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The efficiency of the broadcast seeder combined with the vertical disk plows

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Abstract

The development of agricultural machinery plays a vital role in enhancing production efficiency, reducing labor costs, and addressing challenges such as climate change and labor shortages. Designing machines capable of performing multiple operations simultaneously has become an essential approach for promoting sustainable rice cultivation. This research aimed to develop a broadcast seeder combined with vertical disk plows, and to evaluate its field performance. The machine was designed with a theoretical working width of 1.50 m and achieved an actual average working width of 1.25 m. Field experiments revealed that the machine operated at an average speed of 4.98 km/h, providing a theoretical field capacity of 4.55–4.83 rai/h and an effective field capacity of 4.23–4.60 rai/h, with high field efficiency ranging from 90.47%–99.56%. After four weeks of sowing, plant density was recorded at 124–182 plants/m², with reductions in germination and survival caused by environmental factors such as waterlogging and subsequent drought. The results confirm that the developed machine is efficient, suitable for use with over 40 HP of tractors, reducing labor and operational time, and payback period within 2-3 growing seasons. However, further improvements in speed control, seed distribution uniformity, and post-sowing field management are recommended to enhance crop establishment and ensure stable performance under diverse soil and environmental conditions. The current development of agricultural machinery is important, especially in developing countries. Agricultural machinery helps improve the efficiency of agriculture.

Keywords: Broadcast seeder, Disk plow, Field efficiency, Rice cultivation

1. Introduction

Rice (*Oryza sativa* L.) is a staple food crop for the global population, particularly in Asia, which accounts for more than 90% of both rice production and consumption worldwide [1]. In Thailand, rice is not only an important economic crop but also an integral part of the nation's culture and way of life. The country consistently ranks as the world's second-largest rice exporter [2]. Thailand exports more than 7.5 million tons of rice annually [3]. Rice cultivation in the country is predominantly based on transplanting and direct seeding systems, relying on both rainfall and irrigation. However, farmers continue to face several challenges, including climate change [4], pest outbreaks, and rising production costs. To address these issues, modern agricultural technologies such as agricultural machinery (e.g., automatic rice transplanters, fertilizer-spraying drones) and the development of drought-tolerant rice varieties have been introduced to improve production efficiency. The Northeastern region of Thailand is a major agricultural economic zone, with rice as the primary crop cultivated on more than 10 million rai [5]. Direct seeding is the principal method of rice cultivation in this region, as it is better suited to the local terrain and limited rainfall, particularly in provinces such as Khon Kaen, Udon Thani, and Nakhon Ratchasima, where sandy loam soils and high drought risk prevail [6]. However, farmers still face challenges from climate change, which has led to unpredictable rainy seasons, as well as pest outbreaks such as brown planthoppers [7]. Direct seeding in Northeastern Thailand offers advantages in terms of reducing labor and time compared to transplanting, but it requires efficient water and fertilizer management [8]. Modern technologies, such as centrifugal rice seeders and water-saving irrigation systems, have begun to be adopted to increase productivity. Studies have shown that farmers using mechanized equipment can reduce planting time by up to 50% [8]. In addition, the development of drought-tolerant rice varieties, such as Jasmine 105 and RD43, has enhanced production potential under dry conditions [5]. Farmers' cultivation practices have also shifted increasingly from traditional transplanting to dry direct seeding, as this method saves labor, time, and production costs. Dry direct seeding involves broadcasting un-germinated rice seeds directly into prepared fields before the onset of the rainy season. Another factor contributing to the growing adoption of dry direct seeding is the expansion of larger paddy fields, as farmers are required to adjust their fields to accommodate agricultural machinery used in rice farming, such as tractors for land preparation and combine harvesters.

