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Development of a Manure Fertilizer Applicator Attached to a Rotary Cultivator

Virat Wangkuanklang

Faculty of Engineering and Technology, Rajamangala University of Technology Isan, Thailand

Kanya Kosum

Faculty of Engineering and Technology, Rajamangala University of Technology Isan, Thailand

Kiatsuda Suvanapa

Agricultural Machinery Engineering, Faculty of Engineering and Industrial Technology, Kalasin University, Thailand

Khongdet Phasinam

Faculty of Food and Agricultural Technology, Pibulsongkram Rajabhat University, Thailand

Dowroong Watcharinrat*

Division of Educational Administration, Department of Education, Faculty of Education, Kasetsart University, Thailand

Abstract - Rice cultivation flourishes in all regions of Thailand with the country being one of the world's top rice exporters. To attain a high crop yield, it is vital to enhance soil fertility with appropriate preparation and fertilization procedures. However, such processes are not only labor and energy-intensive but also require effectively designed agricultural technology. Thus, the present study aimed primarily to develop a manure fertilizer applicator attached to a rotary cultivator that enabled simultaneous soil preparation and fertilization. The invention comprised four main components, namely a fertilizer tank, a fertilizer smoother, a fertilizer spreader, and the rotary cultivator system of a 46-horsepower tractor, with a functional width of 1.75 m. When tested across the first, second, and third tractor gear speeds at the fertilizer channel of 20%, the applicator was found to achieve the soil preparation capacity of 0.324, 0.368, and 0.459 ac/h, the soil fertilization capacity of 400.638, 316.294, and 253.035 kg/h, and the efficiency of 52%, 59%, and 80%, respectively.

Keywords - Manure fertilizer applicator, Rotary cultivator, Soil preparation, Soil fertilization, Tractor gear speed

INTRODUCTION

Thailand has long been an agricultural country with over 46% of its farmland and forest being devoted to rice cultivation [1]. Rice paddies that scatter across all regions produce a large volume of yields on an annual basis, making Thailand consistently listed as a top global exporter of rice [2]. Since farmers constituting the Thai rice industry evidently play a critical role in advancing the national economy, relevant public and private agencies have attached importance to supporting and promoting their access to technology and resources conducive to productivity improvement [3].

Achieving high rice yields requires proper preparation of soil to ensure sufficient fertility. However, soil nutrients are currently being depleted in many agricultural areas across the world as a result of the widespread application of chemical fertilizer to boost productivity. The consequential decline in the physical, chemical, and mechanical properties of the soil has necessitated the formulation of practical guidelines for soil fertilization. Among others, one common method is to opt for organic fertilizers, such as manure, compost, biological fertilizer, and green manure, especially peanut or soybean cut and plowed into the soil while still green to add organic matter [4], [5].

In addition to issues relating to soil degradation, soil preparation for rice cultivation not only is a labor and energy intensive process but also involves the selection and use of agricultural machinery and fertilizer [6]–[9]. Therefore, this research aimed primarily to invent a manure fertilizer applicator attached to a rotary cultivator in order to enable synchronous soil preparation and fertilization. It is expected that the innovation will help save labor, energy, and expenses in the soil preparation stage of rice cultivation.

I. Research objectives

- To design and development a prototype of a manure fertilizer applicator attached to a rotary cultivator
- To identify methods to increase the efficiency of the invention
- To test the prototype for practical application

MATERIALS AND METHODS

I. Design of the invention

The invention weighed 160 kg when empty and 955 kg with the largest possible amount of manure fertilizer added, calculated from the maximum measurement at the tip of the hydraulic arm of a 46-horsepower tractor. It comprised a 0.65X1.75X0.7 m applicator attached to a 1.93X0.85X1.06 m RCT rotary applicator weighing 345 kg. Inside the fertilizer tank was the fertilizer spreader installed to disperse and decompress the soil that received power through the transmission drive chain from the axle of the C-shaped fertilizer smoother comprising six blades operating to open and close the fertilizer tank channel, as displayed in Figs. 1a and 1b. In turn, the fertilizer smoother was powered through the transmission drive chain with the axle of the rotary cultivator.

II. Operation of the invention

The manure fertilizer applicator received power from the axles of the rotary cultivator, fertilizer smoother, and fertilizer spreader through the transmission drive chain. In other words, the axles of the fertilizer smoother and spreader operated nearly simultaneously with the rotary cultivator, and disruption to the rotary cultivator would thus cause the applicator to stop. While the fertilizer smoother in the fertilizer tank functioned as a channel for regulating the amount of fertilizer, the fertilizer spreader served to disperse and decompress the fertilizer in order to facilitate the operation of the fertilizer smoother. The rotary cultivator blades that followed in the process helped to mix the fertilizer with the soil, thereby aiding farmers in completing soil preparation and fertilization simultaneously. It is worth noting that the weight of the applicator and the fertilizer combined had no effect on the motion of the rotary cultivator due to the two frame skis installed to enable plowing adjustment with the highest possible depth of 20 cm.

