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Solar Agri Fertilizer Design and Construction of a Solar-Powered Electric Bicycle with a Dual-Side Precision Fertilization System for Agricultural Land

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ABSTRACT

Fertilization is an important activity in agriculture to meet the nutrient needs of plants. However, fertilization is still commonly carried out manually, which requires considerable time and physical effort. In addition, manual fertilization can result in uneven amounts of fertilizer being applied. Therefore, a tool is needed to make the fertilization process easier and more controlled.This study aims to design SOLAR AGRI FERTILIZER, an electric bicycle equipped with a two-sided fertilization system and a solar panel as an additional energy source. The system uses a BLDC motor as the main drive, a battery as the primary energy source, and a fertilizer tank with a dosing system to control the amount of fertilizer released. Fertilizer from the tank is regulated by the dosing system and then distributed to the right and left sides of the vehicle. The bicycle is designed to move between crop rows so that fertilizer can be applied to both sides simultaneously without the wheels passing over the plants. The position of the fertilizer outlets can also be adjusted according to the distance between crop rows.Testing is conducted to determine the accuracy of fertilizer dosage, uniformity of fertilizer distribution on the right and left sides, energy consumption, working capacity, and the ability of the bicycle to operate on agricultural land. The test results will be used to evaluate the overall performance of the system. SOLAR AGRI FERTILIZER is expected to provide a more practical, controlled, and easy-to-use fertilizer application system to support small-scale agricultural activities.

1. Introduction

Fertilization is an important agricultural activity that provides essential nutrients for plant growth and productivity. However, fertilizer application is still commonly performed manually, requiring considerable time and physical effort. Manual application can also result in uneven fertilizer distribution and inaccurate dosage. Therefore, a practical and controlled fertilizer application system is needed to improve the efficiency of small-scale agricultural activities [1].

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Precision agriculture provides an approach to improving the efficiency of agricultural inputs through more controlled fertilizer application. Nawar et al. [2] reported that variable-rate nutrient application can improve farm efficiency compared with conventional uniform-rate application. More recently, Cai et al. [3] reviewed 51 peer-reviewed studies and reported that precision agriculture technologies can improve nutrient-use efficiency and fertilizer management. However, many precision agriculture technologies are developed for large-scale agricultural applications and may require relatively complex systems.

To address this issue, SOLAR AGRI FERTILIZER is designed as a solar-powered electric bicycle equipped with a dual-side precision fertilization system. The system uses a BLDC motor as the main drive, a battery as the primary energy source, and a solar panel as an additional energy source. Fertilizer from the tank is regulated through a dosing mechanism and distributed to the right and left sides of the bicycle. The fertilizer outlets can be adjusted according to crop-row spacing, allowing fertilizer to be applied to both sides while the bicycle moves between crop rows.

The research gap lies in the development of a relatively simple and mobile fertilizer application system that integrates electric propulsion, supplementary solar energy, controlled fertilizer dosing, and dual-side fertilizer distribution into a single platform. This integration is expected to provide a practical solution for small-scale agricultural activities. Therefore, this study aims to design and develop SOLAR AGRI FERTILIZER and evaluate its performance based on fertilizer dosage accuracy, fertilizer distribution uniformity, energy consumption, working capacity, and the ability of the bicycle to operate on agricultural land.

2. Methodology

2.1 Research Design and System Configuration

This study employs an experimental design approach to develop and evaluate SOLAR AGRI FERTILIZER, a solar-powered electric bicycle equipped with a dual-side precision fertilization system. The system is designed to assist fertilizer application on agricultural land by combining an electric bicycle as the mobility system with a controlled fertilizer dosing mechanism. The main components consist of a BLDC motor, battery, solar panel, MPPT charge controller, motor controller, fertilizer tank, dosing mechanism, and right and left fertilizer outlets. The overall configuration of the SOLAR AGRI FERTILIZER system is shown in Fig. 1.

The energy system begins with the solar panel, which converts solar energy into electrical energy. The generated electrical energy is regulated by the MPPT charge controller and supplied to the battery, which serves as the main energy storage unit. The battery supplies electrical energy to the motor controller and other electrical components. The motor controller regulates the power delivered to the BLDC motor, allowing the bicycle to operate according to the required operating conditions.

The fertilization system consists of a fertilizer tank, a dosing mechanism, and two fertilizer outlets positioned on the right and left sides of the bicycle. Fertilizer from the tank is regulated by the dosing mechanism before being distributed through the two outlets. The outlet positions can be adjusted according to the spacing between crop rows. The working principles of the energy and fertilization systems are illustrated in Fig. 2.

