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The performance of rotary power tiller using prototype rotary blades in dry-land field

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Abstract: The effect of shape of prototype rotary blades on the performance of rotary power tiller was investigated in this study. Three sets of rotors, i.e. 14-blade rotor of the Japanese C-shape blade (4.5 cm tilling width of one blade; T1), 14-blade rotor of the prototype rotary blade no. 1 (4.5 cm tilling width of one blade; T2), and 10-blade rotor of the prototype rotary blade no. 2 (6.5 cm tilling width of one blade; T3) were used. The tests were conducted in a dry-land field of clay loam with soil moisture content of 16.04 % (d.b.) and dry bulk density of 1.51 g/cm3 at different rotational speeds of 300, 350 and 400 rpm at one and two tilling passes. For all rotors, experimental results showed that the mean soil clod diameter decreased and soil inversion increased with increasing rotational speed of the rotor. The mean soil clod diameter decreased at pass 2. Soil inversion during pass 2 was higher than pass 1. However, the three sets of rotors showed no significant difference on mean soil clod diameter and soil inversion. The shape of blade prototype rotary blade no. 1 and the decreasing number of prototype rotary blade no. 2 did not affect the tillage performance as compared with the Japanese C-shaped blade.

Keywords: prototype rotary blade, rotary power tiller, mean soil clod diameter, soil inversion

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Introduction

Rotary tiller is advantageous over the conventional implement (i.e. moldboard plow and rake) due primarily to the main effect of the direct application of power to the soil-engaging tool rotating around a horizontal-transverse axis. Two benefits of the direct application effect are: (i) rotary tiller achieves both plowing and harrowing in a pass of machine on the field, and (ii) the reduction in traction demanded of tractor driving wheels due to the ability of the soil-working blades to provide some forward thrust [1]. In Thailand, rotary power tillers have been imported since 1943 [2] and have become popular until now. The number of two-wheel tractors in the country has increased over the years. In 2005, 2.1 million two-wheel tractors were reported [3], and they have tended to increase every year. Consequently, rotary tillers attached to a two-wheel tractor were developed by Senanarong and Sngiamphongse [4], and Niyamapa and Rangdaeng [5]. Ruangrungchaikul reported that numerous imported farm tractors appeared with rotary tillers, but nowadays Thai farmers use both the imported rotary tillers and the locally made rotary tillers in the field [6]. However, the rotary blades, i.e. Japanese C-shaped blade, European L-shaped blade, and European C-shaped blade produced in Thailand, which were originally designed by foreign companies work ineffectively in local conditions. Among the three imported designs, the Japanese C-shaped blade uses the highest specific tilling energy. The impact characteristic of torque, which causes severe vibration of the operating machine, is found in both of the European blades [7].

Recently, prototype rotary blades with 15°, 30°, and 45° lengthwise slice angle for power tiller were developed by Chertkiattipol and Niyamapa (unpublished). The lengthwise blade portion of the prototype rotary blades was designed to be straight and lean against the soil surface level. It was the first-tilling portion to reduce the impact force. The tilling width of the three prototype rotary blades was designed to be 6.5 cm to reduce the specific tilling energy. The shape of the prototype rotary blades was designed to simplify the manufacturing process of the rotary blades.

The rotary blade prototype with 15° lengthwise slice angle and 6.5 cm tilling width of blade was therefore selected for further study in the field. This paper reports on the effect of the blades on mean soil clod diameter and soil inversion.

