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EFFICIENCY TESTS OF ROTARY TILLER AND POWER HARROW

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Abstract- Rotary tiller and power harrow are tillage tools. They are mainly used to pulverize soil so as to obtain suitable soil clod size for planting. This test was to compare working efficiency of rotary tiller and power harrow. The field tests were conducted in three clay loam soil plots with difference in moisture contents. It was found that both rotary tiller and harrow power generated negative draft and their ratios to working widths were not significantly different. The recorded signal showed that the draft of rotary tiller was more fluctuate than that of power harrow. The vertical force was negative for rotary tiller but positive for power harrow. No significant difference was found in soil pulverizations for both mean clod sizes and standard deviations of clod sizes.

Keywords- Draft, Power Harrow, Rotary Tiller, Soil Preparation, Soil Pulverization.

I. INTRODUCTION

Soil preparation is very important for planting. The problem of decreasing yield is partly due to lack of knowledge in using tools properly and effectively. Soil preparation is costly since there are many steps of working needed to complete well soil preparation. At present, efforts have been made to reduce the soil preparation steps to reduce costs and reduce soil compaction as well. One method to reduce soil preparation steps is using combined tools such as a subsoiler with a tiller installed behind. The tillers used power from PTO power of a tractor such as rotary tillage or power harrow are of interest since they use blades for soil cutting and can reduce the size of the clods in the fewer trip than using disk plow.

The rotational blade of a rotary promotes mixing and movement of soil. Adversely, the blade wears off quite rapidly. Also under some conditions it may cause the soil clod too small. Kawamura [1] described that the torque of rotor shaft is always changing since the blades of a rotary tiller cut the soil discontinuously. The magnitude of torque changing depended on the condition of the soil, the type of blade, the alignment of the blade on the rotor shaft and forward speed. Power harrow is also used to reduce the soil clod. This implement equipped with two opposite tines on each working unit. Nowadays, it is getting more popular for soil preparation in Thailand. The tine blades of power harrow are arranged vertically. After plowing, the soil still existed in the same soil layer, which helped maintain soil moisture [2]. Soil quality after plowing depended on initial soil conditions, the ratio of blade rotational speed and dynamics of moving soil [3]. The cutting intensity depends on the proportion of blade speed and tractor speed [4]. However, Kouwenhoven and Terpstra [5] showed that the particularly vertical blade could cause large clod of soil to move upward while the small clod to move downward. Mixing or separation of soil occurred on the back of the particular blade. If the blade was tilted to the rear and operating at low speed it would cause mixing of the soil. On the other hand, if the blade was tilted to the front it would cause separation of the soil.

With the ultimate goal of finding the suitable tiller to accompany with a subsoiler this study was to compare the working efficiencies of a rotary tiller and a power harrow under different soil moisture contents.

II. DETAILS EXPERIMENTAL

2.1. MATERIALS AND METHOD

The equipment used in the test consisted of a MASSEY-FERGUSON tractor series 390 12 speed gears 4-wheel 87 hp. A rotary tiller equipped with C-L shaped blades had a working width of 1.8 m and the working depth of 12 cm. A power harrow had a working width of 1 m and the working depth of 20 cm (Fig. 1).

Fig.1. Tested equipment (a) Rotary tiller and (b) Power harrow

Three plots of experiment were conducted in clay loam soil field. The soil properties lists in Table 1. In the first plot, the average moisture content of the soil was 19.46 %(db) and the penetration resistance was 0.9 MPa. In the second plot, the average moisture content of the soil was 13.90 %(db) and the penetration resistance was 1.85 MPa. In the third plot, the average moisture content of the soil was 15.54 %(db) and the penetration resistance was 2 MPa. All tests were conducted at forward speed of 2.7 km/h and PTO speed of 540 rpm. Each treatment was replicated two times.

Table 1: Soil properties

Soil composition	%
Sand	29.45
Silt	31.72
Clay	39.23
Plastic limit	21.47
Liquid limit	29.13

The items to be measured and observed were draft, slip, working depth and soil pulverization. The soil dry bulk density and the penetration resistance were measured using a core sampler and a soil cone penetrometer as shown in Fig 2.

Fig.2. Soil sampling and Soil penetrometer

Wheel slip of the tractor (i) was determined by equation (1) when m0 is traveling distance of 5 revolutions of a driving wheel on the surface of experimental site under no load condition while m is the traveling distance under loading condition.

$$i = \frac{m_0 - m}{m_0} \quad (1)$$

The draft was measured by three pin transducers: two lower pin transducers and one top pin transducer (Fig 3). For determining the mean soil clod diameter, three samples of 2 kg loosened soil were collected after tilling experiment. According to RNAM Test Codes [6], 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 equation (2):