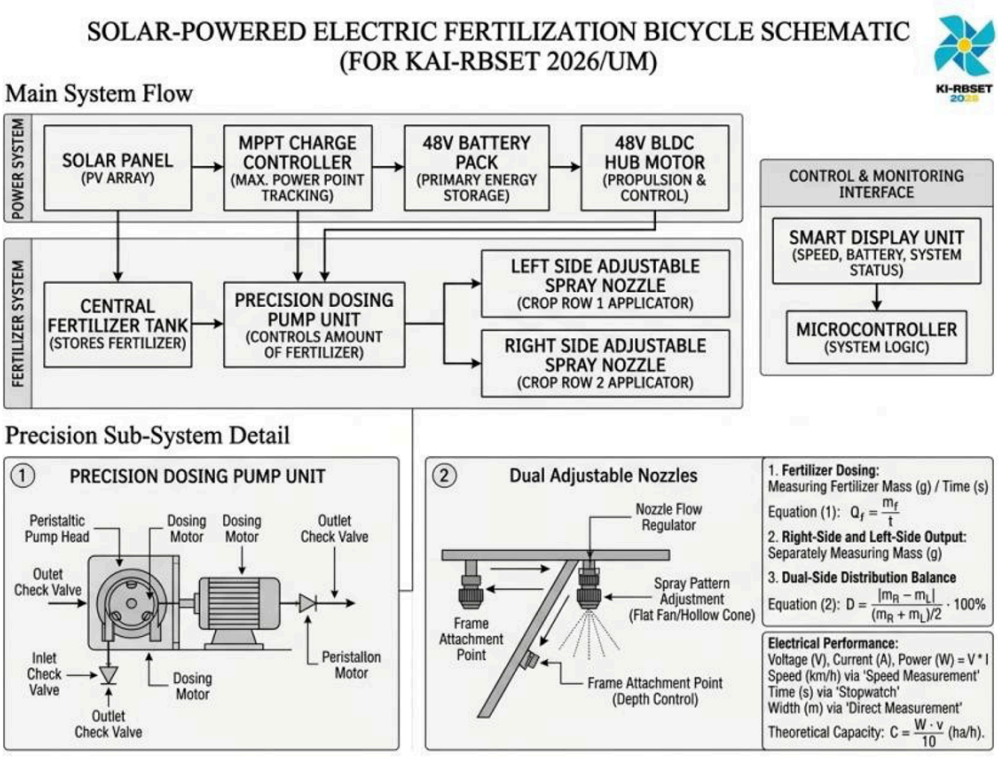


Fig. 1. Overall configuration of the SOLAR AGRI FERTILIZER system

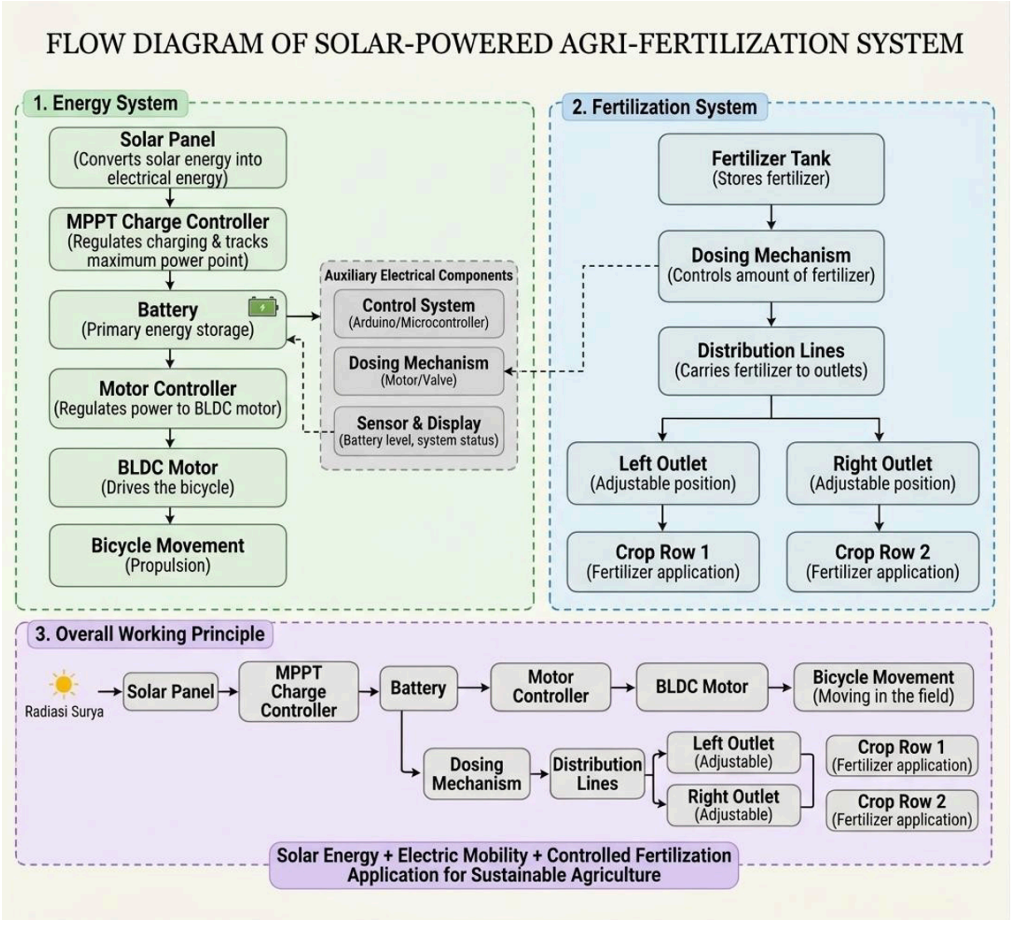


Fig. 2. Working principle of the SOLAR AGRI FERTILIZER system

2.2 Fertilization System

The fertilization mechanism is designed to distribute fertilizer simultaneously to two crop rows as the bicycle moves between them. Adjustable outlets on both sides direct fertilizer toward the plants, allowing two rows to be fertilized in a single pass. The dosing mechanism regulates fertilizer