At present, various labor-saving machines for rice cultivation have been developed to address the shortage of agricultural labor. Such machines are capable of operating more rapidly, while also ensuring proper planting distance, depth, and uniformity. This facilitates easier crop management and harvesting. Several related studies on the development of labor-saving machinery for rice farming are summarized as follows: Development and performance evaluation of a precision seeder for sustainable rice cultivation found that the precision hill paddy seeder offers a sustainable solution to rice cultivation challenges, cutting costs by 25% and boosting yields by 7.7% compared to traditional methods [9]. The developed power-operated paddy hill seeder demonstrates efficient performance with quality feed indexes up to 91.1%, field capacities of 0.22-0.26 ha/h, and operational efficiencies of 76-80%, offering a viable mechanized solution to labor challenges in Indian rice cultivation [10]. The 8-row self-propelled planter delivers reliable field performance with consistent plant density (soil-independent but hopper-dependent) when using 24h pre-germinated seeds at 2.5 km/h [11]. While mechanical rice transplanters offer superior efficiency and agronomic benefits, their adoption remains limited by high costs and technical knowledge gaps - addressing these through training, accessible rental systems, and improved designs could accelerate uptake [12]. Precision agriculture leverages IoT, drones, and AI to optimize yields sustainably, though challenges remain in data management, adoption costs, and technology integration for widespread implementation [13]. IoT-enabled smart farming enhances agricultural productivity through real-time monitoring and precision inputs, though widespread adoption requires addressing cost barriers, data security concerns, and improving farmers' digital literacy [14]. Furrow ridging fertilization (FRF) significantly boosts grain yields (6.04–28.25%) and enhances lodging resistance in mechanically direct-seeded rice by improving stem strength and biomass production, outperforming surface and whole-layer fertilization methods [15]. The newly developed 15kg drum seeder offers Bangladeshi farmers a cost-effective (USD 18.15) and efficient seeding solution with optimal 86.33 kg/ha seed rate at 1/4 drum capacity, addressing spacing accuracy challenges in direct-seeded rice systems [16]. South China Agricultural University's precision hill-drop drilling technology demonstrates significant advantages in labor savings, yield improvement, and seed efficiency, offering strong potential for advancing mechanized direct-seeded rice cultivation in China [17]. The power-operated paddy seeder effectively reduces labor demands while maintaining comparable yields to transplanted rice, offering superior performance to broadcast methods through controlled seeding rates and line-sowing precision [18]. The AE Bed Form Planter system demonstrated superior field performance (higher capacity, lower fuel use) and cost-efficiency (318,034 THB/year savings) compared to the Double Disc Opener system, despite marginally lower germination rates, making it ideal for large-scale soybean-sugarcane rotation [19]. The moldboard plow demonstrated superior performance with deeper tillage (0.30m), higher weed control (82%), and lower operating costs (7,106.81 THB/year) compared to the disk plow, despite slightly higher fuel consumption (7.59 vs 7.20 l/h) [20]. From the studies reviewed above, it was found that agricultural machinery costs should be reduced by redesigning the equipment to be more user-friendly, thereby improving operational efficiency. This is particularly important in developing countries, where simplified designs can help overcome barriers related to technical knowledge and cost-effectiveness.

This study focuses on the development of a rice broadcast seeder combined with a 7-disk plow, targeting small- to medium-scale farmers. The machine is designed for tractors within the 35–50 HP range, which represents the most suitable specification for its intended operation. Therefore, this research is to 1) develops a broadcast seeder combines with the vertical disk plows that enables simultaneous plowing and seed distribution, reducing labor demand, seed rate, and production costs while improving time efficiency. 2) tests efficiency. Focusing on reducing labor costs and increasing productivity. To enable quick operations, reduce labor in sowing rice seeds, save seeds and fuel. And it is a way to make better use of the existing tools. The development of this integrated rice seeder will elevate Thai agriculture by reducing labor costs and increasing productivity. Solve the labor shortage problem and serve as a database for the development of smart farming according to the Thailand 4.0 policy, especially in the country's main rice-growing areas.

