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Power Consumption of a Subsoiler Attached with Rotary Harrow for Cassava Cultivation

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Abstract

In order to accomplish primary and secondary tillage in one-pass operation for seedbed preparation, a combined tillage tool which consisted of a subsoiler and a rotary harrow was developed. The subsoiler had two shanks with a lateral distance of 50 cm. The rotary harrow with a working width of 100 cm was attached behind the subsoiler with bar case roller. The operating depth of subsoiler and rotary harrow were 40 cm and 20 cm, respectively. The soil type at the experimental site was sandy loam. The average bulk density was 1.7 gcm^{-3}. The average moisture content of the soil was 4.87% (dry weight basic). The field experiments were conducted under two forward speeds (1.8 and 2.6 kmh^{-1}) and two rotational speeds of rotary harrow (323 and 598 rpm), for the field conditions tested, the drawbar power and total power were significantly affected by the forward speed. Total power of the developed tillage tool comparing to when a subsoiler and rotary harrow worked separately (pass 1 by subsoiler and pass 2 by rotary harrow) could reduce up to 24.39% when operated at the rotational speed of 598 rpm and forward speed of 1.8 kmh^{-1}.

Keywords: subsoiler, rotary harrow, drawbar pull, power requirement, combined tillage tool.

1 Introduction

Tillage is one of important factors in soil management for crop production and is a process of utilizing energy to the soil to change its physical condition. Since the energy use in field preparation is of great concern for framers, tillage equipment should be effective of preparing a suitable soil with minimum cost (Gill and Vandenberg, 1968).

Agriculture machinery is a major cause of soil compaction. A consequence of the heavy equipment is the risk of soil compaction (Hadas, 1994; Jones et al., 2003; Smith and Dickson, 1990; Alakukkuet al., 2003). Moreover, the number of repeated machinery passes also causes severe soil compaction and consequently yield reduction (Dauda and Samari, 2002; Flowers and Lal, 1998). In order to reduce such problem combine machines have been introduced.

When time is the important factor for operating, one of the most effective ways for improving the field efficiency is to use combined machines (Akbarnia et al., 2010). The combined machine for soil preparation composes of two or more different tillage implements operates at the same time, to manipulate the soil and reduce the number and time of field operations (Sahu and Raheman, 2006; Premet al., 2016; Anpat and Hifjur, 2017; Dhakane et al.,2010). Combine machine allows the completion of breaking and harrowing operations during one pass (Weise, 1993). One of advantages of using combine machine is found when active elements were forward thrust that was in a negative draft (Shinnerset al., 1990). The energy required for the preparation of the seed bed will be reduced by using combination tillage tool (Kumar and Manian, 1986). Many combine machines are integrated with the rotary and passive elements and found to be more energy efficient than conducting a similar single passive tillage implement when tested in actual field conditions (Manian et al., 1999; Shinners et al., 1993).

The advantage of using rotary harrow for final soil condition after tillage is that it conserves soil moisture by not exposing the lower soil layer to the surface (Chan et al., 1993). Perdok and Van De Werken (1983) reported the power and energy requirement of a rotary harrow were considered for stirring and cutting intensities referring to cycloid paths generated by the blades. In this research the combine implement between subsoiler and rotary harrow was studied which three benefits of application were of interest: (1) it can both breaking hardpan and reducing soil clod in one-pass operation for seedbed preparation, (2) the reduction of drawbar pull due to the soil cutting of rotary harrow to provide some force thrust, and (3) the reduction in the processes of seedbed preparation for growing cassava.

Therefore, the objective of this research was to study the performance parameters of a combined implement comparing to summation of two single implement works on different operating conditions (i.e., forward speed, the rotational speed of rotary harrow) under actual field conditions.

2 Materials and Methods

2.1 Description of the test site.

The experimental tests were conducted at the cassava field in Thungkraphanghom sub-district, Kamphaengsaen district, Nakhonpathom province, Thailand. Prior to the tests, cassava in the field was harvested, trash incorporating was conducted by a disk plow and the field was left for two weeks. The soil type at the experimental site was sandy loam, consisting of 11.5% sand, 73.1% silt, and 15.4% clay. The average cone index of the field was 0.94, 2.27, 4.5 MPa at a depth 0-15 cm, 15-30 cm, 30-50 cm, respectively. The average bulk density was 1.7 gcm-3. The average moisture content of the soil was 4.87% (dry weight basis).

2.2 Test implement and instrumentation.

A developed tillage implement set combined passive and active implements which were a subsoiler and a rotary harrow. The operating depth of subsoiler and rotary harrow were 40 cm and 20 cm. The subsoiler had two shanks with a lateral distance of 50 cm. The rotary harrow with a working width of 100 cm was attached behind the subsoiler with bar case roller is shown in Figure 1. The rotary harrow consisted of four rotors with 25 cm apart. Each rotor had two blades. The combine tillage implement was mounted on 87 hp 4-wheel MASSEY-FERGUSON tractor series 390 12 speed gears. The experiments were conducted under two operating parameters: two forward speeds of low 1 (1.8 kmh^{-1}) and low 2 (2.6 kmh^{-1}), the two rotation speeds of 323 and 598 rpm. Total of 30 treatments were conducted and analyses of variance were made on three performance parameters (i.e., drawbar pull, drawbar power and total power). Also, the experiments of separately working of subsoiling and harrowing were also conducted in order to compare with the results from the combined tillage implement. The total power for the tillage implement can be determined by an equation as follows:

$$Tt = Da + Pptо \qquad (1)$$

Where T_t is the total power (kW), P_{pto} is the PTO power (kW) and D_a is the average drawbar power (kW).

$$P_{pto} = \frac{2\pi NT}{60000} \qquad (2)$$

Where P_{pto} is the PTO power (kW), N is PTO speed (rpm) and T is PTO torque (Nm).

$$D_a = FV \qquad (3)$$

Where D_a is the average drawbar power (kW), F is drawbar pull (kN), V is forward speed (ms^{-1}).

