Development and performance test of a mechanical rice weeder attached to a narrow steel-wheeled tractor

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Abstract: A narrow steel-wheeled tractor was modified from a conventional rubber tire-wheeled tractor to facilitate the attachment of a chemical sprayer for paddy field use. A mechanical rice weeder was designed to attach to the tractor's three-point hitch system, aiming to minimize environmental impacts. The developed mechanical weeder, 2 m wide×1.2 m long×1 m high, was attached to a narrow steel wheel tractor. It was designed to operate in 30-cm row spacing, working seven rows simultaneously. In the test results from 2, 40, and 60-day-old rice plants, the field capacities were 0.29, 0.29, and 0.35 hm²/h, resulting in 49.88%, 41.83%, and 44.62% field efficiencies, respectively. The weeding efficiencies were 61.36%, 63.68%, and 86.03%, while the average plant damage factors were 10.38%, 7.51%, and 4.85%, respectively. The fuel consumption was 7.02, 7.44, and 7.06 L/hm², respectively. The slippage of the tractor was relatively high, at 27.33% and 27.12% for the 20- and 40-day-old rice plants, but was reduced to 10.56% after increasing the contact area of the narrow steel wheels for the 60-day-old rice plants. The performance index 1038.41 for the 60-day-old rice plants was the highest, attributed to a higher forward speed, compared to 305.84 for the 20-day-old and 460.33 for the 40-day-old rice plants.

Keywords: mechanical weeder, narrow steel wheel tractor, rice weeding

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1 Introduction

Rice is a significant global carbohydrate source, especially in Asia. Thailand, the world's second-largest rice exporter, has a fifth of its arable land under rice cultivation[1]. Weeding needs sufficient care to avert any negative effect on yield and quality. Hasanuzzaman et al.[2] reported that weeds decreased crop yields from 15% to 50% depending on the species, density, and weeding time. Weeding is costly and labor-intensive, requiring 10 to 15 person-days per hectare and amounting to 21.6% of rice production cost[3]. The movement of workers from rural to urban areas has led to the use of chemical sprayers and mechanical weeders to meet labor demand. However, mechanical weeder development should be fast-tracked to overcome environmental degradation and ensure food safety by employing non-chemical methods for weed control.

Various researchers have developed mechanical weeders. The Cono-weeder is a mechanized weeding (manual) method, capable of weeding about 0.18 hm²/d [4]. Parida[5] modified the IRRI conical weeder, evaluated its performance in paddy fields, and reported that under experimental conditions, the field capacity was 0.2 hm²/h, while the field efficiency was 80%. Other relevant studies show that applying a weeder will increase the field capacity and decrease the time and cost of the operation[6,7]. Manuwa et al.[8] designed and developed a power weeder with a working width of 0.24 m for weeding row-crop planting. Test results show that the machine's field capacity, fuel consumption, and field efficiency are 0.53 hm²/h, 0.7 L/h, and 95%, respectively. Fazlolallh et al.[9] researched to compare two mechanical weeders in rice: a mechanical weeder with engine power and a mechanical weeder without engine power. They reported that both provided effective and economical weed control, resulting in good yield. Victor and Verma[10] designed and developed a power-operated rotary weeder for wetland paddy using a 0.5 hp petrol-driven engine with a reduction gearbox. They concluded that with 200 mm spacing, the field capacity varied between 0.04-0.06 hm²/h, and weeding efficiency was 90.5%. Keshavalu et al.[11] reported that the weeding operation cost savings using a power weeder compared to manual weeding was 63.62%. Ragesh et al.[12] confirmed that the affordability and adjustability of a mechanical weeder, concerning operational cost and energy consumption, promote the necessity of mechanized weeding. Operational difficulties and slow weeding rates may lead to significant drawbacks with this weeder, particularly in large-scale cultivation. Therefore, the primary aim of this study was to develop a mechanical weeder for paddy fields that can be attached to a tractor with modified narrow steel wheels commonly used for current chemical spraying.

2 Materials and methods

2.1 The developed mechanical rice weeder

The mechanical rice weeder was designed to be used with a narrow steel wheel tractor typically used for chemical spraying. The developed weeder consisted of the main structural frame with a

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three-point hitch that can be attached to a tractor, a supporting bar for installing seven weeding sets, and a spring rake set. Its overall size was 2 m wide×1.2 m long×1 m high and designed for a 30 cm row spacing paddy field capable of seven inter-rows (six plant rows) at a time. The weeding set comprised a parallel mechanism frame with a coil spring, two tandem drums for removing weeds, and a leveling plate with a plant row opener. One drum had a tooth configuration, as proposed by Usaborisut et al.[13]. Based on the results of previous research that weeding efficiency depended on weight and number of weeder passages[13], the parallel mechanism frame was designed for vertical loading adjustment up to 400 N by spring coil and vertical movement of 15 cm, as shown in Figure 1.

