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Soil Loosening Robot in Dry Land Chili Farming Using Flysky FS-I6 Remote Control Technology and Microcontroller

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ABSTRACT: Tilling agricultural land is one of the important aspects of farming, especially for chili plants, as it can help improve air circulation in the soil, enhance drainage, reduce soil compaction, increase nutrient availability, promote the growth of microorganisms, and maintain the health of chili plants. Tilling the soil using traditional tools in dryland chili farming still poses a significant risk of work accidents. On the other hand, the development of soil-tilling machinery mechanization still poses several problems, one of which is air pollution caused by using fuel-powered machines. The presence of soil-tilling robots in dryland chili pepper farming using Flysky FS-iA6 remote control technology solves both issues. The robot, which has a 24 V 12 Ah battery capacity, can operate for 15 minutes using a 24 V 350 W electric motor. The robot with chain wheels can move at a maximum speed of 3.90 m/s with an RPM of 327.40. The soil tiller used is of the rotary cultivator type. The maximum remote control range is 100 m. Camera sensors are used as remote land monitor.

KEYWORDS: camera sensor, chain wheel motion system, chili land soil loosening robot, cultivator knife, flysky FS-iA6 remote control technology.

I. INTRODUCTION

The process of soil loosening is a land management process carried out to improve the physical and chemical properties of the soil to make it more fertile and support better plant growth(Mehra et al., 2018)(Lysych, 2019). It can improve the root zone of plants, accelerate infiltration, and control pests on plants (Wicaksono et al., 2022). This soil loosening is often done in conditions of heavy-textured soil such as sandy loam, clay, and soil that lacks an aeration system. The stages in soil loosening usually include plowing and harrowing using various methods, both traditional and modern. Soil cultivation tools generally use traditional implements such as hoes, shovels, and harrows (Sembiring et al., 2017).

The use of traditional tools over a long period poses a high risk to farmers' health (Siskandar et al., 2022). Health risks that can be experienced include physical injuries, fatigue, non-ergonomic body posture, and joint problems. In addition, the use of traditional tools that are still often used by farmers poses a risk of work accidents because they are still done manually without prioritizing safety factors (Simbeye & Tongora, 2022). Then, modern tilling methods usually use agricultural machines such as tractors, rotavators, and harrows (Tiffany et al., 2023), but the use of machines still has drawbacks, including operation by farmers directly (manned machines), which poses health risks from excessive vibrations that can cause blood circulation disorders and nerve damage in the hands and arms (hand-arm vibration syndrome) (Dwinaffebri et al., 2021)(Sarkar et al., 2012). Moreover, the use of agricultural machinery consumes a significant amount of energy and costs because the machines still rely on gasoline power (Denni, 2023). Moreover, the pollution generated by the machines will cause respiratory issues for the farmers. Therefore, technological advancements can be a solution to address this issue by creating an agricultural robot that uses environmentally friendly energy.

Thus, the focus of the research is to develop (create and test) the performance of a soil tilling robot for dryland chili farming using the FlySky FS-i6 remote control system, which has criteria including a flexible system for wheel movement, cultivator arms, and cultivator blades based on remote control (unmanned machine); the use of environmentally friendly energy sources (electric); and a chain wheel movement system on the robot based on skid steer point turn configuration.

II. MATERIAL AND METHODS

The research was conducted from August 2024 to February 2025, located at the Hardware Lab and Electromechanical Workshop of the Vocational School of IPB University and the experimental field (Pamijahan Village Farmers Group, Bogor, Indonesia). The results of the needs analysis from the obtained/provided solution are a soil tilling robot for chili plant agriculture assisted by FlySky FS-i6 remote control technology. There are tools and materials along with the working mechanism based on the needs analysis results shown in Table 1.