Materials and Methods

Experimental site

Three sets of rotary power tillers were tested for their performance in the experimental field at the Agricultural Engineering Department, Kasetsart University, Khampaeng Saen Campus, Nakhonpathom. The experimental site was tilled by the vertical disk plow and harrowing in September 2006, and was abandoned until the experimental operations were conducted in August 2007. The weeds were cut by a mower before doing the experiments. The soil type at the experimental site was clay loam, consisting of 30.43% sand, 41.73% silt, and 27.84% clay. The liquid limit (LL) of soil was 34.5% and the plastic limit (PL) was 23.7%. The soil average moisture content and the dry bulk density of top soil at the depth 0-15 cm were 16.04% (d.b.) and 1.51 g/cm^3 respectively. The cone index was 1.14 MPa. The cohesion and the angle of internal friction of soil were 19.00 kPa and 40.80° respectively, while the soil adhesion and the angle of soil-metal friction were 4.24 kPa and 14.91° respectively.

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Rotary blades used in field experiment and attachment of rotary blades to the rotor shaft

Three types of rotary blades, viz. the Japanese C-shaped blade (4.5-cm tilling blade width), the prototype rotary blade no. 1 (15° lengthwise slice angle, 4.5-cm tilling blade width), and the prototype rotary blade no. 2 (15° lengthwise slice angle, 6.5-cm tilling blade width), were installed on the rotor shaft. Figure 1 shows the blade fitting for each type.