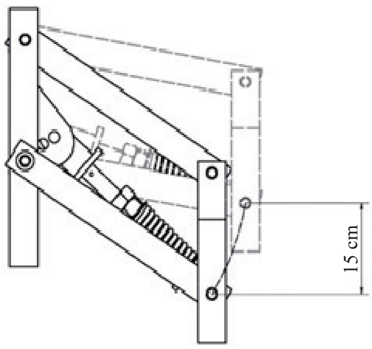

Figure 1 Parallel mechanism frame for vertical loading adjustment

The designed configuration of coil springs on a parallel mechanism helped maintain the vertical loading as constant as possible throughout the lifting distance. Figure 2 shows the changing characteristics of vertical load with the lifting distance of the weeding set. The configuration design could maintain vertical loads ranging from 200.0 to 247.6 N and 400.0 to 451.9 N, along with increasing the lifting distance to 15 cm at both the 200 and 400 N settings at the spring coils.

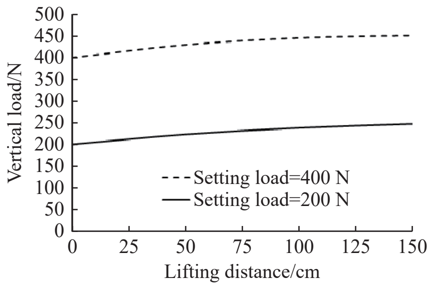

Figure 2 Characteristics of vertical load throughout the range of lifting distances

The device used a spring rake to weed the rice plant row, which was comprised of spring wires with a spiral coil at the base. A spring wire was designed based on pre-test results to find the forces necessary for damaging rice plants and uprooting weeds from the soil. The force damaging rice plants of 28.7±6.7 cm height was 62.4±14.5 N, while it was only 9.6±7.4 N for uprooting weed grass, 29.7±2.6 cm height, out of the soil. The designed spring wire was 3.58 mm in diameter and 40 cm in length. Pre-test results indicated that the spring wire could uproot weed grass out of the soil at a depth of 10-15 cm, in which the measured forces were 23.6±5.2 N and 33.7±10.4 N, respectively. The final designed spring rake consisted of six sets of eight spring wires. The developed mechanical weeder is shown in Figure 3.

2.2 The narrow steel wheel tractor

The narrow steel wheel tractor used in this study was a conventional rubber wheel tractor (Kubota B2420, 24hp). The original purpose of modification was to attach a paddy field chemical boom sprayer, as its narrow wheels can travel in paddy fields without destroying the rice plants. After conversion, the specifications changed as follows: weight: 820 kg in total, 515 kg at the front and 305 kg at the rear; wheel width: 10 cm; front- and rear-wheel radii: 49 and 74 cm, respectively; center of gravity: 98.16 cm longitudinally ahead and 4.95 cm vertically above the rear axis. The narrow steel wheel tractor with the developed weeder attached is shown in Figure 4.

Figure 3 Developed mechanical weeder

Figure 4 Narrow steel wheel tractor with the developed weeder

2.3 Field test of weeder

The developed mechanical weeder was evaluated in paddy fields with 20-, 40-, and 60-day-old rice plants, in which a six-row transplanter transplanted rice seedlings with an inter-row spacing of 30 cm. The two fields of 20-day-old rice plants were 2672 and 2800 m^2 in area size with an average plant height of 10.59±0.48 and 8.31±1.02 cm, respectively. The first field had been a paddy field for more than ten years, while the second was an agricultural machinery testing area. Testing of 40-day-old rice plants with an average height of 30.71±1.50 cm was done at the 2800 m^2 field. The field test was continued with 60-day-old rice plants with an average height of 42.42±1.70 cm, using the tractor with wheel modification. The related data were recorded and calculated for travel speed, field capacity, draft, weeding efficiency, and performance index.

The soil in the experimental plots was clay, typical of the Thai central region. Such conditions represent many rice-growing areas in Thailand, making the results applicable to a broader agricultural perspective. The plots also contained common Thai weeds, including barnyard grass (*Echinochloa crus-galli* (L.) T. Beauv.), cyperaceae (*Cyperus rotundus* L.), and red sprangletop (*Leptochloa chinensis* Nees). Among these, *Cyperus rotundus*, commonly known as purple nutsedge, presented the most significant challenge due to its deep root system and underground tubers, which store nutrients and enable regeneration even after above-ground cutting.