Table 1. Analysis of component needs

No	Function, Sub Function	Component/ Alternative Mechanization	Selected Components/ Mechanisms
1	As a motor driving the wheels (forward-reverse, turn)	Electric motor 350 W 24 V DC	Electric motor 350 W 24 V DC
2	As the driving motor of the arm system (up-down)	Linear Actuator 40 cm	Linear Actuator 30 cm
3	As the drive for the rotary cultivator/knife	Electric motor 600 W 24 V DC	Electric motor 350 W 24 V DC
4	As a medium for remote control communication (transmitter-receiver)	FlySky FS-i6	FlySky FS-i6
5	Data processing components	ESP32	Arduino Mega 2560
6	Pulse width modulation (PWM) controller for high current electric motors (Max. 43A).	Cytron 6V-30V DC Motor Driver MD20A 20A	Motor Driver BTS7960 43A H Bridge
7	Lowering the voltage from 24 V to 7-12 V for powering the Arduino Mega2560 and linear actuator.	Stepdown	Stepdown
8	As a power source to drive the wheels, arms, and cultivator blades through Arduino Mega2560 and BTS2560	Battery 12 V 6Ah	Accu 12 V 6Ah
9	Left-right wheel	Chain 415H and gear 45T, 14T	Chain 428H and gear 45T, 15T
10	Mover of the cultivator knife	Rantai 415H and gear 14T	Rantai 428H and gear 15T
11	To loosen the soil	Rotary cultivator	Rotary cultivator
12	Applicator frame	Made of lightweight materials, such as alumunium alloy	Hollow iron material (4x2 cm)
13	Robot Body	Made of lightweight materials, such as alumunium alloy	Hollow iron material (1,2mm and 1,8mm) and Akrilik 2mm
14	Camera sensor	logitech	logitech

There are two main methods used, namely design and performance testing. Both are divided into several parts, namely: design and performance testing of the wheel drive system, design and performance testing of the cultivator arm drive system, design and performance testing of the cultivator blade drive system, design and performance testing of the remote control system, and design and performance testing of the power supply requirements (Siskandar et al., 2023a). The main design of the soil tiller robot for dryland agriculture with the FlySky FS-i6 remote control system is shown in the figure 1.

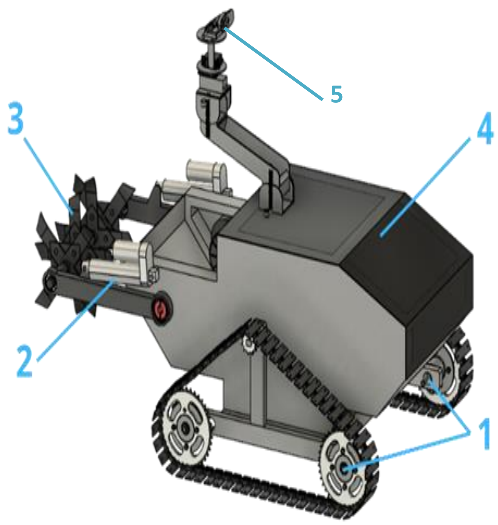

Figure 1. Designing the main design of the chili plant soil tilling robot: (1) chain wheel; (2) knife arm; (3) cultivator knife; (4) remote control electric system; (5) remote monitoring camera sensor

Design and Performance Testing of Wheel Drive System

The wheel motion design uses two 350 W 24 V electric motors designed to rotate in opposite directions. The electric motor and gearbox are connected with a small 15T gear. The 15T gear is connected to a chain that supports two 45T gears. Thus, the chain will form a triangle with the base serving as the support for the wheel (Verstraten et al., 2023). More clearly, the design of the wheel drive system is shown in the figure 2.

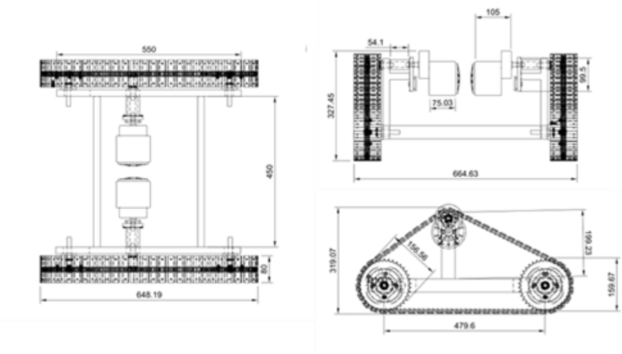

Figure 2. Design of wheel drive system engineering

The construction of the robot wheel is tailored to the conditions of dryland agriculture, specifically chili fields, where the wheel made from a chain connects three gears with a surface length in contact with the ground of 648.18 mm, a width of 80 mm, and a height of 315.46 mm.

