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Comparative Study on Soil Tillage Using Rotary Tiller and Power Harrow

Watcharachan Sukcharoenvipharat, Prathuang Usaborisut, Sirisak Choedkiatphon

***Abstract*—**Farmers try to reduce steps of soil preparation by using subsoiler and then following by equipment for soil pulverization such as a rotary tiller and a power harrow which take advantage of using a power take-off of a tractor. Therefore, this study was conducted to compare the tilling performances of a rotary tiller and a power harrow applying after subsoiling. The results showed that both the rotary tiller and the power harrow had negative slip, indicating that they generated force to push a tractor. The rotary tiller created negative vertical force to lift up the tractor whereas opposite result was found when using the power harrow. Since working depths were different, vertical forces, torques and PTO powers for two equipment types were significantly different. However, no significant differences were found for the forward speeds, slips, drawbar pulls and drawbar powers. Comparative analysis showed that two equipment types had significant difference in PTO power to working depth, drawbar power to working depth, PTO power to working area, drawbar power to working area and soil pulverization.

***Keywords*—**Rotary tiller, power harrow, drawbar pull, drawbar power, PTO power.

I. Introduction

SOIL preparation is one of the most important steps to obtain successful cultivation. The purpose of land preparation is to provide the necessary soil conditions which will enhance the successful establishment of plant. Normally, the process of seedbed preparation for sugarcane in Thailand includes five steps: trash incorporating, subsoiling, tilling and harrowing [1], which are often not cost effective. Recently, there is an attempt to reduce steps of soil preparation. After subsoiling, farmer combines tilling and harrowing steps by using either a rotary tiller or a power harrow. Mandal et al. [2] said that a rotary tiller is a specialized mechanical tool used to plough the land by a series of blades which are used to swirl up the earth. The rotary tiller is simple structure and high efficiency. Topakci et al. (cited by [2]) recommended that by taking advantage of rotary tillers, the primary and secondary tillage applications could be conjugated in one stage. Since rotary tiller power is directly transmitted to the tillage blades, the power transmission efficiency in rotary tillers is high [3].

A power harrow has the advantage of conserving soil moisture by not exposing the lower soil layer to the surface [4]. Several research works have focused on a horizontal axis rotary tiller while limited studies have been done on a power harrow. Therefore, the field experiments were conducted to evaluate the tilling performances of a rotary tiller and a power harrow applying after subsoiling under different working speeds.

Watcharachan Sukcharoenvipharat is a doctoral student in Department of Agricultural Engineering, Faculty of Engineering at Kamphaengsaen, Kasetsart University, Kamphaengsaen Campus, Nakhonpathom 73140, Thailand (phone: 6634-351-896; fax: 6634-351-896; e-mail: prammykk@hotmail.com).

Prathuang Usaborisut is an Associated Professor and Sirisak Choedkiatphon is a Lecturer in Department of Agricultural Engineering, Faculty of Engineering at Kamphaengsaen, Kasetsart University, Kamphaengsaen Campus, Nakhonpathom 73140, Thailand.

II. Methodology

Field experiments were conducted in the sugarcane farm at Chong Dan subdistrict, Bo Phloi district Kanchanaburi province, Thailand. Soil in the experiment field was sandy loam soil (62% sand, 19.8% silt and 18.2% clay). Firstly, the experiment field was subsoiled by a conventional subsoiler. Then, soils were sampled by core samplers for dry bulk density and moisture content at the depth of 10 cm. Penetration resistances were determined by cone penetrometer. The average cone index of the field was 2.2 Mpa at 0-20 cm depth and 3.4 MPa at 20-40 cm depth. The average bulk density was 1.4 g/cm^3 at 10 cm depth. The average moisture content of the soil was 7.33% (dry weight basis). For determining the mean soil clod diameter, three samples of 2 kg loosened soil were collected after tilling experiment. According to RNAM Test Codes [5], the soil was sieved into six sizes (>50, 40-50, 30-40, 20-30, 10-20 and <10 mm diameter) and, then, the soil retained on each sieve was weighed. The mean soil clod diameter was calculated using (1) [5]:

$$dsc = \left(5A + 15B + 25C + 35D + 45E + NF\right)/W \quad (1)$$

where dsc = Mean soil clod diameter (mm), N = Mean diameter of soil clods on the largest aperture sieve (mm), W = The total weight of the soil sample (kg) and A, B, C, D, E and F = Weight of soil retained at each sieve (kg).