Speed of travel:

A 10 m field length was measured and marked to calculate the travel speed; the time to cover this distance was noted by using a stopwatch.

Field capacity:

The field capacity of a weeder (*S*) is the coverage of the actual area divided by the total time taken. According to RNAM Test Codes[14], the field capacity (hm²/h) is given by

$$FC = \frac{A}{T_p + T_l}\% \tag{1}$$

where, A is area covered, hm²; T_p is productive time, h; T_l is non-productive time, h.

Field efficiency (F_e) is the percentage of productive time compared to the total time.

$$F_e = \frac{T_p}{T_p + T_l} \times 100\% \tag{2}$$

Draft of weeder:

The draft of the weeder was measured by three-pin transducers installed at three-point hitches.

Weeding efficiency:

Weeding efficiency (W_E) is the ratio of the number of weeds destroyed compared to the number before weeding an area of 0.3×1.0 m, and is calculated by the following equation[15]:

$$W_E = \frac{N_1 - N_2}{N_1} \times 100\% \tag{3}$$

where, N_1 is the number of weeds before weeding; N_2 is the number of weeds after weeding.

Damaged plants:

The percentage of damaged plants (DP) during field operation was calculated using the following equation[16]:

$$DF = \frac{Q_2}{Q_1} \times 100\% \tag{4}$$

where, Q_1 is the number of plants in a 10 m row length before weeding; Q_2 is the number of plants in a 10 m row length after weeding.

Performance index:

The performance index of the weeder was calculated by using the following equation[16]:

$$PI = \frac{FC \times W_E \times (100 - DF)}{P} \tag{5}$$

where, P is power input calculated by draft and speed of travel, kW.

Fuel consumption:

The fuel consumption was measured by the top-fill method. Before testing, the fuel tank was filled to its total capacity. After completion of the test operation, the amount of fuel required to top-fill was fuel consumption.

3 Results and discussion

For testing the 20-day-old rice plants with average soil moisture contents of 36.56% and 29.09%, an average bulk density of 1.35 and 1.46 kg/m³ in the 2672 and 2800 m² fields, respectively. The narrow steel-wheeled tractor operated at average speeds of 3.29 and 3.32 km/h and average slips of 28.00% and 27.33%, respectively (Table 1). From Table 2, the field efficiencies were 36.65% and 49.88%, while field capacities were 0.26 and 0.29 hm²/h, respectively. The drawbar pull and power were 2.29 kN and 2.09 kW in the first field, and 4.23 kN and 3.89 kW in the second field, respectively. The fuel consumption was 1.89 and 2.04 L/h or, equivalently, 7.27 and 7.02 L/hm², respectively, in both fields. The dominant weed in the 2672 m² field was barnyard grass, with an average density of 662.23 plant/m² and a height of 5.86 cm. The weeds in the 2800 m² field were barnyard grass, small flower umbrella sedge, and jointvetch, of which the average density and height were 251.10 plants/m² and 7.24 cm, respectively. Weeding efficiencies were 91.26% and 61.36%, while average plant damage factors were 1.56% and 10.38%, respectively. Performance indices were 833.66 and 305.84, respectively.

Table 1 Field properties and working results weeding the 20-day-old rice plants

Field	Area/m²	Soil moisture content/%	Bulk density/kg·m⁻³	Travel speed/km·h⁻¹	Slip/%	Drawbar pull/kN	Drawbar power/kW	Fuel consumption/L·hm⁻²
1	2672	36.56±6.04	1.35±0.32	3.29±0.22	28.00±4.80	2.29±0.86	2.09±0.79	7.27
2	2800	29.09±2.58	1.46±0.08	3.32±0.20	27.33±4.47	4.23±1.09	3.89±1.00	7.02

Table 2 Working performances and efficiencies in weeding the 20-day-old rice plants

Field	Field efficiency/%	Field capacity/hm²·h⁻¹	N_1	N_2	Weeding efficiency	Q_1	Q_2	Damage factor	Performance index
1	36.65	0.26	198.67±19.63	17.33±18.04	91.26±8.57	63.00±1.73	1.00±1.00	1.56±1.56	833.66
2	49.88	0.29	75.33±19.73	61.36±8.66	61.36±8.66	5.67±1.53	10.38±2.23	10.38±2.22	305.84