The performance test on the robot's wheel drive system consists of forward, backward, and turning motion tests. The terrain used includes asphalt, rocks, hills, and plantations (Mehra et al., 2018; Salar et al., 2013), with the aim of testing the durability of the robot's wheels in various land conditions. Data on the minimum and maximum PWM values will be obtained, followed by the values of voltage, current, RPM, and torque, which will be derived from the calculations. Through this test, a graph showing the relationship between PWM and RPM and voltage can be produced. The instrumentation used in the performance test includes a digital tachometer, multimeter, and digital oscilloscope.

Design and Performance Testing of the Cultivator Arm Motion System

The linear actuator movement system on the robot uses a 350 W 24 V DC electric motor. The electric motor is connected to the gears and the main screw that pushes the

stroke rod in and out along the linear axis (Matasov et al., 2021). The cultivator arm motion system is connected to the linear actuator at one end and to the robot body at the other end. The linear actuator pushes or pulls this arm to produce rotational movement at the pivot point indicated by the fulcrum on the arm. The maximum angle formed is 45° at the pivot point of the cultivator arm. The details related to the design of the cultivator arm are shown in Figure 3.

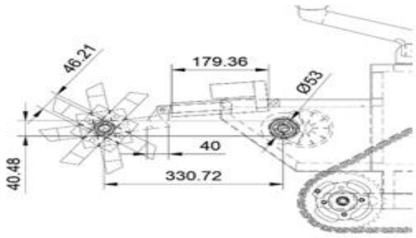

Figure 3. Design of the cultivator arm technique

The design of the robot's arm is shaped like the arm of a motorcycle that supports a 40 cm long axle. This arm is designed using hollow steel with a size of 4x2 cm and a length of 20 cm.

Performance testing on the cultivator arm movement system is conducted to determine whether the arm can move up and down properly. The testing was conducted by measuring the relationship between the actuator length, tilt angle, distance from the blade to the ground, and the load capacity received by the actuator. The measurements were taken by moving the actuator every 2 cm. The instrumentation used is a ruler and a protractor.

Design and Performance Testing of the Cultivator Knife Movement System

The design concept of the rotary cultivator knife consists of four blades arranged symmetrically at 90° angles. The rectangular shape makes it easier for the blades to chop the soil. This knife also has a sharp tip that can help break up hard clumps of soil (Salar et al., 2013).

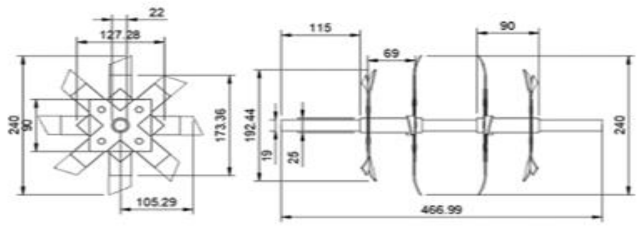

Figure 4. Mechanical design knife cultivator

This blade is mounted on the shaft of the rotary cultivator (Matasov et al., 2021)(Yang et al., 2015). The rotary cultivator shaft will rotate when the electric motor is supplied with electrical power. The rotation of the shaft will cause the blades to spin and till the soil. The technical design of the cultivator blade is shown in the figure 4.

Figure 4 is the technical design of the cultivator knife used. The size of the knife blades is 240 mm with a thickness of 2 mm. The length of the shaft is 466.99 mm, which can be integrated with two rotary cultivator blades.