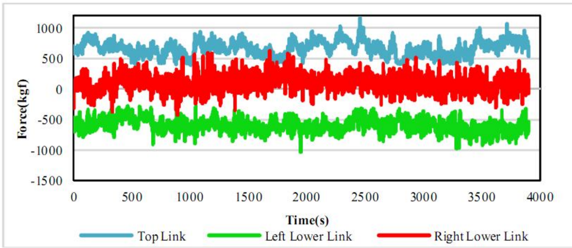
Fig.3. Pin transducers

$$dsc = \frac{1}{W}(5A + 15B + 25C + 35D + 45E + NF) \quad (2)$$

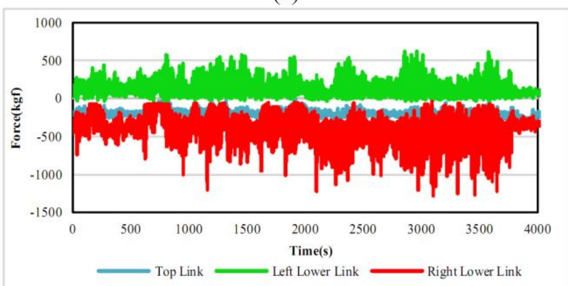
Where dsc = mean soil clod diameter (mm), N = mean diameter of soil clods on the largest aperture sieve (mm), W = the total weight of the soil sample (kg) and A, B, C, D, E and F = weight of soil retained at each sieve (kg).

III. RESULTS AND DISCUSSION

The signal of force at the three point hitch for power harrow is shown in Fig 4(a) while the signal of force for rotary tiller is shown in Fig 4(b). The Result showed that the rotary tiller had higher magnitude of force fluctuation than power harrow. This was because the rotary tiller had a strong impact action of the blades on the soil while they rotationally cut into the soil.



(a)



(b)

Fig.4. The signal of force for (a) Power harrow (b) Rotary Tiller

The working depths of the power harrow and the rotary tillers were averagely 18 cm and 10 cm respectively (Table 2). Even though the tractor was set to work at the same forward speed and PTO speed, the actual forward speed of the tractor with the rotary tiller was significantly higher than that of the tractor with the power harrow. The negative slip of the tractor with rotary tiller may contribute to the higher forward speed. Drafts of both equipment were significantly different. Besides, the negative draft indicated that both equipment generated thrust force to push the tractor. Vertical forces were found to be absolutely different. The rotary tiller created negative vertical force and lift up a tractor whereas power harrow gave opposite reacting force to the tractor as shown in Table 2.
When taken working width in to the comparison between the rotary tiller and the power harrow, it was

found that two types of equipment had no significant difference in draft per working width but in vertical force per working width as listed in Table 3. Soil pulverizations in terms of mean soil clod, standard deviation and coefficient of variation for both equipment were not significantly different.

Table 2: Test results of rotary tiller and power harrow.

Type	Field	working depth (cm)	Forward speed (km/h)	Draft (kgf)	Vertical force (kgf)	Slip (%)
Rotary Tiller	1	11.0	2.89	-458.89	-0.96	-1.09
	2	10.0	2.91	-372.91	-13.00	-0.58
	3	9.0	2.93	-485.12	-48.73	-1.62
	mean	10.0a	2.91a	-438.97a	-20.90a	-1.09a
Power Harrow	1	19.0	2.67	30.02	65.03	1.71
	2	17.5	2.62	-241.82	79.51	2.69
	3	17.5	2.62	-250.50	-32.61	2.81
	mean	18.0b	2.63b	-154.09b	37.31b	2.40b

Remark: Based on Duncan's New Multiple Range Test, mean values with a same letter in the same column are not significantly different at 5% level.

Table 3: Soil pulverization and the forces per working width.

Type	Field	Draft/ working width (kgf/m)	Vertical force/ working width (kgf/m)	Soil pulverization (mm)		
				dsc (mm)	SD	CV
Rotary Tiller	1	-254.94	-0.53	16.03a	15.15	1.17
	2	-207.17	-7.22	17.02a	15.86	0.93
	3	-269.51	-27.07	12.20a	10.21	0.96
	mean	-243.87a	-11.61a	15.66a	15.11a	1.06a
Power Harrow	1	30.02	65.03	12.60a	11.65	0.92
	2	-241.82	79.51	15.63a	18.31	1.17
	3	-250.50	-32.61	17.46a	13.61	1.01
	mean	-154.09a	37.31b	14. 78 a	16.02a	1.07a

Remark: Based on Duncan's New Multiple Range Test, mean values with a same letter in the same column are not significantly different at 5% level

SD = Standard Deviation CV = coefficient of variation

CONCLUSIONS

The rotary tiller had higher magnitude of draft fluctuation than the power harrow. The rotary tiller and the power harrow had negative draft indicating that they generated thrust force to push a tractor. The rotary tiller created negative vertical force resulting in lifting up a tractor whereas power harrow exerted opposite reaction to the tractor. Two equipment had no significant effect on soil pulverization and the draft per working width.

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