. This drip irrigation system uses a low-pressure irrigation system [11], [12], [13], [14].

This system has a disadvantage in that it can only be used at low pressure. Then, water will continue to flow to the plants.

Therefore, in an automatic fertilization irrigation system for citrus orchards, the technology to be developed can also be used for spraying using a sprayer equipped with a PVC stop valve and supporting technology. It is hoped that this will simplify the maintenance of the citrus orchard fertilization irrigation system, as it is equipped with a photocell timer that can regulate the amount of water and fertilizer applied to each citrus plant. Solar-powered irrigation (SPDI) is a potential solution that can enhance sustainable agricultural productivity [15].

Based on the results of several journals reviewed, there is no irrigation system that uses photocells and PVC stop valves in groups to control the water and fertilizer sprayed onto citrus trees, presenting an opportunity to engineer an automated irrigation and fertilization system for orange trees.

2. METHODOLOGY

The development of an automatic citrus fertilization irrigation system using a photocell timer was carried out at a citrus orchard in the Simalungun area with a land area of approximately 1 ha.

2.1 Innovation of an Automatic Citrus Fertilization Irrigation System Using a Photocell Timer

This paper aims to design an automatic irrigation system that uses a photocell timer and a PVC valve in groups of plants in a citrus orchard with a land area of approximately 1 ha, and in it, there are 230-250 citrus trees. The main objective of this study is to automate irrigation for orange trees rather than relying on conventional spraying methods. In this automated system, a Photocell Timer alternately regulates irrigation flow to different groups of plants, while a PVC Valve automatically stops irrigation to any group that requires maintenance or has sustained damage.

The main components of the designed system are described as follows:
Mixing Tank: The material used is a 3000-liter water tank, which functions to mix water and fertilizer before being pumped into the automatic irrigation system.

a) Pump Drive Engine: The type of engine used to drive the sprayer pump is a 6.5 HP gasoline type.
b) Sprayer Pump: Selection of the Tanika TWN 22 brand sprayer pump, which functions to pump water and fertilizer into the main irrigation system and the group irrigation system.
c) PVC Valve and Photo Cell Timer: These components are found in each group of citrus plants, and after the valve is equipped with a photocell timer in each group of plants, these two combinations of components function to regulate how long water and fertilizer are distributed to each group of plants.
d) Sprayer/Sprinkle: This component functions to spray water and fertilizer onto each citrus tree.

Before presenting the specifications in detail, the main components of the irrigation system are summarized in Table 1, which displays each element and its function in the overall design.

Table 1. Main Components of Irrigation Systems

No	Component	Model / Type	Function
1	Mixing Tank	Water Tank- 3000 Liters	Mix water and fertilizer before being pumped into the automatic irrigation system
2	Pump Drive Engine	Gasoline 6.5 HP	Operate Sprayer Pump
3	Sprayer Pump	Tanika TWN 22	Pump the mixture of water and fertilizer into the main pipeline and plant group pipes.
4	Main Pipeline	PVC 1 Inch	Distribute the mixture of water and fertilizer to the plant group's pipes
5	Control Valve	PVC Ball Valves	Close and open the flow to the plant group if there are repairs or maintenance
6	Automatic Flow Controller	Timer Photocell	Set automatic watering and fertilization times based on the programmed settings on the photocell timer device, which is powered by light intensity
7	Sprayer	Sprayer / Sprinkle	To spray water and fertilizer onto each citrus tree

As shown in Table 1, the system uses locally available components commonly found on the market, with a design that allows for easy assembly and maintenance. The integration of these components enables the irrigation system to operate automatically according to the lighting conditions and time programmed into the photocell timer device, thereby reducing the need for manual labor and cutting operational time. The photocell timer activates the irrigation cycle based on a predetermined duration and light intensity, while the PVC valve controls the flow stoppage for maintenance or damage handling. This system innovation will improve irrigation efficiency and improve the uniformity of fertilizer distribution to all plants. To ensure sustainability and cost efficiency, all system components were sourced from local suppliers in Simalungun, guaranteeing ease of procurement and long-term availability.

Figure 1 shows that development began with clarifying the task, which was to automate the fertilization process that was previously done manually. The next stage was to determine the system specifications, prepare the design, develop the concept, and, in the final stage, produce a detailed design ready for implementation. The focus on improving efficiency and standardizing the fertilization process must be carried out at every stage to ensure cost efficiency and feasibility in the field.