In the 2800 m² field, the average soil moisture contents were 33.52% and 32.92%, and the average bulk densities were 1.51 and 1.48 kg/m³ of 40- and 60-day-old rice plants, respectively (Table 3). On testing the 60-day-old rice plants, the tractor had a higher speed than while testing the 40-day-old rice plants. Consequently, the tractor slip was more than 50% higher for the 60-day-old rice plants, at 10.56%, compared to 27.12% for the 40-day-old rice plants. Also, the drawbar pull, power, and fuel consumption were lower, at 1.99 to 3.04 kN, 2.07 to 2.81 kW, and 7.06 to 7.44 L/hm², respectively, compared to the 40-day-old rice plants. The field efficiencies were 41.83% and 44.62%, while the field capacities were 0.29 and 0.35 hm²/h on testing the 40- and 60-day-old rice plants, respectively (Table 4). The fuel consumptions were 2.16 and 2.47 L/h, corresponding to 7.44 and 7.06 L/hm², respectively, for the 40- and 60-day-old rice plants. The weeding efficiency for the 60-day-old rice plants was 86.03%, higher than the 63.68% observed for the 40-day-old rice plants. Also, the damage factor was lower, at 4.85%, compared to 7.51% when weeding the 40-day-old rice plants. The performance index was consequently higher when weeding the 60-day-old rice plants.

The mechanical weeder developed in this study had field capacities in the range of 0.26-0.35 hm²/h, which were higher than the manual Cono-weeder (0.18 hm²/d), IRRI conical weeder modified by Parida[5] (0.2 hm²/h), and the small-scale power weeder of Hegazy et al.[17] (0.119 hm²/h), but less than a power weeder of Manuwa et al.[8] (0.53 hm²/h). One of the factors associated with field capacity is field efficiency. The field capacity of Manuwa's weeder was high, at 95%, compared to the developed weeder, approximately 43%. Since the narrow steel wheel tractor used in this study had large rear wheels, the steering was strenuous, resulting in more time to complete turning maneuvers. During its narrow turning radius, the front wheels often lifted off the ground even with ballast weight as the large wheels stuck, and the high torque turned up the tractor body. This narrow steel wheel tractor operation may have had higher field efficiency in a large field, as the large turning radius could be managed better. With few small, thin lugs, the narrower steel wheel tractor performed under a high slippage of about 27%, but when contact area was increased by using a chain around the wheel, the slippage was reduced to about 10%.

Table 3 Field properties and working results weeding 40- and 60-day-old rice plants

Rice plant age/d	Soil moisture content/%	Bulk density/kg·m^{-3}	Travel speed/km·h^{-1}	Slip/%	Drawbar pull /kN	Drawbar power/kW	Fuel consumption/L·hm^{-2}
40	33.52±3.36	1.51±0.05	3.33±0.09	27.12±1.86	3.04±0.97	2.81±0.02	7.44
60	32.92±0.59	1.48±0.05	3.74±0.13	10.56±3.21	1.99±1.14	2.07±1.18	7.06

Table 4 Working performances and efficiencies in weeding the 40- and 60-day-old rice plants

Rice plant age/d	Field efficiency/%	Field capacity/hm^2·h^{-1}	N_1	N_2	Weeding efficiency	Q_1	Q_2	Damage factor	Performance index
40	41.83	0.29	121.00±16.14	43.60±15.31	63.68±13.80	57.60±3.65	4.40±2.88	7.51±4.63	460.33
60	44.62	0.35	37.00±15.34	5.50±7.55	86.03±21.70	44.25±4.35	2.00±2.45	4.85±6.27	1038.41

The weeding efficiencies from the developed weeder ranged from 61.36-91.26%, showing similar values to previous research. Ragesh et al.[12] conducted a power weeder field performance evaluation. They showed that the paddy power weeder manifested a higher weeding efficiency of 74.22% compared to the Ambika paddy weeder efficiency of 63.04% for 20-day-old rice fields. The power weeder showed the highest result of 86.00% for 45-day-old rice fields. The performance index of the weeder is directly related to the field capacity, plant damage, and weeding efficiency and is inversely associated with the power exerted. This study found the highest performance index in operation on the 60-day-old rice field, where the tractor had been modified with increased contact area. This made the tractor work with less slippage and high travel speed, coinciding with the recommendation of Mohan et al. [18], who observed that the performance index increased with the increase in forward speed.