The experimental design was a split plot with two types of rotavator (rotary tiller (Fig. 1 (a)) and power harrow (Fig. 1 (b)) as mainplots, three forward speeds of a tractor rotary shaft as split plots. Each plot size was 3 m x 40 m and three replications were used. As the tractor was operating, the forward speed, PTO torque, PTO rotational speed and forces at 3-point hitch were recorded. The sensor installation for the measurement of drawbar pulls, PTO torque and PTO speed is shown in Fig. 2. The drawbar pulls were measured by three pin transducers at three point hitch of tractor. The PTO torque was measured by the torque transducer (TP-50KMCB, Kyowa Electronic Instruments Co. Ltd., Tokyo, Japan) while PTO speed was measured by an inductive sensor. For universal recorder (EDX-100A, Kyowa Electronic Instruments Co. Ltd., Tokyo, Japan) a 16 channels strain amplifier was used to amplify the signals, recording signals were saved in the internal memory and on the laptop. For reading data from the laptop or CF card, the DCS-100A data acquisition software was applied. Statistical analysis of the split-plot design was applied to evaluate the significance of the treatment effect on mean soil clod diameter. Also the forward speed, the tilling depth, force and power parameters were statistically analyzed.

(a) Rotary tiller

(b) Power harrow

Fig. 1 Two types of rotavator used in the field test.

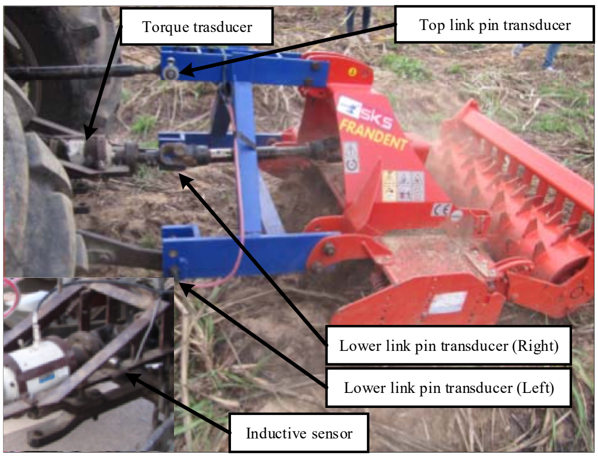

Fig. 2 The sensor installation for the measurement of drawbar pulls, PTO torque, and PTO speed

III. Results

The result showed that the average working depth was 8.9 cm). Slips showed negative value and the drawbar pulls were also negative as shown in Table I. It is indicated that the rotary tiller generated thrust force to push a tractor in the longitudinal. The vertical forces of three forward speeds were -1.66, -1.29 and -0.88 kN respectively. The vertical force of rotary tiller showed that the rotary tiller created negative force to lift up the tractor. Statistical analysis indicated that forward speed did not affect the working depth, drawbar pull, vertical force, torque of rotary tiller and soil clod diameter as shown in Table II.

Statistical analysis indicated that forward speed significantly affected the PTO power to working depth and the PTO power to area. However the effect of forward speeds did not significantly appear on the drawbar power to working depth and drawbar power to working area.

In case of power harrow, working depth was 20.2 cm. It also generated negative slip and negative drawbar pull as shown in Table IV. The vertical forces of three forward speeds were 0.10, 2.23 and 4.52 kN respectively. The power harrow created higher positive vertical force as forward speed increased. Statistical analysis indicated that forward speed significantly affected drawbar pull, vertical force, torque of power harrow, PTO power and PTO speed but not the working depth, soil clod diameter and slip.