The development of an automatic citrus fertilization irrigation system follows a systematic technical design process. The objective of each stage in this process is to transform the initial problem of manual fertilization into a fully integrated automated solution and to improve operational efficiency and productivity in citrus cultivation.

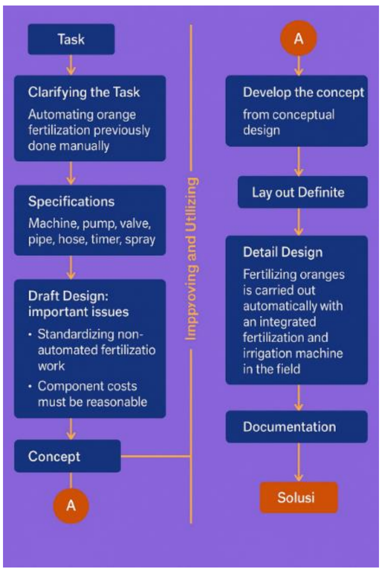

Figure 1: Flow Chart Methodology

The design process consists of several main stages, which are described as follows:

1. Task Identification
   The first stage involves identifying and clarifying the problems to be solved. The task is to automate the manual citrus fertilization process for oranges. The manual fertilization process is time-consuming, uneven, and labor-intensive, depending on the availability of labor. Identify tasks by setting clear system objectives for automation, efficiency, and standardization.
2. Specification Development
   At this stage, the specifications of the irrigation system components are determined, including the type of machine, pump capacity, valves, pipes, timers, and sprinklers/spray nozzles. Each specification is selected based on the availability of tools and existing needs in the field, such as land area (±1 hectare), number of citrus trees (230–250), and the desired flow for optimal fertilizer distribution.
3. Draft Design
   This stage produced a preliminary design to identify key technical issues, such as:
   Standardizing fertilization tasks that were not yet automated and ensuring that component costs remained reasonable and economical for farmers. This initial design became the basis for developing an irrigation system, starting from the layout and conceptual irrigation system, which included the main channel, crop group distribution channels, photocell timers, and PVC ball valves for each crop group.
4. Development of the Concept and Definitive Layout
   At this stage, the conceptual design was refined into a definitive layout to determine the placement of components. This layout is done to ensure efficient distribution of water and fertilizer to each plant group by integrating mixing tanks, pump drives, PVC pipes, and sprayers/sprinklers with a photocell timer control system. It also maintains even water and fertilizer distribution pressure throughout the system.
5. Detailed Design and Implementation
   The detailed design stage focuses on determining the automation method. The photocell timer automatically opens the water flow and activates the system at a predetermined light level or time and duration of operation, enabling scheduled fertilization without manual operation. PVC valves serve to regulate the opening/closing of the flow in case of irrigation repairs or maintenance.
   This integrated design enables a fully automated irrigation process and reduces human intervention.
6. Documentation and Solutions
   The final stage requires documentation of the irrigation system, including technical drawings, a list of components, cost estimates, and operating procedures. These documents serve as guidelines for system assembly, testing, and future maintenance.

The resulting solution for automating the citrus fertilizer irrigation system is practical, efficient, and applicable in the field. The solution involves using a photocell timer and a PVC valve as the main components. This solution ensures the reliability of the irrigation system and facilitates maintenance and repairs. This system can be operated for medium-scale agriculture.

2.2 Study

Conducting a Literature Review to determine the method of agricultural irrigation systems, photocell timers, and PVC valves, including their advantages, costs, efficiency, and effectiveness of operating time, which are then compared with conventional fertilization systems. Sources of information include scientific journals, technical reports, and related articles.

2.3 Comparison of Conventional Fertilization Time with Automatic Irrigation System Design

This time comparison analysis aims to measure the time efficiency between the manual (conventional) method and the proposed automated system.

Table 2 presents the results of fertilization time calculations using the conventional method, where the fertilization process is still carried out manually on each orange tree without the aid of an automated system.

Table 2. Calculation of Conventional Fertilization Time:

Number of Citrus Trees (a)	Spraying Time (b)	Number of Spraying Times (c) = (a) x (b)
230	2 minutes	460 minutes 7 hours and 40 minutes (average 8 Hours)

Table 2 These results indicate that the conventional fertilization method requires approximately eight hours to complete fertilization on 230 orange trees. This condition shows that the manual method is inefficient and time-consuming, especially when done repeatedly or in unfavorable weather conditions. To improve the efficiency of the fertilization process, an automatic irrigation system was designed using a solar-powered photocell timer and PVC valves to regulate the flow. The results of the operational time calculations using this system are presented in Table 3.