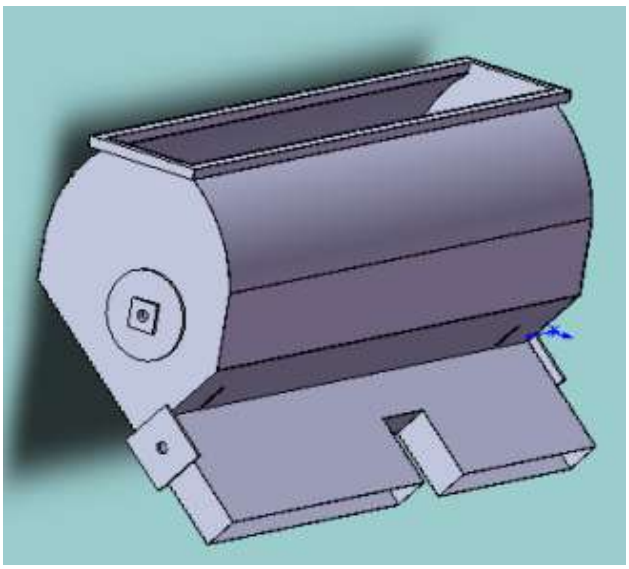

FIGURE 1A

FERTILIZER TANK

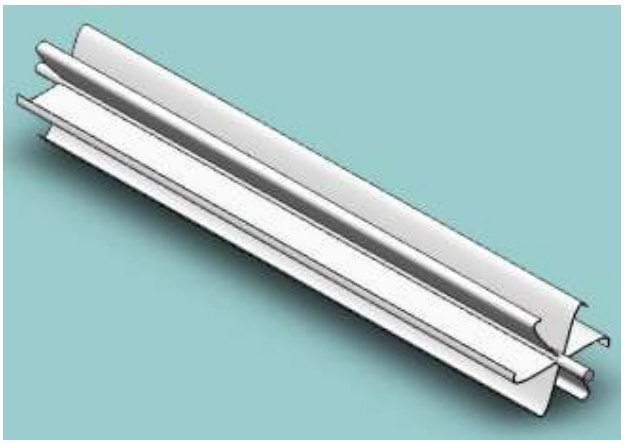

FIGURE 1B

FERTILIZER SMOOTHER

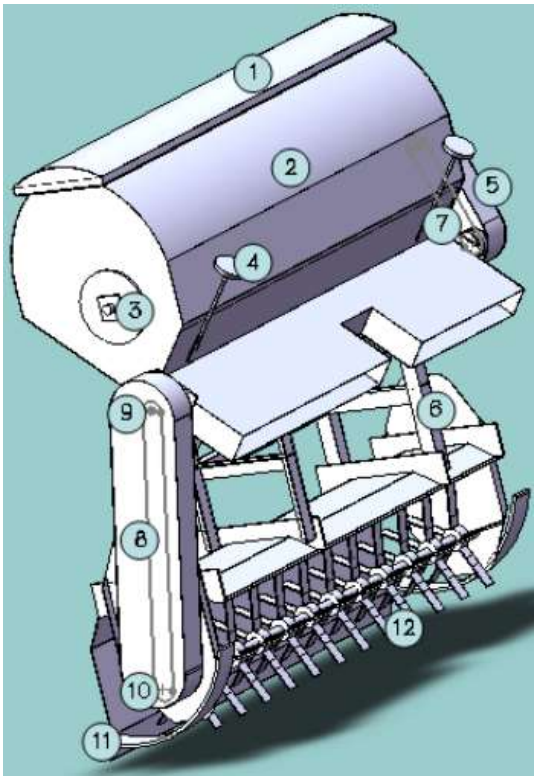

FIGURE 2

MANURE FERTILIZER APPLICATOR ATTACHED TO A ROTARY CULTIVATOR

1. Tank lid, 2. Fertilizer tank, 3. Fertilizer spreader axle, 4. Channel adjustor, 5. Transmission housing, 6. Fertilizer tank stand, 7. Transmission drive chain, 8. Transmission drive chain, 9. Fertilizer smoother axle,

10. Rotary cultivator axle, 11. Rotary cultivator

12. Rotary cultivator blades

III. Assessment of the capacity of the invention

The manure fertilizer applicator was assessed across three low gear speeds from the first to the third on nine 15X40 m plots of experimental farmland in an authentic environment. The fertilizer channel was opened to 20%. Each gear speed was tested three times. The soil preparation capacity of the applicator was determined using the following (1):

$$C = \frac{A}{T_t} \quad (1)$$

Where C represents the soil preparation capacity (ac/h)