flow to maintain a consistent application rate during operation. The dual-side fertilizer distribution mechanism is illustrated in Fig. 3.

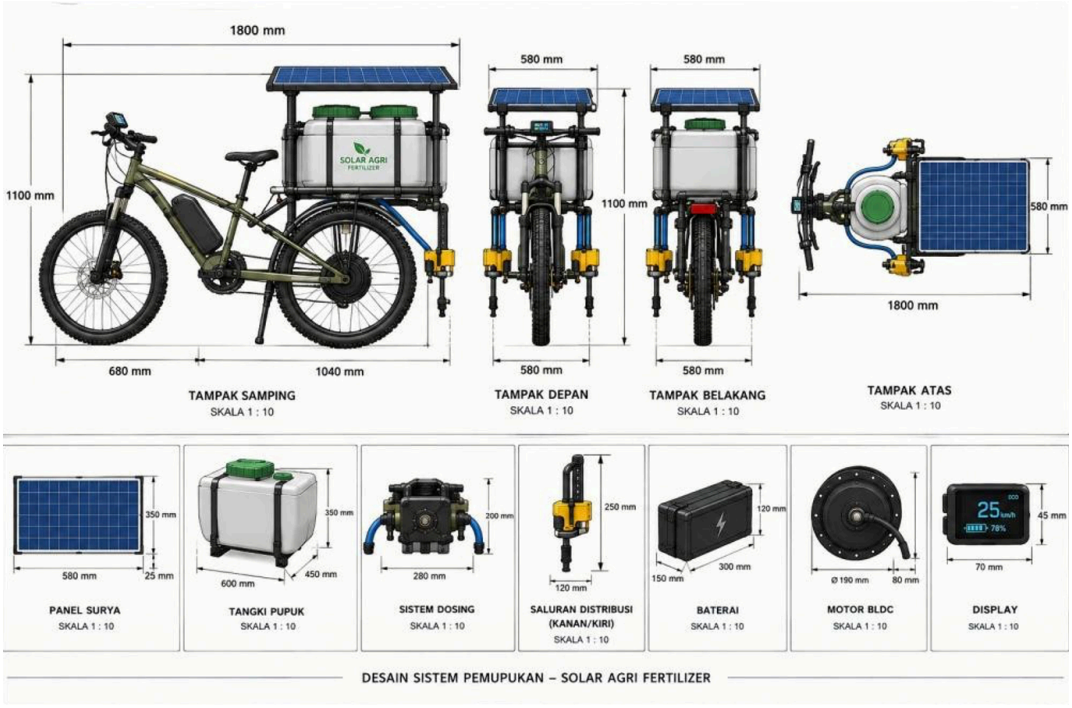


Fig. 3. Dual-side fertilizer distribution mechanism

The fertilizer discharge rate is determined by measuring the mass collected over a specified operating period and is calculated using Eq. (1).

$$Q_f = \frac{m_f}{t}$$

where Q_f is the fertilizer application rate (g/s), m_f is the mass of fertilizer released (g), and (t) is the operating time (s).