Table 3 The data in the table shows the estimated fertilization time using an automatic irrigation system, where the process is centrally controlled by a photocell timer for each group of plants.

Table 3. Fertilization Time Calculation: How to Design an Automatic Irrigation System Using Photocell Timer and PVC Valve in Groups of Plants:

Number of Citrus Trees in One Group	Number of Plants (a)	Spraying Time (b)	Number of Spraying Times (c) = (a) x (b)
9	26	2 minutes	52 minutes

The results show that using an automatic irrigation system per plant group can be completed in 52 minutes, which is a significant reduction in operational time compared to conventional methods.
The comparison results show a very significant increase in time efficiency in the application of an automatic irrigation system. Fertilization time, which originally took about eight hours, can be reduced to less than an hour when done with an automatic irrigation system, which is equivalent to an efficiency increase of 89.2%. This efficiency is mainly due to the integration of a photocell timer, which allows the system to operate automatically in each plant group based on light intensity, which controls consistent flow in each plant group.

In addition to increasing time efficiency, the automated system also plays a role in reducing labor requirements, reducing field workloads, and ensuring even distribution of fertilizer to each plant. This design not only increases productivity but also supports sustainable agricultural practices through optimal resource utilization and photocell timer-based irrigation technology.

2.4 Irrigation Engineering

Conducting irrigation system engineering using a photocell timer and PVC Valve in groups of plants will speed up the fertilization time of citrus trees, because watering of citrus trees is done simultaneously in a group of plants. When carrying out maintenance and repair of fertilization irrigation, the PVC valve also functions to regulate the flow of water into a group of plants, and when there is damage to the irrigation of a group of plants, the PVC valve can be closed without disrupting the main irrigation line and irrigation of other groups of plants.

3. RESULTS AND DISCUSSION

3.1 Objective Tree

Researchers identify the main objectives and several supporting objectives in designing an automatic irrigation and fertilization system that utilizes a photocell timer and PVC valve as control components. These objectives are arranged in the form of an objective tree to illustrate the relationship between the main research objectives and the technical and operational objectives to be achieved. This structure helps researchers determine design priorities and parameters to be tested in the field.

Figure 2 below shows the structure of the relationship between the main objectives, sub-objectives, and technical targets displayed in the form of an objective tree as a visual representation of the system design hierarchy.