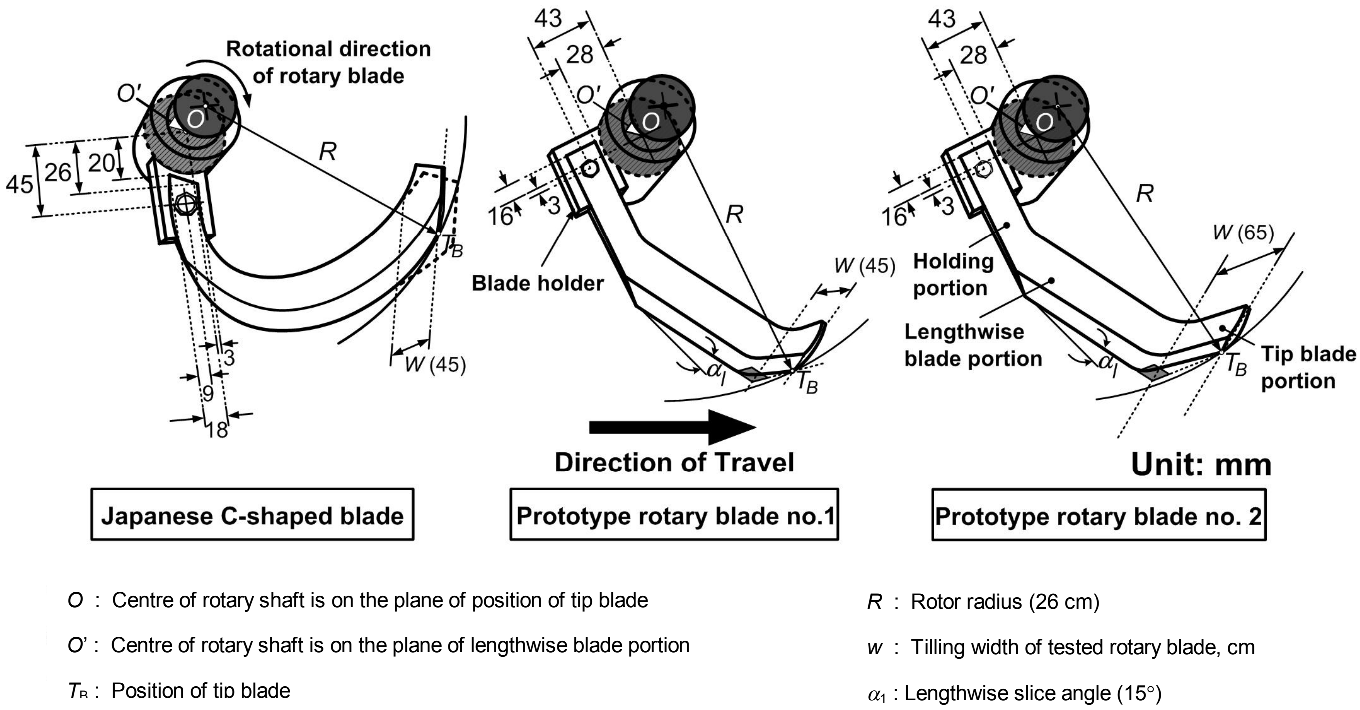

Figure 1. Blade fitting in blade holder

A two-wheel tractor with a 7.72 kW diesel engine was used as the power source of the rotary tiller. The power transmission of the rotary power tiller was the centre-drive type. The 3 sets of rotors (Figure 2a) used for field tests were: the 14-blade rotor of the Japanese C-shaped blade as the rotary power tiller no. 1; the 14-blade rotor of the prototype rotary blade no. 1 as the rotary power tiller no. 2; and the 10-blade rotor of the prototype rotary blade no. 2 as the rotary power tiller no. 3. The rotor radius of the three-blade types was 27.5 cm.

The arrangements of rotary blades on the rotor shaft of rotary power tillers no. 1, no. 2, and no. 3, are shown in Figure 2b. From the rear, the rotor was divided in the middle by the chain case. The numbers beside the blades indicated the order of soil cutting (Figures 2b and 2c) during the down-cut process. The spaces between the planes of blade holders along the rotor were equal. In these experiments, the 14-blade rotor of Japanese C-shaped blade as a conventional rotary tiller was assigned as the control treatment. In order to study the effect of the shape of the straight lengthwise blade portion of the prototype rotary blade on the performance, the tilling pattern of the 14-blade rotor of the prototype rotary blade no. 1 was assigned to be the same as the 14-blade rotor of Japanese C-shaped blade. Also, in order to study the effect of the decreasing number of the prototype rotary blade no. 2, the arrangement of the prototype rotary blade no. 2 on the rotor shaft was assigned for testing in the field.

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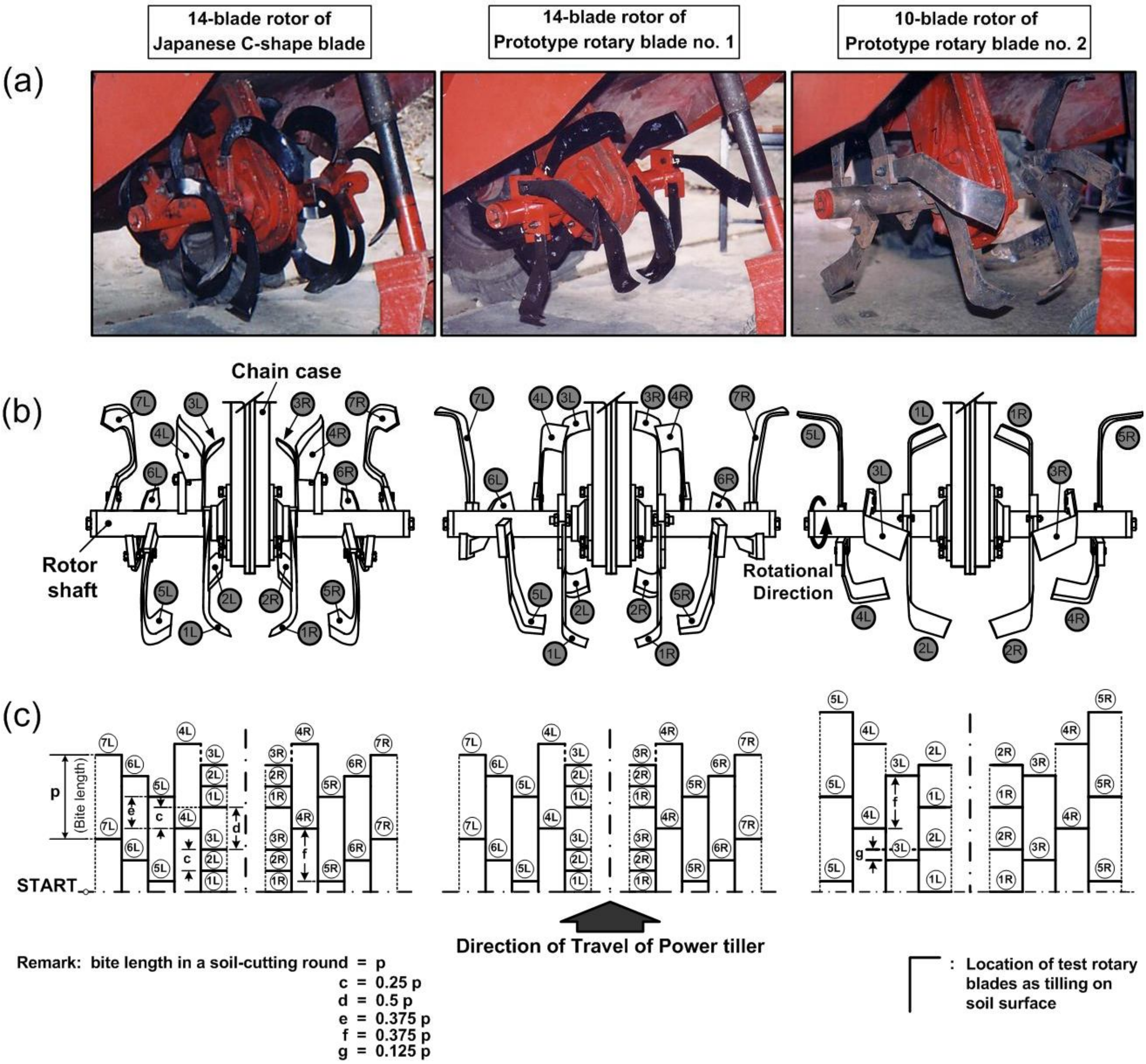