Performance testing on the cultivator knife movement system is conducted to determine the optimal results of soil tilling using the knife based on several conditions. These conditions are based on variations in the knife RPM, robot speed, and robot mass (Shofie Hanifah et al., 2024). From the tests, it was found that the soil clumps produced had different diameters. The instrumentation used includes a digital tachometer, a digital scale, and a ruler

Design and Performance Testing of a Remote Control System

The robot design operates based on the input, process, and output flow. The input comes from the Flysky Fs-i6 remote control, which is a device used to transmit radio wave signals at a frequency of 2.4 GHz from the user to the control system (Omer, 2013). The process is then carried out by the Arduino Mega 2560, which is a microcontroller capable of controlling various types of input and output (WIECZOREK, 2017).

Figure 5. Block diagram of the remote control system

Arduino Mega 2560 with the specified programming language can process signals from the remote control and provide instructions to the output (Mudarisov et al., 2020; Soon-Young Yang et al., 2008). The output of this agricultural robot is demonstrated by actuators and electric motors connected to the BTS 7960 driver. Actuators and electric motors are types of motors that can be controlled with precision, allowing them to produce movements that are accurate according to the instructions from the Arduino Mega 2560.

Thus, the output of this robot can produce movements that are accurate and in accordance with the user's instructions via remote control (Siskandar et al., 2023b). Clearly, the block diagram of the remote-controlled robot control system is shown in the figure 5.

Performance testing on the remote control system was conducted to determine the performance of the FlySky FS-i6 remote control. The testing was conducted by moving all the robot's functionalities within a range of 10-180 m (Fang et al., 2016). With that range, the maximum distance that can be controlled by the remote control over the robot can be determined. The instrumentation used is a measuring tape.

Design and Performance Testing of Electrical Needs

The main power source for the robot's electricity consumption is four 12 V 6 Ah batteries. Two batteries are connected in series to maximize the capacity of the power source to 24 V, and the other two batteries are connected in parallel. Thus, the power source generated is 24 V 12 Ah. The power requirements of the robot are shown in the table 2.

Table 2. Electric power demand

Component	Voltage (V)	Amount	Watt (W)	Watt Total (W)
Arduino Mega	7	1	1	1
Motor	24	3	350	1050
Aktuator	12	2	60	120
Total				**1171**

Table 2 shows the power requirement for the operation of the robot, which is 1171 W. The use of this electrical power will occur when all components are turned on simultaneously at maximum capacity. The maximum power that can be generated by using a 24 V 12 Ah battery is 288 W.

$$P = V \ x \ I \quad (1)$$

$$P = 24V \ x \ 12Ah \quad (1)$$

$$P = 288 \ Watt \quad (1)$$

Based on the calculations in equation 1, the maximum power that can be generated from the use of a 24V battery 12Ah is equivalent to 288 watts..

$$Operating\ hours = \frac{battery\ capacity\ (Wh)}{Total\ power\ consumption\ (W)} \quad (2)$$

$$Operating\ hours = \frac{288Wh}{1171W} \quad (2)$$

$$Operating\ hours = 0.25\ hours = 15\ minute \quad (2)$$

Equation 2 shows the estimated operating time that the battery can provide to power the robot's functions. With a capacity of 288 Watts, the battery can run electronic components with a power of 1171 watts for 15 minutes (equation 2). Thus, the energy requirement for this robot is sufficient to power the robot's functions for one operation before the battery needs recharging (Verstraten et al., 2023). For the robot's operational needs exceeding 15 minutes, an increase in battery capacity is required.

The battery endurance test conducted on this robot is carried out to provide an overview of how long the robot can operate before needing to be recharged. The testing was conducted by measuring the battery voltage at 1-15 minutes. The instrumentation used are a stopwatch and a multimeter.

III. RESULTS AND DISCUSSION

The dry land agricultural tilling robot for chili farming was designed with a mass of 40 kg and a ground clearance of 11 cm. Meanwhile, the dimensions of this robot are 66.6 cm in width, 118 cm in length, and 44.5 cm in height. Chain wheels with iron plate treads coated with rubber are used to prevent slipping on slippery soil conditions. The use of a 24 V electric motor with a gearbox allows the robot to move at a speed of up to 1.39 m/s without the load from the soil tiller. The camera system can monitor up to a distance of 100 m.