2. Materials and methods

2.1 develops broadcast seeder combines with the vertical disk plows

The development began with designing the seed metering disc to rotate smoothly in order to ensure uniform seed distribution. The seed hopper had a maximum capacity of 50 kg. For the drive wheel, initial design and field tests were conducted. It was observed that in soft soil conditions, the tractor's rear wheel compressed the soil surface, creating deep ruts that prevented the drive wheel of the seeder from making contact with the ground, resulting in the seed metering system not operating. Based on these findings, a drive wheel with a diameter of 25.5 cm was adopted. A roller bearing (shielded on both sides) was selected to support the drive shaft, as the seeder operates in agricultural environments often exposed to dust, soil, mud, and debris, which can easily enter the bearing. The shielded bearing on both sides protects against contamination, thereby extending service life and reducing the frequency of maintenance [21].

For the seed delivery system, black steel pipes with a diameter of 1 inch were used, with five seed tubes installed. The outlets of the seed tubes were spaced approximately 25 cm apart. Seeds discharged from the metering disc fell through the seed guide channel and down the tubes, exiting at the outlets where they struck the plow frame and dispersed onto the soil surface. After the seeder was fully developed, it was mounted onto a 7-disk plow and its performance was evaluated. The main newly developed components are the seed disc assembly, the drive wheel with double-sealed bearings, and the seed tube. This differs from commercial machines, which often separate the functions of ploughing and seed sowing. The evaluation was divided into two phases: a laboratory test and a field test.

2.2 tests efficiency

2.2.1 Theoretical testing

This experiment aimed to determine the seed rate of the machine, to assess the extent of seed damage caused by machine operation, and to evaluate the germination percentage of rice seeds before and after passing through the broadcast seeder combined with a 7-disk plow. The procedures were carried out as follows:

1. The number of rice seeds discharged from the five seed tubes was determined using Jasmine 105 paddy seeds. The hopper was filled to 1/3, 1/2, and full capacity, respectively. Plastic bags were attached to the outlets of all five seed tubes to collect the discharged seeds. The drive wheel was then rotated for 100 revolutions, and the collected seeds were placed in plastic bags, weighed, and the number of seeds discharged from each tube was counted [22].

2. The proportion of broken seeds was determined by randomly sampling approximately 1,000 g of rice seeds obtained from Section 1 and separating those that were cracked or damaged to the extent that they could not germinate into normal seedlings, as Equation 1.

$$B = \frac{W_b}{W_w} \times 100 \quad (1)$$

Where; B is broken seeds (%), W_w is total seed weight (g), W_b is broken seed weight (g) [23].

3. The germination of rice seeds before and after passing through the broadcast seeder was evaluated. Seed samples were obtained by rotating the drive wheel of the seeder as described in Section 1, with 100 seeds collected per sample. Additionally, 100 seeds of Jasmine 105 rice that had not passed through the seeder were randomly selected as a control. All seed samples were sown in germination trays, and the number of normal seedlings was recorded. The germination percentage of seeds before and after passing through the seeder was then calculated according, as Equation 2.

$$G = \frac{N_g}{N_t} \times 100 \quad (2)$$

Where; G is Germination percentage, (%), N_g is germinated seeds (g), N_t is total seeds tested (g) [24].

4. The seed rate of rice was tested using the broadcast seeder combined with a 7-disk plow on a concrete, as shown in Figure 1. The plow disk was adjusted to slightly lift off the ground, while the drive wheel of the seeder was set to remain in contact with the floor. Paddy seeds were loaded into the hopper at 1/3, 1/2 and full capacity, respectively. The tractor was then operated in gear-5 to achieve a speed comparable to field conditions, with the seeder's drive wheel in contact with the ground, moving over a distance of 20 m. Seed samples were randomly collected within a rectangular frame measuring 0.67 m × 1.50 m (equivalent to 1 m²) at distances of 5 m, 10 m, and 15 m along the test track. The collected seeds were placed into plastic bags for further measurement. The detailed testing procedure is illustrated in Figure 2.