Figure 2. (a) Three rotary tillers attached behind two-wheel tractor, (b) the arrangements of rotary blades on the rotor shaft, and (c) diagrams of soil-cutting patterns of three rotary tillers

Mean soil clod diameter

In each plot, three samples of 2-kg loosened soil were collected after tilling experiment to determine the mean soil clod diameter. The soil was sieved into a gradation in size (>50, 40-50, 35-40, 20-35, 10-20, and <10 mm diameter) and weighed, as shown in Table 1. After sieving, the mean soil clod diameter was calculated using the equation (1) [8] :

$$dsc = (5A + 15B + 27.5C + 37.5D + 45E + NF) / W \quad \ldots (1)$$

where dsc : Mean soil clod diameter (mm)

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N : Mean of measured diameters of soil clods retained on the largest aperture sieve (mm)

$$W = A + B + C + D + E + F \text{ (kg)} \qquad \ldots(2)$$

Table 1. Weight of soil retained on the sieve

Size of sieve aperture (mm)	Diameter of soil which passed the sieve and retained on the next small aperture sieve (mm)	Representative diameter of soil (mm)	Weight of soil (kg)
10	<10	5	A
20	10-20	15	B
35	20-35	27.5	C
40	35-40	37.5	D
50	40-50	45	E
	50>	N	F

Soil inversion

Soil inversion is quantitatively expressed as ratio of the amount of weeds on soil surface after operation to the amount before operation [8] :

$$F = \frac{W_p - W_E}{W_p} \times 100 \qquad \ldots(3)$$

where F : Indicator for soil inversion; ratio of weeds or crop stubble being filled up
W_p : No. of weeds before operation per unit area
W_E : No. of weeds exposed on the surface per unit area after operation

Tillage experiment

The experimental design was a split-split plot with three rotor sets of rotary power tiller as main plots, three rotational speeds of the rotary shaft as split plots, and two tillage passes as split-split plots. Each plot size was 1.2 m × 25 m and two replications were used. The dry bulk density of soil, its moisture content, the cone penetration resistance, the cohesion and angle of internal friction of soil, and the adhesion and soil-metal internal friction were measured one day prior to these operations. The number of weeds within the frame with an area of 0.25 m^2 in each condition was collected before the operations were started. Besides, as the rotary power tiller was operating (Figure 3), the forward speed was recorded. After the experiment in each condition was finished, three plastic bags were packed with 2-kg of soil each and the number of weeds exposed on soil surface was counted in order to determine the mean soil clod diameter and the indicator for soil inversion.