A represents the area (ac)

T_t represents the total amount of time spent (h)

Subsequently, the soil fertilization capacity of the applicator was calculated using the following (2):

$$FC = FA/A \quad (2)$$

Where FC represents the fertilization capacity (kg/ac)

FA represents the total amount of fertilizer tested (kg)

A represents the actual area (ac)

Finally, the efficiency of the applicator was identified using the following (3):

$$E = \frac{T_e}{T_t} \times 100 \quad (3)$$

Where E represents the efficiency

T_e represents the actual amount of time spent (h)

T_t represents the total amount of time spent, including that wasted on turning, stopping, or stopping the machine (h)

FIGURE 3

ASSESSMENT OF THE OPERATION OF THE MANURE FERTILIZER APPLICATOR

RESULTS

The test of the manure fertilizer applicator across three low gear speeds on the experimental farmland at the 20% fertilizer channel setting showed that the third tractor gear speed achieved the highest soil preparation capacity and efficiency of 0.459 ac/h and 80%, respectively, but the lowest fertilization capacity of 253.035 kg/h. In contrast, the first tractor gear speed contributed to the highest fertilization capacity of 400.638 kg/h but the lowest soil preparation capacity and efficiency of 0.324 ac/h and 52%, respectively. The findings are illustrated in Table I.

TABLE I

TEST OF THE OPERATION OF THE MANURE FERTILIZER APPLICATOR

Areas of test	Tractor gear speeds		
	1st gear speed	2nd gear speed	3rd gear speed
Soil preparation capacity (ac/h)	0.324	0.368	0.459
Soil fertilization capacity (kg/ac)	400.638	316.294	253.035
Efficiency (%)	52	59	80

DISCUSSION

The present findings demonstrate that a rotary cultivator supplies power through a transmission drive chain to a fertilizer smoother, fertilizer spreader, and eventually manure fertilizer applicator, resulting in the nearly concurrent operation of all the mechanical devices. Thus, a halt to the rotary cultivator will disrupt the continuity of the manure fertilizer applicator. Additionally, tractor gear speed has a direct correlation with the soil preparation capacity, soil fertilization capacity, and efficiency of a manure fertilizer applicator; that is, a lower gear speed will boost soil preparation capacity and efficiency but reduce soil fertilization capacity, and vice versa for a higher gear speed. An invention that enables simultaneous soil preparation and fertilization like the one developed in this study will lessen reliance on labor, cut energy consumption, and shorten cultivation duration to a considerable extent.

Corroborative evidence was reported in [10]. They proposed a fertilizer applicator comprising a hopper, a vertical spiral conveyor, a fertilizer distribution channel, two wheels, a set of Hall sensors, two electric motors, a controller, a switch, and a support frame. The motor drove the vertical spiral conveyor to transfer the fertilizer into the distribution channel, while the Hall sensors measured the wheel speed to determine the fertilization rate, and the electric motor regulated fixed-amount and variable-rate fertilization applying the pulse-width modulation method. Since their invention involves manual control and movement of the fertilizer applicator, it is hard to draw a reasonable comparison as to which proposal is more efficient and beneficial for farmers. However, either technology will clearly facilitate rice cultivation by optimizing the process of soil preparation and/or fertilization.

CONCLUSION AND RECOMMENDATIONS

I. Conclusion

Rice is one of the most significant economic crops of Thailand. As a top global rice producer and exporter, it is essential for the authorities, researchers, and those involved to identify problems likely to hinder the cultivation process. Generally, obstacles to rice farmers include the complexity of soil preparation and fertilization, the shortage of labor, and high energy consumption. To address these issues, the present study developed a simple invention made up of a 1.75-wide manure fertilizer applicator attached to the rotary cultivator of a 46-horsepower tractor, a fertilizer tank, a fertilizer smooth, and fertilizer spreader, and a transmission drive chain. A trial on the experimental farmland in an authentic environment indicated that at the first, second, and third tractor gear speeds and the fertilizer channel of 20%, the soil preparation capacity of the fertilizer applicator reached 0.324, 0.368, and 0.459 ac/h, the soil fertilization capacity approached 400.638, 316.294, and 253.035 kg/h, and the efficiency approximated 52%, 59%, and 80%, respectively.

II. Recommendations

1) Equipment to transfer fertilizer into the fertilizer tank should be incorporated.

2) The fertilizer spreader ought to be lengthened to enhance its mixing capacity.

3) It is advisable that the chain tensioner be changed to a roller bearing type since it has a prolonged service life.

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