4 Conclusions

The main parts of the weeder included drums set for weed removal with leveling, a rice row opening set, and a spring rake set for removal of the weeds close to rice straws. Its overall size was 2 m×1.2 m×1 m. It was designed for a 30 cm row spacing paddy field capable of seven inter-rows (six plant rows) using two tandem drums set with adjustable load and a spring rake set for weeding. In the performance tests using 20-, 40-, and 60-day-old rice plants, field capacities ranged from 0.29-0.35 hm^2/h. Although field capacities were relatively low, at 41.83-49.88%, this was due to steering difficulty at the headland. The weeding efficiencies were 61.36%, 63.68%, and 86.03%, similar to previous research. With travel speeds of 3.32-3.74 km/h, the drawbar pull and power ranged from 1.99-4.23 kN and 2.07-3.89 kW, respectively. With few small thin lugs, the narrow steel wheel tractor performed under a high slippage of 27.33% and 27.12% at the 20- and 40-day-old rice plants, but when the contact area was increased, by using a chain around the wheel, the slippage was reduced to about 10% for the 60-day-old rice plants. Increasing the contact area also resulted in the highest performance index, at 1038.41, for the 60-day-old rice plants, compared to before modification, at 305.84 and 460.33 for the 20- and 40-day-old rice plants, respectively.

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[References]

[1] Office of Agricultural Economics (OAE). Journal of Agricultural Economics. Ministry of Agriculture and Cooperatives, Bangkok, Thailand, 2022; pp.56. https://www.oae. go.th/assets/portals/1/files/journal/2566/OAE 795Web.pdf. Accessed on [2023-03-20]

[2] Hasanuzzaman M, Fujita M, Islam M N, Ahamed K U, Nahar K. Performance of four irrigated rice varieties under different levels of salinity stress. Int J of Integrative Biology, 2009; 6: 85–90.

[3] Haq K A, Islam M D. Performance of indigenous hand weeders in Bangladesh, Agric. Mechanization in Asia, Afr. Latin Am., 1985; 4: 47–50.

[4] Ratnaweera A, Rajapakse N, Ranasinghe C, Thennakoon T, Kumara R, Balasooriya C K, et al. Design of power weeder for low-land paddy cultivation. International Conference on Sustainable Built Environment, Kandy, 2013. Accessed on [2010-13-14]

[5] Parida B C. Development and evaluation of star-cum conoweeder for rice. Agric. Mechanization in Asia, Afr. Latin Am., 2002; 33(3): 21–22.

[6] Gite L P, Yadav B G. Optimum handle height for a push-pull type manually operated dry land weeder. Ergonomics, 1990; 33(12): 1487–1494.

[7] Kumar V J F, Durairaj C D, Salokhe V M. Ergonomic evaluation of hand weeder operation using simulated actuary motion. Int. Agric. Eng. J., 2000; 9(1): 29–39.

[8] Manuwa S I, Odubanjo O O, Malumi B O, Olofinkua S G. Development and performance evaluation of a row-crop mechanical weeder. J. Eng. Appl. Sci., 2009; 4(4): 236–239.

[9] Fazlollah E C, Bahrami H, Asakereh A. Evaluation of traditional, mechanical and chemical weed control methods in rice fields. AJCS, 2001; 5: 1007–1013.

[10] Victor V M, Verma A. Design and development of power-operated rotary weeder for wetland paddy. Agricultural Mechanization in Asia, Africa and Latin America, 2003; 34(4): 27–29.

[11] Keshavalu, Patil B, Raghavendra V, Khan S. Performance evaluation of wet land power weeder for paddy. Asian Journal of Agricultural Extension, Economics & Sociology, 2017; 18: 1–8. DOI: 10.9734/AJAEES/2017/34910.

[12] Ragesh T, Jogdand S, Victor V. Field Performance Evaluation of Power Weeder for Paddy Crop. Current Agriculture Research Journal, 2018; 6: 441–448.

[13] Usaborisut P, Sukcharoenvipharat W, Thanpattranon P. Development and evaluation of a pulling-type mechanical weeder for paddy fields. IAEJ, 2017; 26(4): 33–37.

[14] Economic and Social Commission for Asia and the Pacific Regional Network for Agricultural Machinery. RNAM Test Codes & Procedures for Farm Machinery, Technical Series No. 12, 1983.

[15] Remesan R, Roopesh M S, Remya N, Preman P S. Wetland paddy weeding-A comprehensive comparative study from south india. Agricultural Engineering International: the CIGR Ejournal. Manuscript PM 07 011. Vol. IX, 2007.

[16] Gupta C P. Report on weeders. Regional Network for Agricultural Machinery, Manila, Philippines, 1981.

[17] Hegazy R A, Abdelmotaleb I A, Emara Z M, Okasha M H. Development and evaluation of small-scale power weeder. Misr J. Ag. Eng., 2014; 31: 703–728.

[18] Mohan S, Sanjana G K, Kumar D A. Evaluation of performance parameters of power weeder. International Journal of Chemical Studies, 2019; 7: 1760–1764.