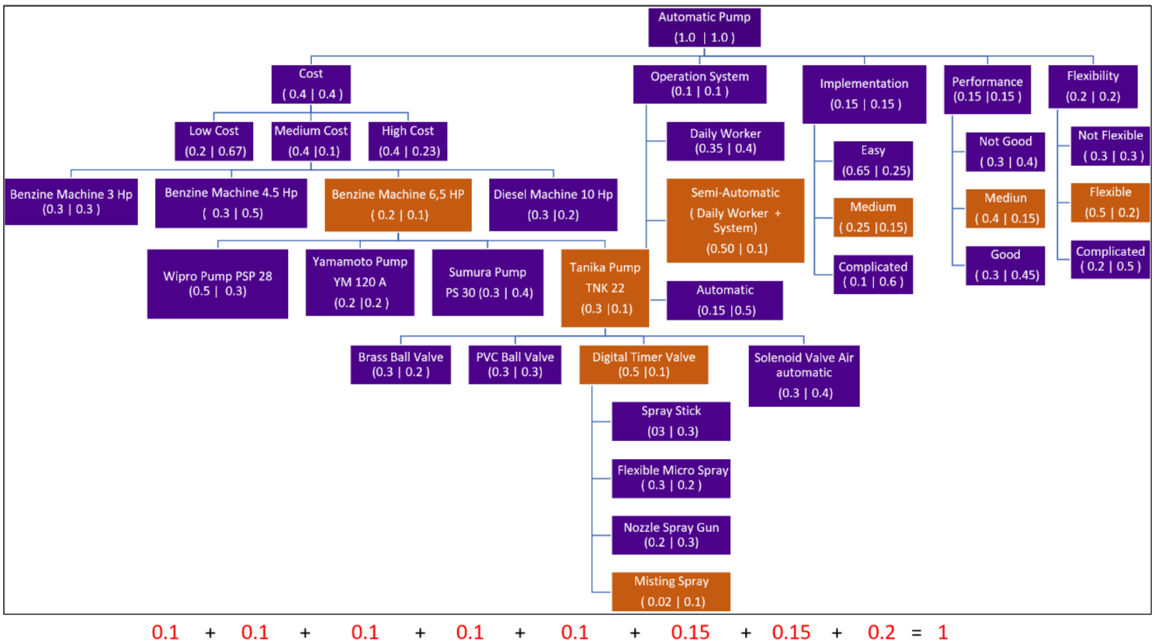

Figure 2: Objective Tree Automatic Citrus Fertilization Irrigation System

The sub-objectives of this research include several important aspects that support the achievement of the main objectives. The first is to improve time efficiency and reduce labor requirements in the fertilization and irrigation processes, so that agricultural activities can be carried out more quickly and effectively. The second is that the designed system is expected to ensure the even distribution of fertilizer and water throughout the crop area, to improve the uniformity of citrus tree growth. The third objective emphasizes the use of locally available components that are readily available on the market, as an effort to reduce production costs and support technological independence at the farmer level. The fourth objective is to design a system that is flexible and easy to operate, so that it can be used by users with varying levels of technical expertise without requiring complex specialized training.

Through the objective tree approach, the system design process becomes more focused, as each component and method is evaluated based on the extent to which it contributes to the achievement of the main research objectives.

3.2 Function Structure

After the system objectives have been determined through the objective tree, the next step is to develop a function structure that represents the process flow and interrelationships between components in the automatic irrigation and fertilization system. This function structure serves to explain the working mechanism of each system element in an integrated manner, so that the overall design is able to achieve optimal efficiency in the irrigation and fertilization processes for citrus plants.

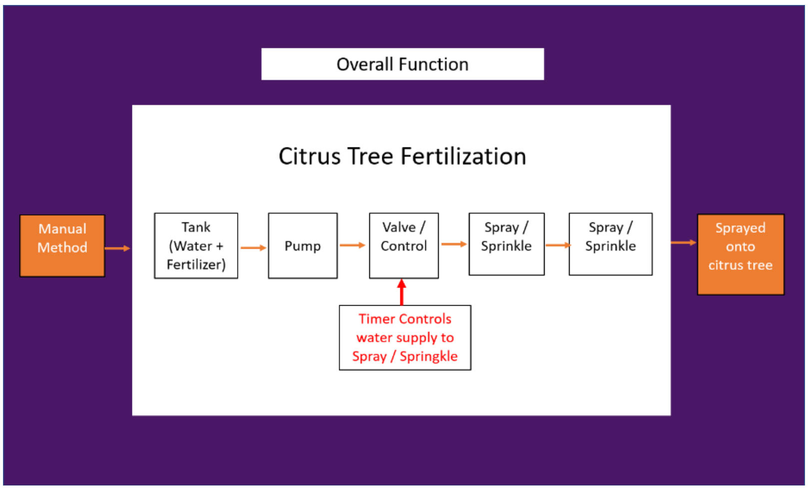

Figure 3: Function Structure of the Automatic Citrus Fertilization Irrigation System

Figure 3 shows the relationship between the components in the system, illustrating the stages of operation from energy input, fertilizer mixing, distribution of the solution throughout the irrigation network, to the final result received by the plants.

The function structure of the automatic citrus fertilization irrigation system is divided into several main integrated functions:

a) The energy input section acts as the main power source, where energy is obtained from a 6.5 HP gasoline engine used to drive the spray pump.
b) The control system uses a photocell timer as the main controller that automatically regulates the system's operating time and energy source based on sunlight intensity.
c) The fluid drive system block utilizes a Tanika TWN-22 pump to distribute the mixture of water and fertilizer from the mixing tank to the main distribution pipe.
d) The distribution system block consists of a network of 3/4-inch PVC pipes that distribute the liquid to each group of plants through PVC valves, where each valve can be controlled separately as needed, such as when repairing or maintaining a group of plants without disturbing the main system and other groups of plants.
e) The system output block plays a role in distributing the results of the control process to the plant area, namely in the form of even distribution of water and fertilizer through a network of pipes and sprinklers.

Through the established functional structure, the interrelationship between the mechanical, control, and distribution subsystems can be fully understood. The presence of a photocell timer as an automatic timer allows the system to operate independently without requiring direct intervention from the operator. With this mechanism, the system will only be active when needed, so that energy and water consumption can be optimized and minimized as much as possible.