Figure 7. Soil tilling robot prototype

Wheel drive system test

Another test conducted was the wheel speed test from maximum voltage to several speeds tested with a robot wheel diameter of 173 cm and a weight of 59.25 kg. The speed of this robot is influenced by the PWM input from the microcontroller through the motor driver.

Table 3. Wheel speed testing based on PWM

Duty cycle	PWM	Voltage (V)	Ampere (A)	Motor RPM	Wheel RPM	Torsi (Nm)	Watt (W)
0.75 %	1,92	0	0	0	0	0	0
20.00%	51,13	4,74	5,63	56,4	8.3	4,52	26,7
40.40%	103,02	9,7	6,99	89,1	13.8	7,27	67,84
60.79%	155,02	14,72	8,55	156,1	21.1	7,46	122,04
80.00%	204,07	19,88	9,67	221,6	28.2	8,29	192,34
98.02%	255	24,44	11,18	327,4	37.3	7,97	273,33

Table 3 shows the relationship between PWM and voltage with the speed of the soil tiller robot's wheels. An increase in PWM value and voltage will increase the rotational speed of the electric motor, thereby increasing the speed of the robot's wheels. However, this relationship is not always linear. At high PWM values and voltages, the efficiency of the electric motor begins to decrease. This causes the speed of the robot's wheels to not increase significantly, even though the PWM value and voltage continue to be increased. The data shown in Table 3 are the results of testing on each left and right wheel. The testing was conducted without load (the robot body was left not touching the ground).

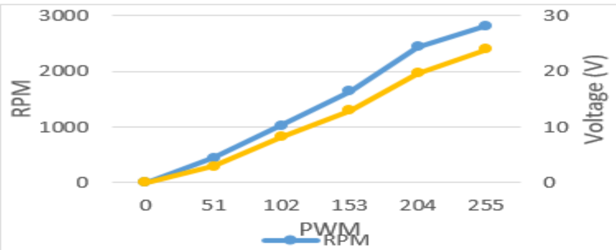

Figure 8. The relationship between PWM, RPM, and Voltage

Figure 7 shows the graph of the relationship between PWM, RPM, and voltage. The blue curve shows the change in motor speed (RPM) in relation to the PWM value. As the PWM value increases from 0 to 255, the RPM also increases almost linearly. In addition, the yellow-colored curve also shows that the average voltage applied to the motor increases almost linearly with the PWM value. This indicates that the PWM value is capable of increasing the motor speed (RPM) because the average voltage applied to the motor increases.

Test of the Cultivator Arm Movement System

The movement of the cultivator knife arm is performed to facilitate the robot's mobility without tilling. The arm will rise when in idle or normal walking condition, and the arm will lower when the robot is operating as a soil tilling robot for chili plant agriculture.

Table 4. Test the cultivator arm movement

Length of the actuator (cm)	Angle of inclination (°)	Distance from the knife to the ground (cm)	Load capacity (N)
20	0	16.00	0.00
22	13	9.80	0.00
24	28	0.00	193.68
26	35	-3.20	213.78
28	45	-7.82	227.02

Table 10 shows that the angle of inclination formed by the cultivator arm is influenced by the stroke length of the rod on the linear actuator. In the shortest condition, which is 20 cm, the angle of inclination of the cultivator arm is at the highest or raised position, resulting in the knife being 16 cm above the ground, and the load or compressive force received by the linear actuator is still 0.00 N. Meanwhile, in the condition of a length of 28 cm, the position of the cultivator arm is at its lowest point, causing the cultivator blade to be 7.82 cm below the soil surface. This results in a maximum load on the linear actuator of 227.02 N.

Knife Movement System Test

The cultivator blades used are of the rotary type because they are more effective in land preparation with dry soil conditions, which are suitable for cultivating plants that grow well without waterlogging. Optimal soil tilling results can be achieved by balancing three factors: knife RPM, robot speed, and robot weight.