Figure 1 The rice seeder combined with a 7-disk plow on a concrete

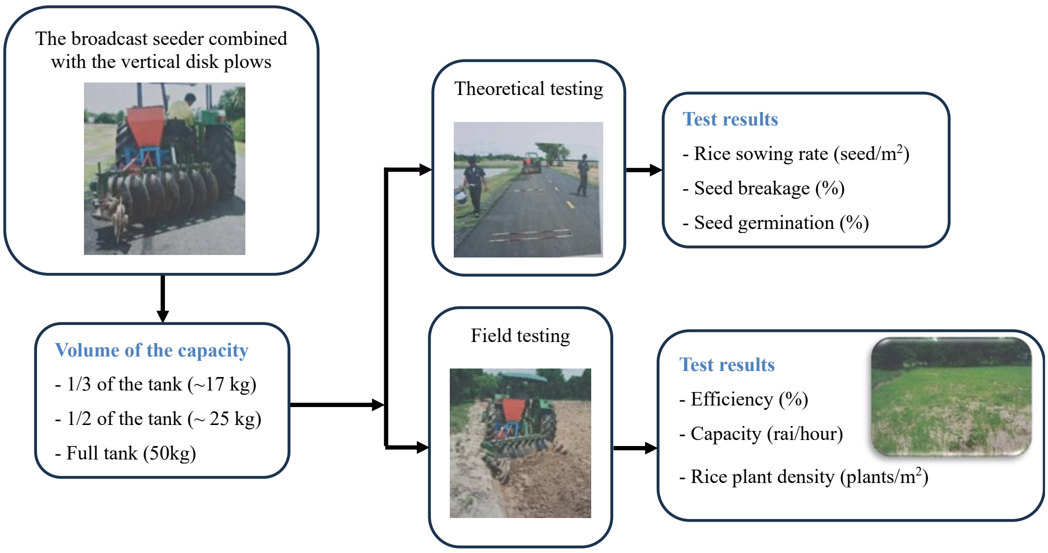


Figure 2 Flow chart of the test of the rice seeder combined with a 7-disk plow

2.2.2 Field testing

1. Soil moisture in the test plots was determined by collecting soil samples from five random locations within the experimental field. The samples were weighed and then oven-dried at 105 °C for 24 hours. After drying, the samples were reweighed, and the soil moisture content was calculated according to Equation 3. The characteristics of the experimental plots are as in Table 1.

$$M_w = \frac{(w_1 - w_2)}{w_1} \times 100 \quad (3)$$

Where; M_w is moisture content (%), W_1 is weight of sample before drying (g), and W_2 is weight of sample after drying (g) [25].

Table1 Planting plot information

Test area	Planting plot 1	Planting plot 2	Planting plot 3
Soil characteristics		Sandy loam	
Soil moisture during the test (%)	10.75	10.06	10.40
Rice variety		Khao Dawk Mali 105	
Field size (m^2)	34×76	34×76	58×82
Test field (rai)	1.61	1.61	2.97
Primary tillage equipment		7-Disk plow	

2. The efficiency and capacity of the rice broadcast seeder combined with a 7-disk plow were evaluated by operating the tractor in gear-5. The test included measuring the effective working area and the actual working width of the implement, while recording the total operating time (including both productive time and lost time) within the test field. Subsequently, the number of rice plants was counted to determine plant density and germination uniformity, and the seeding rate was analyzed according to Equations 4, 5, and 6. The detailed procedure of the test is illustrated in Figure 2.

$$\mathrm{C} = \frac{\mathrm{A}}{\mathrm{T_{th}} + \mathrm{T_f}} \quad (4)$$

Where; C is work capability (rai/h), A is work area (m^2), T_{th} is theory work time (sec), and T_f is work lost time (sec).

$$\mathrm{FE} = \frac{\mathrm{C}}{\mathrm{C_{th}}} \times 100 = \frac{\mathrm{T_{th}}}{\mathrm{T_{th}} + \mathrm{T_f}} \times 100 \quad (5)$$

Where; FE is work efficiency (%), C is work capability (rai/h), and C_{th} is theory work capability (rai/h).

$$N = \frac{P}{\mathrm{A}} \quad (6)$$

Where; N is number of rice plants (plants/m^2), P is rice plants (plants) [23].