Statistical analysis indicated that forward speed of power harrow had no significant effect on the PTO power to working depth, the PTO power to working area, the drawbar power to working depth and drawbar power to working area.

TABLE I
Performance Parameters of a Rotary Tiller

Gear position	Replication	Forward speed (km/h)	working depth (cm)	Drawbar pull (kN)	Vertical force (kN)	Drawbar Power (kW)	Slip (%)
L2R 3.2 km/h	Replication I	3.60	9.0	-2.49	-1.07	-2.49	-1.52
	Replication II	3.47	8.7	-6.36	-2.06	-6.13	-5.38
	Replication III	3.52	9.3	-6.21	-1.85	-6.08	-3.76
	Average	3.53a	9.0a	-5.02a	-1.66a	-4.90a	-3.55a
L3T 4.5 km/h	Replication I	5.19	9.2	-4.39	-1.07	-6.32	-1.31
	Replication II	5.16	8.6	-7.61	-1.42	-10.91	-1.75
	Replication III	4.95	8.8	-6.42	-1.40	-8.83	-6.28
	Average	5.11b	8.9a	-6.14a	-1.29a	-8.69a	-3.11a
L3R 6 km/h	Replication I	6.44	9.0	-4.09	-1.08	-7.32	-1.45
	Replication II	6.41	9.1	-2.30	-0.69	-4.09	-2.00
	Replication III	6.77	8.7	-7.27	-0.88	-13.68	3.45
	Average	6.42c	8.9a	-4.55a	-0.88a	-8.36a	0.00a

Remark: Average values in the same column with the same lower case letter are not significantly different by Duncan's multiple range test at the 95% significance level.

TABLE II
ADDITIONAL PERFORMANCE PARAMETERS AND SOIL PULVERIZATION OF A ROTARY TILLER

Gear position	Replication	Torque (Nm)	Rotational speed (rpm)	PTO Power (kW)	Soil pulverization (mm)
L2R 3.2 km/h	Replication I	414.54	524.27	22.76	7.87
	Replication II	349.98	526.41	19.29	10.40
	Replication III	429.42	527.40	23.72	9.20
	Average	397.98a	526.03a	21.92a	9.16a
L3T 4.5 km/h	Replication I	541.91	527.69	29.95	10.14
	Replication II	424.34	526.83	23.41	10.09
	Replication III	393.89	520.67	21.48	9.82
	Average	453.38a	525.06a	24.94a	10.02a
L3R 6 km/h	Replication I	365.97	543.37	20.82	8.13
	Replication II	392.52	514.29	21.14	13.69
	Replication III	388.89	506.68	20.63	10.92
	Average	382.46a	521.45a	20.87a	10.91a

Remark: Average values in the same column with the same lower case letter are not significantly different by Duncan's multiple range test at the 95% significance level.

TABLE III
POWER PARAMETERS PER WORKING DEPTH AND AREA OF A ROTARY TILLER

Gear Position	Replication	PTO Power/depth (kW/m)	Drawbar Power/depth (kW/m)	PTO Power/Area (kW/m^2)	Drawbar Power/Area (kW/m^2)
L2R 3.2 km/h	Replication I	252.89	-27.67	194.53	-21.28
	Replication II	221.72	-70.46	170.56	-54.20
	Replication III	255.05	-65.38	196.20	-50.29
	Average	243.22ab	-54.50a	187.09ab	-41.92a
L3T 4.5 km/h	Replication I	325.54	-68.70	250.42	-52.84
	Replication II	272.21	-126.86	209.39	-97.58
	Replication III	244.09	-100.34	187.76	-77.19
	Average	280.61b	-98.63a	215.86b	-75.87a
L3R 6 km/h	Replication I	231.33	-81.33	177.95	-62.56
	Replication II	232.31	-44.95	178.70	-34.57
	Replication III	237.13	-157.24	182.40	-120.95
	Average	233.59a	-94.51a	179.68a	-72.70a

Remark: Averages values in the same column with the same lower case letter are not significantly different by Duncan's multiple range test at the 95% significance level.