Table 5. Testing the cultivator knife movement system

Knife RPM	Robot speed (m/s)	Robot Weight (kg)	Diameter of the soil block (cm)	Explanation
221.6	2.1	28	2.3	The tilling results are suboptimal

Knife RPM	Robot speed (m/s)	Robot Weight (kg)	Diameter of the soil block (cm)	Explanation
				(the soil clumps are too large).
327.4	2.1	28	1.5	Optimal tillage results
221.6	3.9	28	3.6	The soil becomes less optimal for tilling (the soil clumps are too small).
327.4	3.9	28	3.0	The tilling results are suboptimal (the soil clumps are too large).

The testing of the knife movement system is conducted based on three parameters: knife rpm, robot speed, and robot weight. The optimal tillage has a medium diameter, which is between 1-1.5 cm. In experiment 2, the optimal tilling result was obtained with a knife RPM of 327.4, a tool speed of 2.1 m/s, and a robot mass of 59.25 kg. Meanwhile, in experiments 1, 3, and 4, the tillage results were less optimal because one of the factors (knife RPM, tool speed, or tool weight) was not within the optimal range.

Remote Control System Test

Remote control system, this robot uses the FlySky FS-i6 remote control (transmitter). There is a 6-channel receiver that can receive radio waves from the transmitter. This transmitter is capable of issuing commands to control wheel movement, which is processed using an Arduino Mega based on the provided program. The command will provide a digital signal to the BTS7960 motor driver to give a high value and PWM signal based on the supplied power of 24 V.

Table 6. Instructions for using the remote control

Figure	Action	Function
	A – B	Robot forward
	A – C	Robot backward
	A – D	Robot turn left
	A – E	Robot turn right
	F – J	Cultivator arm down
	F – I	Cultivator arm up
	G – H	PWM motor 0 – 255
	C1	Robot idle
	C2	Robot on
	D1	Cultivator blade off
	D2	Cultivator blade on

Table 6 shows the instructions for using the remote control to operate the robot according to the designed functions. The robot successfully moved forward, backward, turned, raised and lowered its arm, adjusted the PWM, and controlled the cultivator blade.

Table 7. Testing the remote control system

Distance (m)	Signal	Explanation
10	readable	The remote control can easily operate the soil tilling robot.
45	readable	The remote control can easily operate the soil tilling robot.
90	readable	The remote control can easily operate the soil tilling robot.
135	less readable	The remote control is difficult to operate the soil tilling robot.
180	can not be read	The remote control cannot operate the soil tilling robot.

In Table 7, the test was conducted by measuring the operational range of the Flysky FS-i6 remote control to operate the robot. At a distance of less than 135 m, the signal from the receiver (FS-iA6) to the transmitter (FS-i6) is read well, at a distance of 135 – 179 m the signal starts to become less readable and the robot is difficult to control. Whereas at a distance of more than 180 m, the signal is no longer readable and the robot cannot be controlled. The condition does not meet the specifications of the remote control due to several factors such as the signal conditions in the surrounding environment that are not supportive.

Test of Electrical Resilience System

The power supply for this tilling robot uses four 12 V 6Ah batteries. The configuration of the batteries used is two connected in parallel and the other two connected in series, resulting in an output power of 24 V 12 Ah. The electrical system endurance test is conducted by measuring the voltage of the battery under various time conditions. This is done to determine the actual usage of the battery being used. Here are the results of the testing of the electrical system of the robot that was made.

Table 8. Testing the resilience of the power source

No	Testing Time (hours)	Burden (%)	Initial Voltage (V)	Final Voltage (V)	Ampere (A)
1	0.05	50	24.84	24.55	2.8
2	0.10	50	24.84	23.94	2.0
3	0.15	50	24.84	23.09	2.1
4	0.20	50	24.84	22.58	2.6
5	0.25	50	24.84	21.97	2.5
6	0.05	100	24.76	24.01	2.9
7	0.10	100	24.76	23.24	2.3
8	0.15	100	24.76	22.68	2.2
9	0.20	100	24.76	21.79	2.4

10	0.25	100	24.76	21.06	2.2

Table 8 shows the results of the endurance test of the agricultural soil tilling robot based on different loads. With the use of a 50% load, the battery capacity decreased less in each test compared to a 100% load. The load in question is based on the use of PWM on the electric motor. The robot's initial operation has the highest current usage, which is 2.8 A at 50% load and 2.9 A at 100% load. The initial voltage was charged to the maximum in the battery, which was 24.84 V and 24.76 V. The final voltage at the 15th minute was 21.97 V and 21.06 V. This occurs due to the undervoltage protection to prevent over-discharge of the battery, which causes a decrease in battery capacity.