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Figure 3. Operation of the power tiller in field.

Statistical analysis

An analysis of variance for a split-split plot design was performed by F-test and DMRT test to evaluate the significance of the treatment effect on mean soil clod diameter and soil inversion. Also the forward speed, the tilling depth, and the tilling width of the power tillers were statistically analyzed.

Results and Discussion

Effects of power tiller type, rotational speed, and number of tilling passes on mean soil clod diameter

Average values of mean soil clod diameter resulting from the rotary power tillers no. 1, no. 2, and no. 3 were 13.0, 15.1, and 14.6 mm respectively (Table 2), but were, however, not significantly different. Average values of mean soil clod diameter at 300, 350, and 400 rpm rotational speed were 15.5, 14.3, and 12.8 mm respectively. These values were not significantly different either. Also the effect of number of tilling passes on the average value of mean soil clod diameter was not statistically significant. The average values of mean soil clod diameter at pass 1 and pass 2 were 14.4 and 14.1 mm respectively.

Based on the mean soil clod diameters, results revealed that the performances of the three types of rotary power tiller were similar. The comparison between the rotary power tillers no. 1 and no. 2 showed that the different shapes of the rotary blades did not affect the mean soil clod diameter. The comparison between the rotary power tiller no. 3 and power tiller no. 1 revealed that a smaller number of rotary blades did not affect the mean soil clod diameter.

Effects of power tiller type, rotational speed, and number of tilling passes on soil inversion

Figure 4 shows the presence of weeds on soil surface after the operations of three rotary power tillers. Soil inversion percentages as affected by three rotary power tillers no. 1, no. 2, and no. 3 were 29.22%, 29.21% and 31.11% respectively (Table 2), which were insignificantly different. At different rotational speeds of 300, 350, and 400 rpm, the mean soil inversion was 27.45%, 28.96% and 32.13% respectively. The mean soil inversion was 29.7% and 29.9% at pass 1 and pass 2 respectively. Although the results showed that the soil inversion increased with increasing rotational speed of rotor, the effect of rotational speed of the rotor on soil inversion was found to be insignificant. The effect of the number of tilling passes on soil inversion was also found to be insignificant.

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The shape of the prototype rotary blade of the rotary power tiller no. 2 did not affect soil inversion as compared with the Japanese C-shaped blade of the power tiller no. 1. Similarly, the effect of the number of prototype rotary blade of the rotary power tiller no. 3 with 10 blades in comparison with the rotary power tillers no. 1 and no. 2 with 14 blades, did not show any effect on soil inversion.

Table2. Effect of the rotary power tillers (T1, T2 and T3), rotational speeds (N1, N2 and N3) and number of tilling passes (P1 and P2) on forward speed, tilling width, tilling depth, soil inversion and mean soil clod diameter