Comparative analysis of two equipment showed no significant difference on forward speed, drawbar pull, slip and drawbar power. On the other hand, significant difference was found on working depth, vertical force, torque, drawbar power, soil pulverization, PTO power to working depth, drawbar power to working depth, PTO power to working area and drawbar power to working area as shown in Tables VII and VIII.

Some finding results of this study agreed with the research work by Makange and Tiwari [6] in aspects of soil pulverization and disturbed area. Makange and Tiwari [6] found that the values of soil pulverization, penetration resistance and bulk density of soil were lower after tilling by vertical axis rotavator as compared to the horizontal axis rotavator. Percentage of soil disturbed area was found more by vertical axis rotavator as compared to the horizontal axis rotavator. However, the result of power requirement in this study was opposite to one reported by Makange and Tiwari [6]. Makange and Tiwari [6] reported that vertical axis rotavator consumed comparatively more energy even at the same depth of tilling than horizontal one.

TABLE IV
PERFORMANCE PARAMETERS OF A POWER HARROW

Gear position	Replication	Forward speed (km/h)	working depth (cm)	Drawbar pull (kN)	Vertical force (kN)	Drawbar Power (kW)	Slip (%)
L2R 3.2 km/h	Replication I	3.49	21	-3.36	-0.33	-3.26	-4.67
	Replication II	3.69	19.9	-7.44	0.54	-7.62	1.02
	Replication III	3.58	19.8	-	-	-	-2.13
	Average	3.59a	20.2a	-5.40ab	0.10c	-5.44b	-1.93a
L3T 4.5 km/h	Replication I	5.22	20	-	-	-	-0.73
	Replication II	5.10	20.3	-6.48	2.68	-9.18	-3.07
	Replication III	5.03	20.4	-10.74	1.78	-15.01	-4.53
	Average	5.11b	20.2a	-8.61a	2.23b	-12.09a	-2.77a
L3R 6 km/h	Replication I	6.26	19.6	-4.81	6.77	-8.37	-4.36
	Replication II	6.63	20.5	-3.44	3.45	-6.34	1.45
	Replication III	6.38	20.2	-3.94	3.34	-6.99	-2.36
	Average	6.42c	20.1a	-4.07b	4.52a	-7.23ab	-1.75a

Remark: Average values in the same column with the same lower case letter are not significantly different by Duncan's multiple range test at the 95% significance level.

TABLE V
ADDITIONAL PERFORMANCE PARAMETERS AND SOIL PULVERIZATION OF A POWER HARROW

Gear position	Replication	Torque (Nm)	Rotational speed (RPM)	PTO power (kW)	Soil pulverization (mm)
L2R 3.2 km/h	Replication I	705.15	509.77	37.64	7.58
	Replication II	663.43	511.35	35.53	8.10
	Replication III	-	-	-	8.12
	Average	684.29a	510.56b	36.59a	7.93a
L3T 4.5 km/h	Replication I	-	-	-	7.88
	Replication II	770.10	506.59	40.85	8.12
	Replication III	935.40	501.94	49.17	8.10
	Average	852.75b	504.27b	45.01b	8.03a
L3R 6 km/h	Replication I	765.87	392.29	31.46	8.45
	Replication II	954.37	398.79	39.86	6.70
	Replication III	820.78	465.92	40.05	7.40
	Average	847.01b	419.00a	37.12a	7.52a

Remark: Average values in the same column with the same lower case letter are not significantly different by Duncan's multiple range test at the 95% significance level.