CONCLUSIONS

A robot for tilling chili pepper agricultural land has been successfully created and tested, utilizing Flysky FS-i6 remote control technology with a communication range of 100 m. The robot is built with two main mechanisms, namely the frame and the body made of iron with a thickness of 2 mm. The type of wheel used is the chain type. Chain wheels provide higher traction in all conditions of dry agricultural land. In the tilling section, the use of blades shaped like propellers with opposing ends can break the soil, level the ground, and remove weeds, making the land ready for use. The test results show that the robot has successfully moved forward, backward, and turned at adjustable speeds using a remote control through PWM changes. The maximum speed of this robot is 7.97 m/s with 327.40 RPM and 25.18 V on the electric motor. The robot can move smoothly at maximum speed on asphalt, rocky terrain, hills, and plantations. In the cultivator arm system, it is assisted by an electric linear actuator system with a maximum stroke rod length of 10 cm. The longer the stroke rod, the lower the arm position will be, with a maximum angle of 45 degrees. In the fully lowered position, this rotary-type cultivator blade is capable of digging the soil to a depth of 7.82 cm. The optimum tilling result was obtained at a blade speed of 327.4 RPM; a wheel speed of 3.9 m/s, and an actuator length of 28 cm. The diameter of the soil clumps produced is 1-2 cm.

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REFERENCES

1. Denni, J. (2023). Modifikasi Traktor Mini Penggerak Motor Bensin 6,5 Hp dengan Penambahan Pompa Air Multifungsi Pada Pertanian. In *Cetak) Buletin UtamaTeknik* (Vol. 19, Issue 1). Online.
2. Dwinaffebri, T., Peminatan, M., UniversitasDiponegoro, M., & Keselamatan, B. (2021). Kajian Pustaka : Faktor Terjadinya Hand Arm Vibration Syndrome Pada Pekerja. 9(1). http://ejournal3.undip.ac.id/index.php/jkm
3. Fang, H., Zhang, Q., Chandio, F. A., Guo, J., Sattar, A., Arslan, C., & Ji, C. (2016). Effect of straw length and rotavator kinematic parameter on soil and straw movement by a rotary blade. *Engineering in Agriculture, Environment and Food*, *9*(3), 235–241. https://doi.org/10.1016/j.eaef.2016.01.001
4. Lysych, M. N. (2019). Review of numerical methods for modeling the interaction of soil environments with the tools of soil tillage machines. *Journal of Physics: Conference Series*, *1399*(4), 044014. https://doi.org/10.1088/1742-6596/1399/4/044014
5. Matasov, A. N., Ulyanov, M. V, Tseplyaev, V. A., Kharlashin, A. V, & Ayugin, N. P. (2021). Development of the design of a rotary tool for combing weeds with loosening the soil. *IOP Conference Series: Earth and Environmental Science*, *723*(3), 032052. https://doi.org/10.1088/1755-1315/723/3/032052
6. Mehra, P., Baker, J., Sojka, R. E., Bolan, N., Desbiolles, J., Kirkham, M. B., Ross, C., & Gupta, R. (2018). A Review of Tillage Practices and Their Potential to Impact the Soil Carbon Dynamics (pp. 185–230). https://doi.org/10.1016/bs.agron.2018.03.002
7. Mudarisov, S., Gainullin, I., Gabitov, I., & Khasanov, E. (2020). Improvement of traction indicators of a track-chain tractor. *Communications - Scientific Letters of the University of Žilina*, *22*(3), 89–102. https://doi.org/10.26552/com.C.2020.3.89-102
8. Omer, A. M. (2013). Demand for Energy Efficient, Eco-Friendly Environment, Applications and Sustainable Development. *In World Essays Journal* (Vol. 1, Issue 3).
9. Salar, M. R., Esehaghbeygi, A., & Hemmat, A. (2013). Soil loosening characteristics of a dual bent blade subsurface tillage implement. *Soil and Tillage Research*, *134*, 17–24. https://doi.org/10.1016/j.still.2013.07.005
10. Sarkar, A., Aronson, K. J., Patil, S., Hugar, L. B., & vanLoon, G. W. (2012). Emerging health risks associated with modern agriculture practices: A comprehensive study in India. *Environmental Research*, *115*, 37–50. https://doi.org/10.1016/j.envres.2012.03.005
11. Sembiring, M. T., Wahyuni, D., & Tarigan, I. R. (2017). Perancangan Alat Penggembur Tanah untuk Petani Palawija.
12. Shofie Hanifah, D., Daniswara, M., Wicaksono, A., & Muharfiza. (2024). Investigating the performance of electric mini tiller. *BIO Web of Conferences*, *90*, 02001. https://doi.org/10.1051/bioconf/20249002001