3. Results and discussion

3.1 Instructions for the machine

The rice broadcast seeder combined with a 7-disk plow was mounted onto the three-point hitch of a tractor with a power rating of not less than 55 hp. As the tractor moved forward, the spring mechanism pressed the drive wheel against the ground, causing it to rotate and transmit motion through a chain drive to the seed metering disc. The rotating disc guided the seeds into the seed tube, where they were subsequently discharged through the seed outlets. The seeds then traveled down the delivery tubes and dropped onto the soil surface in front of the plow under the influence of gravity, as shown in Figure 3. The plow immediately followed by turning the soil to cover the seeds. The average moisture content of the paddy seeds used was 12.4%, which was within the recommended seed moisture level (≤13%) for successful cultivation [26].

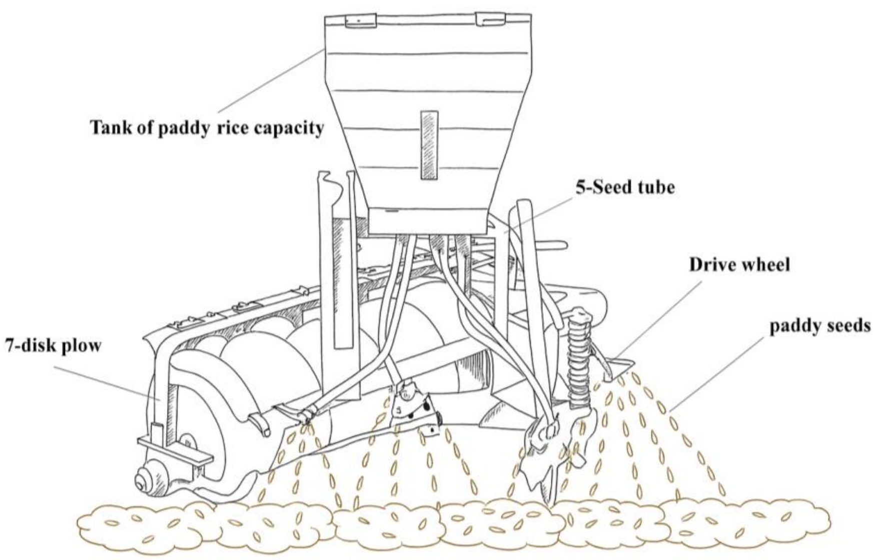


Figure 3 Mechanism for the operation of rice broadcast seeder combined with a 7-disk plow

3.2 Test Results

3.2.1 Theoretical test

Tables 2 and 3, the distribution of rice seeds using the broadcast seeder was evaluated with hopper filling levels of 1/3, 1/2, and full capacity. Within an area of 1 m², the average seed weight discharged from the five seed tubes was 2 kg, corresponding to a seed rate of 16.24 kg/rai. When sampling for seed breakage, the proportions of broken seeds were 1.04% (10.42 g), 0.93% (9.33 g), and 0.52% (5.17 g), respectively, all of which were below the threshold of 5% damage specified in the seed planter testing standard [27].

Seed germination tests showed that untreated rice seeds had a germination rate of 91.82%, while seeds passed through the machine had a rate of 90.90%. According to the standard, the minimum acceptable germination rate is ≤70%, ensuring satisfactory crop establishment and vigorous seedlings [27]. Furthermore, the distribution of rice seeds sown using the broadcast seeder combined with a 7-disk plow revealed average seed densities of 258.80, 293.40, and 324.20 seeds/m², respectively.

Table2 The weight of the paddy seed exiting the seed tube

Seed tube	Weight of the paddy seed (kg)		
	1/3 of the tank	1/2 of the tank	Full capacity
1	0.37	0.37	0.45
2	0.43	0.43	0.45
3	0.40	0.42	0.37
4	0.40	0.38	0.38
5	0.40	0.42	0.40
sum	2.00	2.02	2.05
mean	0.40	0.41	0.42
SD	0.03	0.03	0.05
max	0.43	0.43	0.45
min	0.37	0.37	0.37

Table 4, the statistical test results indicated no significant difference in the weight of rice seeds discharged from the tube at different filling levels ($p > 0.05$), suggesting that the filling factor may not influence seed weight under the conditions of this experiment. However, further studies with larger sample sizes are recommended to validate these findings.