TABLE VI
POWER PARAMETERS PER WORKING DEPTH AND AREA OF A POWER HARROW

Gear	Replication	PTO Power/depth kW/m	Drawbar Power/depth kW/m	PTO Power/Area kW/m^2	Drawbar Power/Area kW/m^2
L2R 3.2 km/h	Replication I	179.24	-15.52	137.88	-11.94
	Replication II	178.54	-38.29	137.34	-29.45
	Replication III				
	Average	178.89a	-26.91a	137.61a	-20.70a
L3T 4.5 km/h	Replication I				
	Replication II	201.23	-45.22	154.79	-34.79
	Replication III	241.03	-73.58	185.41	-56.60
	Average	221.13a	-59.40a	170.10a	-45.69a
L3R 6 km/h	Replication I	160.51	-42.70	123.47	-32.85
	Replication II	194.44	-30.93	149.57	-23.79
	Replication III	198.27	-34.60	152.51	-26.62
	Average	184.41a	-36.08a	141.85a	-27.75a

Remark: Average values in the same column with the same lower case letter are not significantly different by Duncan's multiple range test at the 95% significance level.

TABLE VII
COMPARATIVE PERFORMANCE OF TWO EQUIPMENTS

Type	Forward speed (km/h)	Working depth (cm)	Drawbar pull (kN)	Vertical force (kN)	Slip (%)	Torque (Nm)	Rotational speed (RPM)	PTO power (kW)	Drawbar Power (kW)	Soil pulverization (mm)
Rotary Tiller	5.06a	8.93a	-5.23a	1.28a	-2.22a	411.27a	524.18a	22.58a	-7.32a	10.03a
Power Harrow	5.04a	20.19b	-6.02a	-2.28b	-2.15a	794.68b	477.94b	39.57b	-8.24a	7.82b

Remark: Figures in the same column with the same lower case letter are not significantly different by Duncan's multiple range test at the 95% significance level.

TABLE VIII
COMPARATIVE PERFORMANCE PER WORKING DEPTH AND AREA OF TWO EQUIPMENTS

Type	PTO Power/depth kW/m	Drawbar Power/depth kW/m	PTO Power/Area kW/m^2	Drawbar Power/Area kW/m^2
Rotary Tiller	252.47b	-82.55a	194.21b	-63.49a
Power Harrow	194.81a	-40.79b	149.85a	-31.38b

Remark: Figures in the same column with the same lower case letter are not significantly different by Duncan's multiple range test at the 95% significance level.

IV. CONCLUSION

Average values of soil pulverization for rotary tiller and power harrow were 10.03 and 7.82 mm respectively. The rotary tiller and the power harrow had negative slip indicating that they generated thrust force to push a tractor. The rotary tiller created negative vertical force and lift up a tractor whereas power harrow gave opposite reacting force to the tractor. Further study should be done for soil with different moisture contents.

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REFERENCES

[1] Thai Roung Ruang Sugar Group. (2007) Manual of sugarcane plantation. (in Thai).
[2] Mandal S, Bhattacharyya B, Mukherjee S (2015) Design of Rotary Tiller's Blade Using Specific Work Method (SWM). J ApplMechEng 4:164. doi:10.4172/2168-9873.1000164.
[3] Mahal JS, Manes GS, Prakash A, Singh M, Dixit A (2012) Study on Blade Characteristics of Commercially Available Rotavators in Punjab. Agricultural Engineering Today 36: 8-11.
[4] Chan, C.W. Wood, R.K. Holmes, R.G. (1993) Powered Harrow Operation Parameters: Effects on Soil Physical Properties Transactions of the ASAE VOL. 36(5): 1379-1285
[5] RNAM. 1983. RNAM Test Codes & Procedures for Farm Machinery. Regional Network for Agricultural Machinery.
[6] Makange N.R and Tiwari V.K. (2015). Effect of Horizontal and Vertical Axis Rotavators on Soil Physical Properties and Energy Requirement. Trends in Biosciences 8(12), ISSN 0974-8, 3225-3234.