13. Simbeye, D. S., & Tongora, E. F. (2022). "Design and Development of Intelligent Robotic System for Precision Agriculture." *International Journal of Software & Hardware Research in Engineering*, *10*(10). https://doi.org/10.26821/ijshre.10.10.2022.101020
14. Siskandar, R., Mandang, T., Hermawan, W., & Irzaman, I. (2023a). Engineering of Information Monitoring System Sensor Reading Data Based on Smart Wireless using NVDIA Jetson Nano and Arduino Mega on Agricultural Spraying Machines. *Jurnal Teknik Pertanian Lampung (Journal of Agricultural Engineering)*, *12*(4), 921. https://doi.org/10.23960/jtep-l.v12i4.921-936
15. Siskandar, R., Mandang, T., Hermawan, W., & Irzaman, I. (2023b). Thin Film Potential Ba0.5Sr0.5 TiO3 (BST) doped with RuO2 6% as a Light Detecting Sensor at Solar Tracker ALSINTAN System in Microcontroller-Based. *Biointerface Research in Applied Chemistry*, *13*(6). https://doi.org/10.33263/BRIAC136.545
16. Siskandar, R., Santosa, S. H., Wiyoto, W., Kusumah, B. R., & Hidayat, A. P. (2022). Control and Automation: Insmoaf (Integrated Smart Modern Agriculture and Fisheries) on The Greenhouse Model. *Jurnal Ilmu Pertanian Indonesia*, *27*(1). https://doi.org/10.18343/jipi.27.1.141
17. Soon-Young Yang, Sung-Min Jin, & Soon-Kwang Kwon. (2008). Remote control system of industrial field robot. *2008 6th IEEE International Conference on Industrial Informatics*, 442–447. https://doi.org/10.1109/INDIN.2008.4618140
18. Tiffany, C. A., Ernanda, C. E., & Herdianing, E. S. (2023). Solidaritas Para Buruh Tani dalam Menghadapi Modernisasi di Sektor Pertanian. *2*.
19. Verstraten, T., Hosen, M. S., Berecibar, M., & Vanderborght, B. (2023). Selecting Suitable Battery Technologies for Untethered Robot. In *Energies* (Vol. 16, Issue 13). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/en16134904
20. Wicaksono, A. T., Niswati, A., Arif, M. A. S., & Utomo, M. (2022). Pengaruh Dua Sistem Olah Tanah Dan Aplikasi Herbisida Terhadap Respirasi Tanah Pada Pertanaman Jagung (Zea Mays L.) Musim Tanam Ke-5. *Jurnal Agrotek Tropika*, *10*(1), 75. https://doi.org/10.23960/jat.v10i1.5632
21. Wieczorek, A. N. (2017). Possibilities of Increasing the Durability of Chain Wheels of Armoured-Face Conveyors. *Transport Problems*, *12*(3), 71–82. https://doi.org/10.20858/tp.2017.12.3.7
22. Yang, S., Jiao, Y., Wang, H., Li, J., & Hao, Y. (2015). Barrier-crossing Design of the Inspection Robot in Substation with Wheel-Track. https://doi.org/10.2991/icmmita-15.2015.229