The fertilizer discharged from the right and left outlets is measured separately to evaluate distribution uniformity. The percentage difference between the two outlets is calculated using Eq. (2).

$$D = \frac{|m_R - m_L|}{\frac{m_R + m_L}{2}} \times 100\%$$

where D represents the percentage difference in fertilizer distribution (%), while m_R and m_L represent the fertilizer masses discharged from the right and left outlets (g), respectively.

2.3 Testing Procedure

Performance testing is conducted to evaluate fertilizer dosing accuracy, energy consumption, working capacity, and electric bicycle mobility on agricultural land. The tests are performed under controlled conditions using different fertilizer dosing settings and operating conditions. Each test is repeated to ensure measurement consistency.

The fertilizer dosage test involves collecting fertilizer discharged from each outlet over a predetermined period. The collected fertilizer is weighed using a digital scale and compared with the target dosage. The outputs from both outlets are measured separately to evaluate distribution uniformity. The testing parameters and measurement methods are summarized in Table 1.

Table 1
Testing Parameters and Measurement Methods

Parameter	Measurement Method	Unit
Fertilizer dosage	Measuring fertilizer mass	g/s
Right-side output	Measuring fertilizer mass	g
Left-side output	Measuring fertilizer mass	g
Battery voltage	Digital multimeter	V
Battery current	Current meter	A
Operating speed	Speed measurement	km/h
Working time	Stopwatch	s
Working width	Direct measurement	m

The electrical performance test is conducted by measuring the battery voltage and current during operation. Electrical power consumption is calculated using Eq. (3).

$$P = V \times I$$

where (P) is the electrical power (W), (V) is the battery voltage (V), and (I) is the electrical current (A).

The working capacity test is conducted by measuring the area covered by the bicycle and the time required to complete the fertilization process. The theoretical working capacity is calculated using Eq. (4).

$$C = \frac{W \times v}{10}$$

where (C) is the working capacity (ha/h), (W) is the effective working width (m), and (v) is the operating speed (km/h).

The field mobility test is conducted by operating the bicycle between crop rows to evaluate its movement, stability, ability to follow crop-row alignment, and fertilizer distribution performance during operation.

2.4 Performance Parameters

The performance of SOLAR AGRI FERTILIZER is evaluated based on fertilizer dosage accuracy, distribution difference, energy consumption, working capacity, and field mobility. These parameters are used to assess whether the developed system operates according to its intended design.

Fertilizer dosage accuracy is determined by comparing the measured fertilizer mass with the target fertilizer mass and is calculated using Eq. (5).

$$A = \left(1 - \frac{|m_t - m_m|}{m_t}\right) \times 100\%$$

where (A) is the fertilizer dosage accuracy (%), (m_t) is the target fertilizer mass (g), and (m_m) is the measured fertilizer mass (g).

The test results are compared across different dosing settings and operating conditions. The data are analyzed descriptively to examine the relationship between operating conditions and fertilization system performance.

3. Results

This section presents the performance testing results of SOLAR AGRI FERTILIZER, focusing on fertilizer dosage accuracy, distribution between the right and left outlets, electrical energy consumption, working capacity, and field mobility. The results are presented according to the experimental parameters described in the methodology section.

3.1 Fertilizer Dosage Performance

The fertilizer dosage test was conducted to measure the amount of fertilizer discharged by the dosing mechanism over a specified operating period. The collected fertilizer was weighed and compared with the target dosage. The results for different dosing settings are presented in Table 2.

Table 2
Fertilizer Dosage Test Results

Dosing Setting	Target Dosage (g/s)	Measured Dosage (g/s)	Accuracy (%)
Setting 1	10.0	9.82	98.2
Setting 2	15.0	14.88	99.2
Setting 3	20.0	19.65	98.25

Based on Table 2, the measured fertilizer dosage varies with the dosing setting. The differences between the target and measured dosages reflect the ability of the dosing mechanism to regulate fertilizer output. Dosage accuracy was calculated using Eq. (5).