Table3 The number of paddies seed that scatter on the ground

Volume	Number of paddy seed (seed/m^2)					mean	max	min	SD
	1	2	3	4	5				
1/3 of the tank	216	250	228	310	290	258.80	310	216	40.16
1/2 of the tank	286	275	330	280	296	293.40	330	275	21.90
Full capacity (≈50 kg)	375	406	280	290	270	324.20	406	270	61.91

Table4 ANOVA the variance of the paddy seed sowing rate

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	10704.93	2	5352.47	2.71	0.11^{ns}	3.89
Within Groups	23704.80	12	1975.40			
Total	34409.73	14				

Note: ns = non-significant (p > 0.05) difference,
*, ** and *** = significant differences at p < 0.05, < 0.01 and < 0.001, respectively.

3.2.2 Field Test

The soil in the experimental fields was classified as sandy loam with an average moisture content of 10.4%. Plots 1, 2, and 3 measured 1.61, 1.61, and 2.97 rai, respectively, which represented actual farmer fields in Surin Province (as shown in Table 1). From Figure 4, the speed of movement of the rice broadcast seeder combined with a 7-disk plow was found to be similar across the plots, ranging from 12 to 18 km/h, though variability differed. Plot 2 recorded the highest standard deviation (SD = 1.90), indicating greater inconsistency in operating speed, while Plot 3 showed the most stable performance (SD = 1.27), followed by Plot 1 (SD = 1.44). These results suggest that although the overall performance was comparable among the plots, the stability of operating speed depended on field conditions and the operator's control during each trial.

From Figure 5, the operational performance of the rice broadcast seeder combined with a 7-disk plow was evaluated. The theoretical working width of plowing was 1.50 m, while the actual average working width achieved was 1.25 m. The machine operated at an average speed of 4.98 km/h. The theoretical field capacities were 4.62, 4.55, and 4.83 rai/h, respectively, while the actual field capacities were 4.60, 4.23, and 4.37 rai/h, respectively. The corresponding field efficiencies were 99.56%, 92.96%, and 90.47%. It can be explained that the working efficiency of the machine tends to decrease as the plot size increases. This reduction is primarily due to higher time losses in larger plots, such as turning the machine, adjusting alignment, and handling more complex field management.

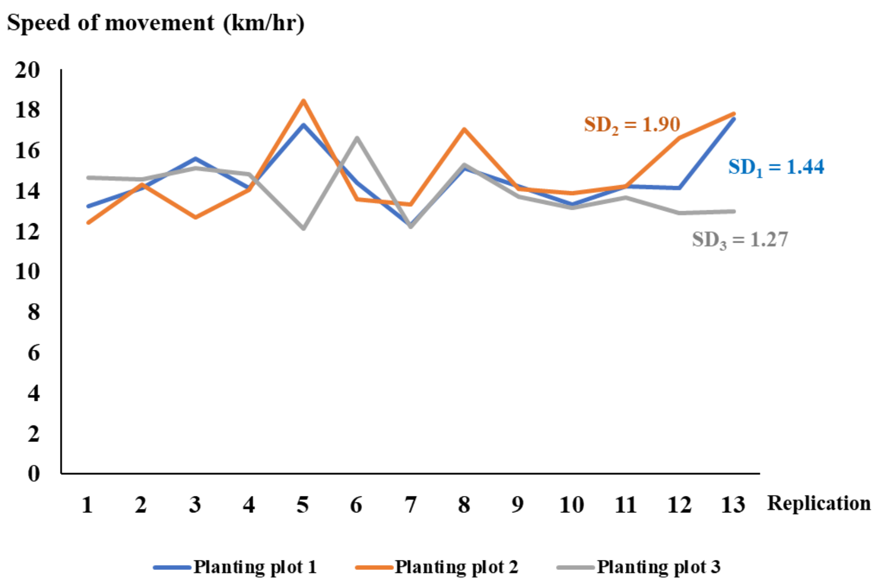
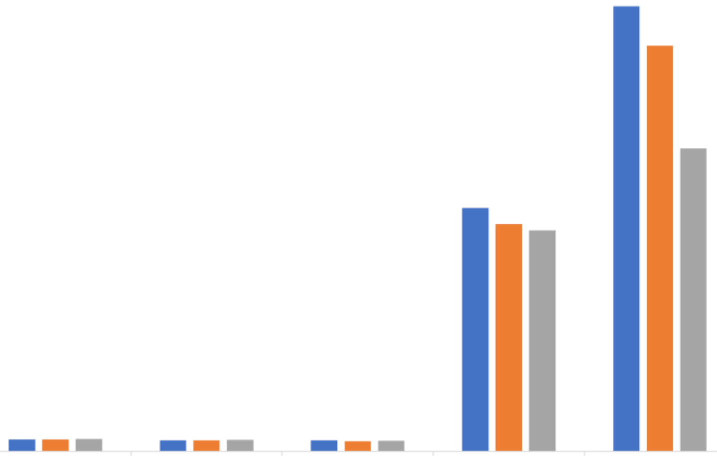