3.3 Morphology Chart Irrigation System

Determining the most efficient combination of components in an automatic fertilization irrigation system is done through morphological analysis. This method is used to evaluate and compare various alternative system designs based on predetermined technical parameters. Each main function of the system is identified and developed into several alternative solutions, then the most optimal combination is selected based on criteria of efficiency, ease of maintenance, and availability of materials in the field.

The alternative structure of the design is shown in Table 4, which illustrates the Morphology Chart of the automatic fertilization irrigation system.

Table 4. Morphology Chart Irrigation System :

No	Parameter / Criteria	Option 1	Option 2	Option 3	Option 4
1	Cost Estimate	Low-cost	**Medium cost**	High cost	
2	Choose Type of Machine	Benzine 3 HP	Benzine 4.5 HP	**Benzine 6.5 HP**	Diesel 10 HP
3	Storage Fertilizer	Sump Basin 1000 liters	Tank 1000 liters	**Tank 3000 liters**	Tank 5000 liters
4	How to Operate a System	Daily workers	**Semi-automatic (Daily worker + system)**	Automatic	
5	Implementation on the farm	Easy	**Middle**	Complicated	
6	Working Flexibility	Not flexible	**Flexible**	Complicated	
7	Selecting an alternative fertilizer channel for materials	Hose	**PVC pipe Size 1 inch and 3/4 inch**	Combination hose and PVC pipe	
8	Selecting a pump available in stores in the Simalungun district	Wimpro Pump Power Sprayer PSP-28	Yamamoto Pump YM 120-A	Sumura Pump PS 30	**Tanika Pump TWN-22**
9	Select Valve	Brass ball valve	PVC pipe ball valve	**Digital timer valve**	Selenoid water valve automatic

No	Parameter / Criteria	Option 1	Option 2	Option 3	Option 4
10	Select Sprayer/Sprinkle	Spray stick	Flexible micro sprayer	Nozzle sprayer gun	**Misting sprinkler 1 spray 3 hole**

The morphological analysis results in Table 4 show that each main function of the system was evaluated using several alternative technical designs. The selection of the best combination was made by considering the aspects of system performance efficiency, ease of maintenance, and component availability at the user level.

1. Cost Estimate:
   The low-cost alternative was chosen because it is in line with the research objective of designing an automatic fertilizer irrigation system that is economical and easy for farmers to implement. This approach aims to reduce production costs while increasing technology accessibility without imposing a significant financial burden on users.
2. Type of Machine:
   A 6.5 HP gasoline engine was determined to be the most optimal choice because it has sufficient capacity to operate a high-pressure pump, while remaining fuel efficient. In addition, this type of engine is also lighter and easier to obtain than a 10 HP diesel engine, making it more suitable for medium-scale field applications.
3. Fertilizer Storage:
   A tank with a capacity of 3000 liters was chosen because it was considered optimal for small to medium-sized citrus orchards. This capacity enables sufficient storage of liquid fertilizer without requiring a large space, while also facilitating the filling, cleaning, and routine maintenance processes in the field.
4. How to Operate:
   A semi-automated operating system was determined to be the best alternative because it can function independently without direct operator supervision. The timing of irrigation and fertilization is controlled using a photocell timer, thereby improving time and labor efficiency.
5. Level of Implementation in the Field:
   The middle implementation option is a priority because the system is designed with an emphasis on ease of installation and operation. This is so that the technology can be applied directly by farmers without requiring complex technical skills or special equipment support.
6. Working Flexibility:
   A system with a high degree of flexibility was chosen because it allows for adjustments to various garden layout configurations and varying numbers of plants. This flexibility is important to ensure that the system can be adapted without major modifications to the main installation, thereby increasing efficiency in the field.
7. Fertilizer Channel Material:
   A combination of 1-inch PVC pipes and ¾-inch PVC pipes was chosen as the most efficient solution. This combination provides fluid flow stability, resistance to high operating pressures, and ease of assembly and maintenance. In addition, the material has good resistance to corrosion caused by mixtures of water and liquid fertilizer.
8. Pump Selection:
   The Tanika TWN-22 pump was chosen as the primary option due to its high availability in the local market (Simalungun Regency), relatively economical price, and technical characteristics that meet the system's flow and pressure requirements. The ease of replacement and availability of spare parts were also key considerations in the selection.
9. Valve Type:
   PVC valves were chosen because they offer the advantages of being lightweight, corrosion-resistant, easily available on the market, and highly compatible with water-based and liquid fertilizer systems. In addition, this type of valve has a long service life and does not require intensive maintenance.
10. Sprayer/Sprinkle Type:
   The 1 sprayer and 3-hole misting sprinkler was chosen because it is capable of producing a more even distribution of water and fertilizer, with droplet sizes suitable for watering citrus plants. The 3-hole design provides a wide spray range and supports group planting patterns, thereby significantly increasing the efficiency of liquid distribution.