Rotary power tiller	Rotational speed (rpm)	Number of tilling pass	Forward speed (m/s)	Tilling width (cm)	Tilling depth (cm)	Mean soil clod diameter (mm)	Soil inversion (%)
Rotary power tiller no.1 using 14 Japanese rotary C-shaped blades; 4.5 cm tilling width of blade (T1)	300 (N1)	pass 1 (P1)	0.39 b	59.9 a	8.3 b	14.3 a	30.67 a
		pass 2 (P2)	0.40 a	61.5 a	10.9 a	12.7 a	15.86 a
	350 (N2)	pass 1 (P1)	0.41 b	57.3 a	7.9 b	14.6 a	25.52 a
		pass 2 (P2)	0.47 a	60.2 a	10.6 a	12.6 a	35.72 a
	400 (N3)	pass 1 (P1)	0.43 b	61.9 a	10.1 b	13.9 a	40.17 a
		pass 2 (P2)	0.47 a	66.2 a	12.3 a	9.9 a	27.36 a
Rotary power tiller no.2 using 14 prototype rotary blades no.1; 4.5 cm tilling width of a blade (T2)	300 (N1)	pass 1 (P1)	0.38 b	58.8 a	12.4 b	16.0 a	21.99 a
		pass 2 (P2)	0.43 a	56.8 a	13.5 a	13.0 a	33.85 a
	350 (N2)	pass 1 (P1)	0.41 b	50.8 a	7.6 b	17.5 a	31.55 a
		pass 2 (P2)	0.50 a	52.2 a	10.4 a	12.8 a	21.97 a
	400 (N3)	pass 1 (P1)	0.44 b	50.2 a	9.4 b	13.8 a	33.67 a
		pass 2 (P2)	0.53 a	47.8 a	9.5 a	17.2 a	32.22 a
Rotary power tiller no.3 using 10 prototype rotary blades no.1; 6.5 cm tilling width of a blade (T2)	300 (N1)	pass 1 (P1)	0.39 b	68.2 a	9.5 b	17.7 a	28.16 a
		pass 2 (P2)	0.39 a	65.9 a	12.0 a	19.5 a	34.16 a
	350 (N2)	pass 1 (P1)	0.44 b	66.7 a	10.6 b	10.6 a	24.02 a
		pass 2 (P2)	0.43 a	67.0 a	12.1 a	17.5 a	40.97 a
	400 (N3)	pass 1 (P1)	0.51 b	67.7 a	9.4 b	10.6 a	31.96 a
		pass 2 (P2)	0.54 a	67.9 a	13.1 a	11.7 a	27.38 a
		P1 mean	0.42 b	60.6 a	9.5 b	14.4 a	29.7 a
		P2 mean	0.46 a	61.0 a	11.6 a	14.1 a	29.9 a
	N1 mean		0.39 c	61.9 a	11.1 a	15.5 a	27.45 a
	N2 mean		0.44 b	59.3 a	9.9 a	14.3 a	28.96 a
	N3 mean		0.49 a	60.3 a	10.7 a	12.8 a	32.13 a
T1 mean			0.43 a	61.2 b	10.0 a	13.0 a	29.22 a
T2 mean			0.44 a	59.1 c	10.5 a	15.1 a	29.21 a
T3 mean			0.45 a	67.3 a	11.1 a	14.6 a	31.11 a
C.V. (coefficient of variation, %)			7.04	5.57	23.32	2.71	36.74

Note: Data with the same letter within a column indicates no significant difference ($p < 0.05$).