3.2 Dual-Side Fertilizer Distribution

The dual-side fertilization test was conducted to evaluate fertilizer distribution through the right and left outlets. Fertilizer discharged from each outlet was collected and weighed separately under identical operating conditions.

Figure 4 compares the fertilizer masses discharged from both outlets. A smaller difference indicates a more balanced distribution.

The percentage difference between the right and left fertilizer outputs was calculated using Eq. (2), and the results are summarized in Table 3.

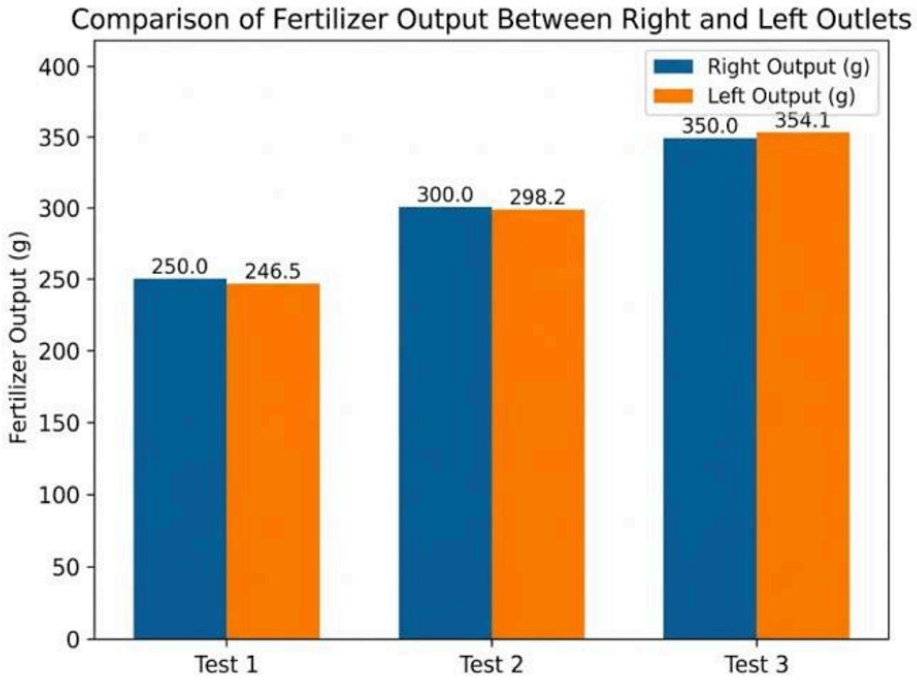


Fig. 4. Fertilizer masses discharged

Table 3
Right and Left Fertilizer Distribution Results

Test	Right Output (g)	Left Output (g)	Distribution Difference (%)
1	250	246.5	1.42
2	275	298.2	0.60
3	300	354.1	1.16

3.3 Working Capacity

The working capacity test was conducted to evaluate the area covered by the bicycle during fertilizer application. The theoretical working capacity was calculated using the effective working width and operating speed, as expressed in Eq. (4).

Table 4
Working Capacity Test Results

Test	Working Width (m)	Operating Speed (km/h)	Working Capacity (ha/h)
1	1.2	3.0	0.36
2	1.2	4.0	0.48
3	1.2	5.0	0.60

The results in Table 4 show the working capacity of the developed system at different operating speeds. Working capacity increases with operating speed when the effective working width remains constant.

4. Conclusions

The SOLAR AGRI FERTILIZER system was developed as a solar-powered electric bicycle equipped with a dual-side precision fertilization mechanism. The system integrates a BLDC motor, battery, solar panel, MPPT charge controller, and motor controller with a fertilizer tank, dosing mechanism, and adjustable right and left fertilizer outlets.

The performance evaluation considered fertilizer dosage accuracy, distribution uniformity, electrical power consumption, working capacity, and field mobility. The dosage accuracy ranged from 98.2% to 99.2%, indicating that the dosing mechanism maintained fertilizer output close to the target values. The theoretical working capacity ranged from 0.36 to 0.60 ha/h at operating speeds of 3.0–5.0 km/h and a working width of 1.2 m. These findings demonstrate the potential of the developed system for controlled fertilizer application in small-scale agricultural operations. However, the overall performance assessment requires verification of the fertilizer distribution results and further reporting of electrical power consumption and field mobility measurements.

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Conflict of Interest Statement

The authors declare no conflicts of interest.

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