Figure 4 The tractor operating speed was measured over a distance of 20 m



	Speed of movement (km/hr)	Theoretical capacity (rai/hr)	Effective field capacity (rai/hr)	Field efficiency (%)	Number of rice plants (plants/m2)
Planting plot-1 (1.61 rai)	4.93	4.62	4.60	99.56	182
Planting plot-2 (1.61 rai)	4.86	4.55	4.23	92.96	166
Planting plot-3 (2.97 rai)	5.15	4.83	4.37	90.47	124

Figure 5 The working efficiency of the rice seeder combined with a 7-disk plow in field test

Regarding plant density after sowing with the developed machine, waterlogging occurred in the field, which reduced germination rates due to seed decay. Subsequently, four weeks after sowing, a dry period without rainfall led to the death of some seedlings. Plant density was determined using a rectangular quadrat of 0.67 m × 1.50 m (1 m²), which covered the working width of the machine. The recorded densities were 182, 166, and 124 plants/m², respectively. Which is consistent with the research of Kumar KA, et al [28] The study presents the design and evaluation of a seed drill attachment for groundnut sowing, developed as a low-cost unit fitted to a tractor-drawn cultivator. The cup-feed mechanism with nine discs (each having 16 cups) ensures precise seed placement at a row spacing of 9 inches without seed damage. Field trials suggest that to achieve an optimum seed rate of 86 kg/ha, the tractor should operate at a speed of 4–6 km/h [28]. The rice broadcast seeder combined with a 7-disk plow demonstrated high operational efficiency, with actual performance closely matching theoretical values. Its design is well-suited for farmers who already own tractors and seven-disc plows, thereby reducing investment costs and facilitating convenient storage during idle periods. Moreover, the operating speed is consistent with previous research, aligning with the optimal range recommended for precise seed broadcasting.

4. Conclusions

The development of a rice broadcast seeder combined with a 7-disk plow was carried out with the aim of enabling simultaneous plowing and seed broadcasting, thereby reducing both conditions commonly encountered by local farmers. The developed machine reduced working time by approximately 45–50% compared to separate broadcasting and plowing operations, while labor costs decreased by about 30–35%. suitable for use by smallholder farmers. However, seed germination and seedling survival were affected by environmental factors such as waterlogging and drought. The developed machine demonstrated high efficiency, proving to be suitable for practical use in farmers' fields and capable of significantly reducing labor and production costs. It is recommended to make further improvements, such as the distance between seed tubes, the size of the drive wheels, and the design of the seed plates. Including speed control, uniformity of seed distribution, and post-sowing field management to enhance machine performance and achieve higher-quality crop yields.

5. Acknowledgements

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