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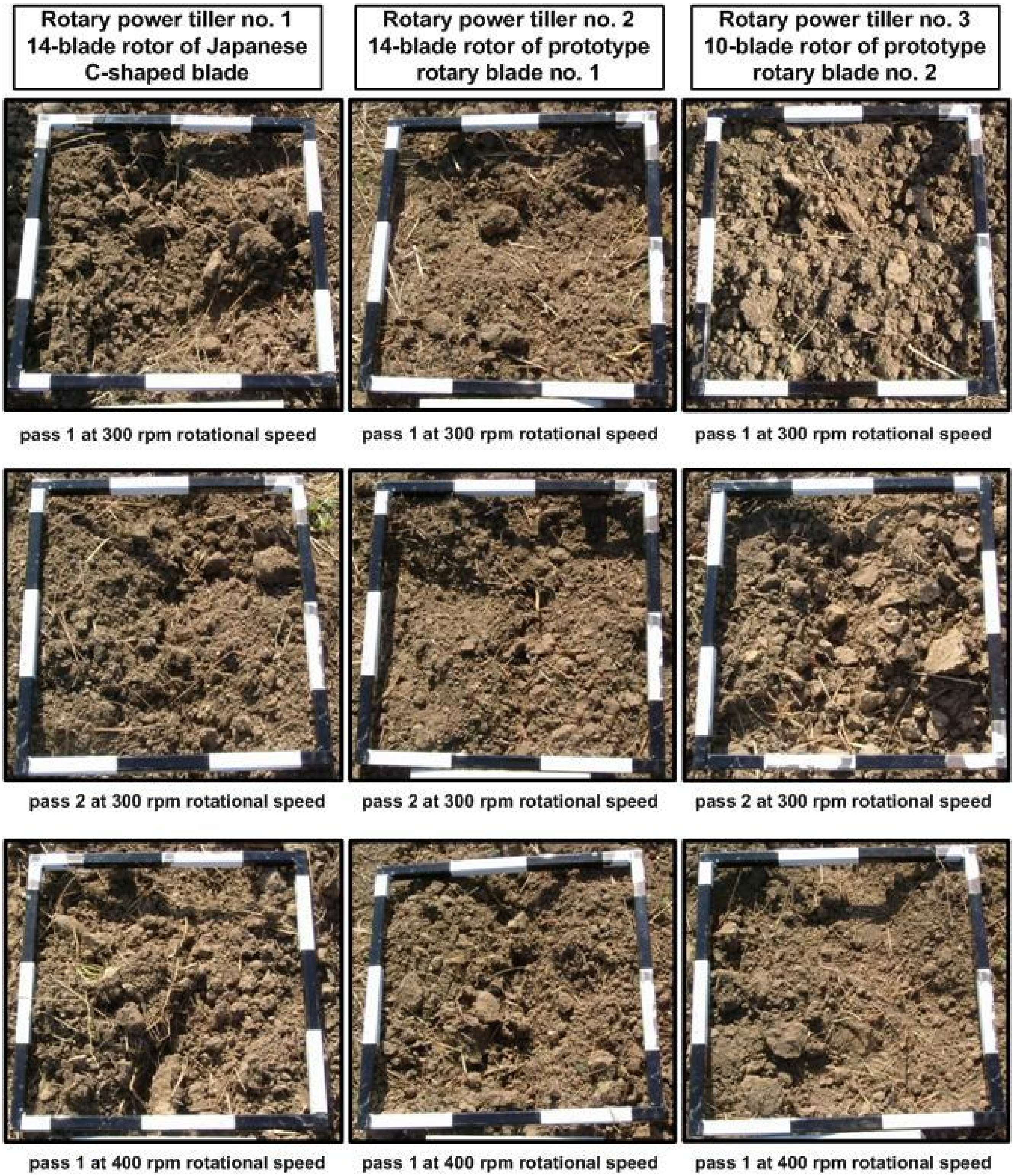

Figure 4. Weeds exposed on soil surface within a frame with an area of 0.25 m^2 after the tilling operations

Effects of power tiller type, rotational speed, and number of tilling passes on tilling depth

Average tilling depths as affected by the rotary power tillers no. 1, no. 2, and no. 3, were 10.0, 10.5, and 11.1 cm respectively. The average tilling depths at pass 1 and pass 2 were 9.5 and 11.6 cm respectively. Statistical results indicated that different rotary power tillers and different rotational speeds of the rotor did not affect the tilling depth. However, the number of tilling passes affected the tilling depth significantly.

Effects of power tiller type, rotational speed, and number of tilling passes on forward speed

The rotary power tillers no. 1, no. 2, and no. 3 operated at an average forward speed of 0.43, 0.44 and 0.45 m/s respectively (Table 2). Forward speed was increased with increasing rotational speed. The forward speeds of rotary power tillers no. 1, no. 2, and no. 3 were not significantly different. Results indicated that rotational speed and number of tilling passes affected the forward speed significantly.