The selected design combination is considered to provide an optimal balance between energy efficiency, low operating costs, and ease of implementation in the field. In addition, the system is designed to operate automatically using solar energy, thereby supporting the implementation of sustainable and environmentally friendly technology.

3.4 Specific Data for Planning an Automatic Citrus Fertilization Irrigation System

Table 5. Specification Planning Table:

No	Name	Type	Amount	Spesification	Unit Prize (IDR)	Description
1	Land ± 1 Ha	Trees	230	8 years of planting age		Citrus tree
2	Storage Tank	Storage TB 5000 Litres	1 unit	Tank	7,799,000	Big Capacity
		or Storage TB 3000 litres	1 unit	Tank		Medium Capacity
3	Machine	**Benzine 6.5 HP**	1 unit	Benzine	3,799,000	Medium capacity
4	Sprayer Pump	**Tanika TWN 22**	1 unit	Sprayer Pump	750,000	Sprayer is available at the shop and around the farm in the Simalungun district.
5	Valve / Control	**Digital timer valve**	1 unit	Timer valve	499,000	Using a solar cell
6	Sprayer / Sprinkle	**Misting Sprinkle 3 hole**	Pcs	Pcs	6,500	Required 230 x 6 pcs
7	Alternative fertilization channels (Hose/PVC Pipe)	Tanika hose	1 unit	50 meters in length	620,000	Length as required
		PVC Pipe sizes 1 inch and ¾ inch	1 rod	4 meters	26,000	The main pipeline uses 1-inch pipes, and the plant group line uses 3/4-inch pipes
		Pipe and hose combination				Main lines using PVC pipe, and for spraying citrus trees using a hose

3.5 Automatic Orange Fertilization Irrigation System Design Planning

After completing the function structure and component specification stages, the next step is to plan the design of the automatic fertilization irrigation system. The main objective of this stage is to design a system that can automatically regulate water and fertilizer flow based on the timer settings on the photocell device, while maintaining low energy consumption and even distribution across all citrus plants.

This system design was developed based on the results of morphological analysis (morphology chart) and specification planning table, which were combined to produce the most efficient configuration. In the design process, aspects of time efficiency, ease of operation, and availability of components in the local market were also considered so that the system could be implemented practically and sustainably at the farmer level.

This automatic fertilizer irrigation system consists of several main components that work together to support the efficient distribution of water and fertilizer. These components include:

a) Energy source unit, in the form of a 6.5 HP gasoline engine, which functions as the main driver of the high-pressure water pump.

b) A 3000-liter fertilizer mixing tank, which is used to mix water and fertilizer homogeneously before being fed into the distribution system.
c) A Tanika TWN-22 pump, which distributes the mixture of water and fertilizer from the tank to the main pipe network.
d) PVC distribution pipes and valves, which distribute the nutrient solution to each group of plants, with a configuration of 9 trees per group (3×3 formation).
e) A photocell timer-based automatic control system, which detects the intensity of sunlight to automatically regulate the timing of irrigation and fertilization.
f) Dual spray nozzles, which evenly spray the liquid mixture onto the orange trees, thereby improving water and fertilizer absorption efficiency.

All these components are designed to work in sync, resulting in an automated, energy-efficient, and easy-to-operate system tailored to field requirements.

Figure 4 shows the workflow of the automatic fertilization irrigation system, starting from the energy source to the output in the crop area. This diagram illustrates the relationship between the main components, starting from the drive motor and water pump, the fertilizer mixing process in the tank, the distribution of liquid through the PVC pipe and valve network, to the final stage of spraying by the nozzle sprayer onto the orange trees. Through this flow, it can be seen that each component is integrated to ensure that the watering and fertilization processes are automatic, efficient, and controlled according to the system design.

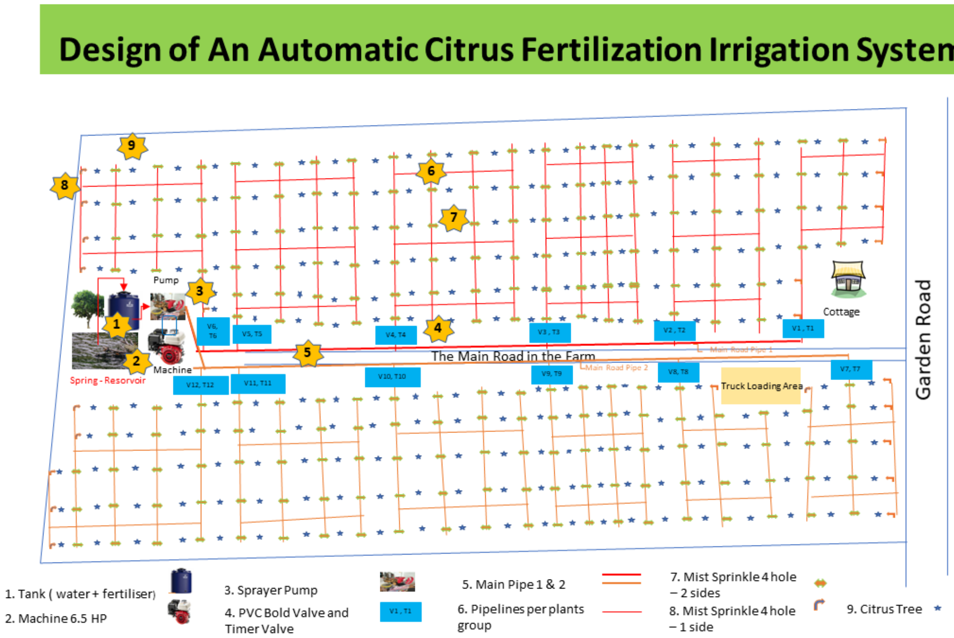

Figure 4: Design of an Automatic Citrus Fertilization Irrigation System

Figure 4 shows that the system starts operating when the photocell timer's operating time matches the scheduled time. Water and fertilizer from the mixing tank will be pumped into the main line through the Tanika TWN-22 pump. Next, the Photocell Timer will open gradually according to the predetermined time setting, so that each group of plants receives an even volume of liquid. After the entire watering and fertilizing process is complete, the photocell timer automatically closes the flow to the orange plant group, marking the end of one cycle of automatic fertilizing irrigation.

After the system design and workflow have been finalized, the next step is to implement the system in the field. This stage aims to directly test the performance of the automatic fertilization irrigation system on citrus plantations under real operational conditions. Through this implementation process, the effectiveness, efficiency, and reliability of the system are evaluated to determine the extent to which the design is able to function optimally in accordance with the research objectives.

The layout of the main components, including the position of the tank, pump, distribution pipe network, and citrus plant group, is visualized in Figure 5. The figure shows the layout of the automatic fertilization irrigation system in the test area, which is designed to ensure that water and fertilizer flow efficiently to all plant groups.