Effects of power tiller type, rotational speed, and number of tilling passes on tilling width

Average tilling widths as affected by the rotary power tillers no. 1, no. 2, and no. 3, were 61.2, 59.1, and 67.3 cm respectively, as shown in Table 2. Results revealed that although the effects of the rotational speed of the rotor and the number of tilling passes on tilling width were found to be insignificant, the effect of the rotary power tiller on tilling width was found to be significant. It thus manifested that the different shapes of the tested rotary blades affected the tilling width. Although the mean tilling width of the power tiller no. 2 was less than that of the rotary power tiller no. 1 (a difference of 2.1 cm between them), both tilling widths were, however, almost the same in practice.

Discussion

Based on all results, there were no differences in the mean soil clod diameters and soil inversion percentages as affected by the three different rotary power tillers. Results further indicated that the straight lengthwise blade portion of the prototype rotary blade no. 1 did not affect the tilling performance of rotary power tiller when compared to the Japanese C-shaped blade. Similarly, the wider tip blade portion of the prototype rotary blade no. 2 did not decrease the tilling performance either.

The similar tilling performance of the 3 types of rotary power tillers studied in the experiment revealed that, firstly, the prototype no. 1 and no. 2 could really be operated in the field. The Japanese C-shaped blade is currently widely used in Thailand and also commercially produced. However, the newly designed straight blade will be simpler to be manufactured. Secondly, the prototype rotary blade no. 2 should be developed further for commercial production because the design requires a smaller number of blades (10 instead of 14), therefore the farm operating cost would be considerably reduced.

Conclusions

The performance of rotary power tillers no. 1, no. 2, and no. 3 was not different. The blade shape of 14-blade rotor of the prototype rotary blade was found to be insignificant as compared with the 14-blade rotor of the Japanese C-shaped blade in the performance of tilling depth, mean soil clod diameter and soil inversion. The rotary power tiller no. 3 with 10-blade rotor of the prototype rotary blade was not significantly different as compared with the rotary power tillers no. 1 and no. 2 on the tilling performance.

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References

1. J. M. Beeny and D. C. P. Khoo, "Preliminary investigation into the performance of different shaped blades for the rotary tillage of wet rice soil", *J. Agric. Engng. Res.*, **1970**, *15*, 27-33.
2. B. Jarimopas, A. Senanarong, and P. Tongsawatwong, "The Evolution of Two-wheel Tractor and the Manufacture of Farm Tractor in Thailand", Funny Publishing, Ltd., Bangkok, **1971** [in Thai].
3. Office of Agricultural Economics, "Agricultural economics indicators of Thailand, use and type of farm machineries", **1999-2003**. Available from: http://www.oae.go.th/indicator/section5/sec5 table5.3.pdf, 2007-04-25.
4. A. Senanarong and S. Sngiamphongse, "Development of power tiller", Agricultural Engineering Research Institute, July – September **1994** [in Thai].
5. T. Niyamapa and C. Rangdaeng, "Rotary power tiller", Final Research and Development Report No. MT-34-06-MAC-11-6, National Metal and Materials Technology Centre, National Science and Technology Development Agency, **1997** [in Thai].
6. T. Ruangrungchaikul, "The utilization of second-hand tractors in Lopburi Province, Thailand", *MS. Thesis, No. AE-96-7*, **1997,** Asian Institute of Technology, Thailand.
7. S. Chertkiattipol, T. Niyamapa, and V. M. Salokhe, "Influence of rotary blade shapes of three rotary blade types on characteristic of tillage resistance torque and specific tilling energy", Proceedings of International Conference on Agricultural, Food and Biological Engineering and Post Harvest/Production Technology, Khon Kaen, Thailand, **2007,** pp. 8-15.
8. Regional Network for Agricultural Machinery, "RNAM Test Codes and Procedures for Farm Machinery", Pasay, Philippines, **1983**.