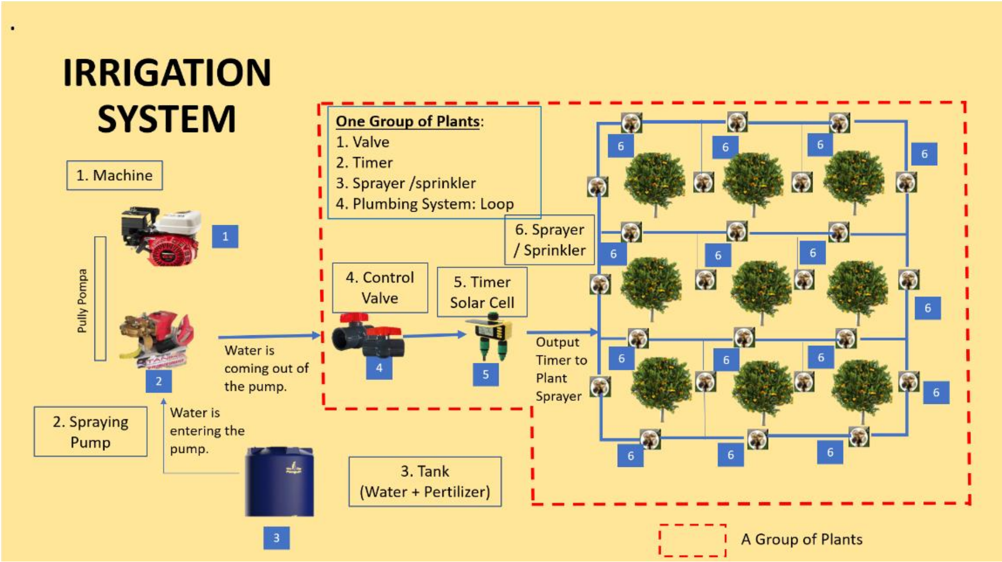

Figure 5: Design for a Group of Plants

Figure 5 shows that the automatic fertilization irrigation system consists of one main tank with a capacity of 3000 liters, one Tanika TWN-22 pump, and a 1-inch diameter PVC for main pipelines that function to distribute the mixture of water and fertilizer to each group of citrus plants. Each group consists of nine orange trees (3×3 formation) and is equipped with one PVC control valve and two double sprayer nozzles that are operated automatically through a photocell timer system. This design allows for the distribution of water and fertilizer to be even, measured, and efficient according to the needs of the plants.

3.6 Analysis of the Efficiency of Automatic Fertilization Irrigation Systems

The experiment was conducted to compare the time efficiency between conventional fertilization systems and automated systems based on photocell timers and PVC valves. The main objective of this experiment was to evaluate the extent to which the implementation of an automated system can accelerate the fertilization process while reducing dependence on manual labor.

In the conventional method, fertilization is done manually by watering each citrus tree one by one. The total time required to complete fertilization on 230 orange trees is approximately 8 hours (480 minutes).

Conversely, the developed photocell timer-based automated system is capable of operating simultaneously on a group of nine trees, with a working time of approximately two minutes for each group. With a total of approximately 26 groups of trees (230/9), the estimated time required to complete the entire fertilization process is:

Time Automatic = 26 x 2 = 52 minutes

Thus, the total time required for the automatic system to fertilize all 230 trees is 52 minutes, which is much shorter than the conventional method.

The time efficiency rate is calculated using the following equation:

$$\text{Efficiency}(\%) = \frac{Conventional\ Time - Automatic\ Time}{Conventional\ Time} \times 100\ \%$$

$$\text{Efficiency}(\%) = \frac{480-52}{480} \times 100\ \% = 89.19\ \%$$

Test results show that the automatic fertilization irrigation system can increase time efficiency by around 89.2% compared to manual fertilization methods.

In addition, with the watering and fertilization processes carried out simultaneously for each group of plants, this system also ensures uniform distribution of fertilizer and water and reduces dependence on human labor.

3.7 Labor Efficiency and Distribution Equity

Automated systems such as those in Table 6 have been proven to reduce labor requirements by more than 70%. With manual methods, 2–3 people are needed to fertilize an entire field. In contrast, with automated systems, only one operator is needed to fill the fertilizer tank and supervise the process.

Table 6. From field observations:

System	Number of Workers Required	Operating Time	Description
Conventional	3 people	8 hours	Manual, watering one by one
Automated	1 person	±52 minutes	Automated system monitoring

Fertilizer distribution using an automated system is also more evenly distributed to citrus plants because the fertilization process is carried out simultaneously in a group of plants using fluid pressure from the Tanika TWN-22 pump and sprayer for each plant.
This condition causes plant growth to be more uniform and minimizes the risk of excess or insufficient fertilizer.
The test results show that the automatic fertilization irrigation system has successfully achieved all the objectives set in this study, namely:
a) Improving the efficiency of implementation time and labor requirements.
b) Ensuring the distribution of water and fertilizer is even.
c) Optimizing energy use to be efficient and independent.
d) Implementing simple automatic control based on a photocell timer.

The findings of this study indicate that an automated system based on photocell timers and PVC valves is an effective solution for citrus farmers in areas with limited infrastructure, such as access to electricity and the internet. This system has been proven to be more energy efficient, time efficient, and easier to implement than IoT-based systems, which require an internet connection and electricity at the farm location, and also require farmers to have special skills in operating IoT system equipment.

4. CONCLUSIONS

The use of an automatic citrus fertilization irrigation system using a photocell timer and PVC stop valve for groups of plants can still be done in areas with limited infrastructure and resources in the area because it uses sunlight to drive the irrigation system automatically.

The citrus fertilization irrigation system for groups of plants can speed up the fertilization process carried out by farmers because fertilization is carried out together in one group of plants.
The photocell timer, as an automatic system regulator, can be set according to the needs of how long the spraying time is for the group of plants.

When carrying out maintenance and repairs in a group of plants, the PVC stop valve can close the irrigation line of that group of plants without disturbing the main irrigation line and the irrigation lines of other groups of plants.

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