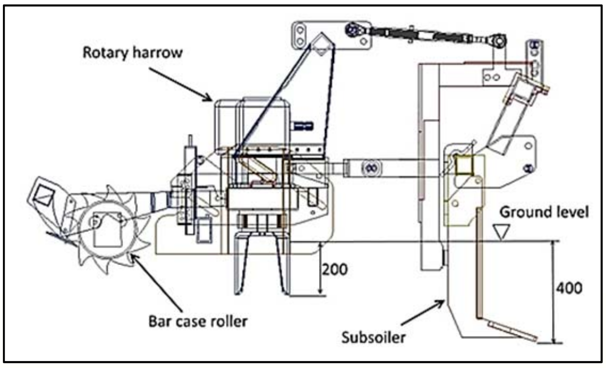

Figure 1 The developed tillage implement set consisting of the rotary harrow attached behind the subsoiler.

The sensor installation for the measurement of drawbar pulls, PTO torque, and PTO speed is shown in Figure 2 The drawbar pulls were measured by six pin transducers at three point hitch of tractor and three point hitch between subsoiler and rotary harrow. The PTO torque was measured by the torque transducer (TP-50KMCB, Kyowa Electronic Instruments Co. Ltd., Tokyo, Japan) while PTO speed 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.

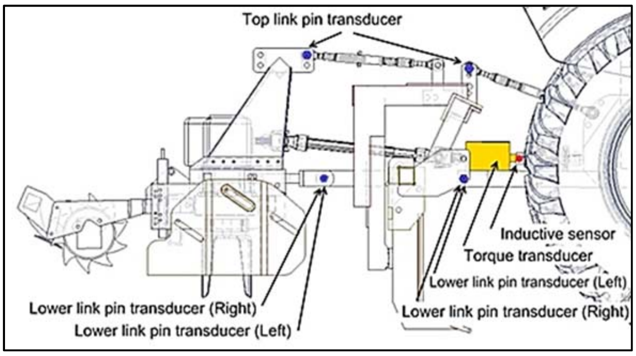

Figure 2 The sensor installation for the measurement of drawbar pulls, PTO torque, and PTO speed.

3 Results and Discussion

When considered only the drawbar pull for subsoiler by subtracting the drawbar pull for rotary harrow out of total drawbar pull, it was about 5.89–7.33 kN, as shown in Table 1. On the other hand, working with sole subsoiler needed the drawbar pull of 11.14–11.62 kN, as shown in Table 2. It is indicated that subsoiler attached with rotary harrow could reduce drawbar pull by 36.9 – 47.1%.

Comparison with separately working of subsoiler and rotary harrow at the rotational speed of rotary harrow 598 rpm and forward speed of 1.8 kmh^{-1} showed that the combined tillage implement used less total power than a summary of separate works by 24.39%. Total drawbar pull of combined tillage implement compare with working separate two times (at pass 1 used subsoiler and at pass 2 used rotary harrow).

The rotational speeds of the combined tillage implement affected the average value of total drawbar pull which higher speed needed 10.56 kN while lower speed resulted in higher total drawbar pull of 13.79 kN. However, the rotational speeds of rotary harrow induced no significant difference of the drawbar pull of subsoiler. Forward speed significantly affected the drawbar pull for rotary harrow of combined tillage implement. The average drawbar pull for rotary harrow increased from 5.06 kN to 6.08 kN when forward speed increased from 1.8 kmh^{-1} to 2.6 kmh^{-1}.

Total power is considered to be the key factor for selecting the size of the tractor to be used in operation.

Table 1 Drawbar pulls on implement.

Condition	Forward speed (kmh^{-1})	Harrow speed (RPM)	Drawbar pull for subsoiler		Drawbar pull for rotary harrow		Total drawbar pull	
			kN	Avg	kN	Avg	kN	Avg
Combined tillage implement	1.8	323	6.47	6.61	5.96	5.57	12.43	12.18
	2.6	323	7.99		7.16		15.15	
	1.8	598	5.31		4.16		9.47	
	2.6	598	6.66		5.00		11.65	
Forward speed (Average)	1.8		5.89 a		5.06 a		10.95 a	
	2.6		7.33 b		6.08 b		13.41 b	
Harrow speed (Average)		323	7.23 b		6.56 b		13.79 b	
		598	5.99 a		4.58 a		10.56 a	

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

Table 2 Performance parameters of a subsoiler and a rotary power working separately.

	Forward speed (kmh^{-1})	Harrow speed (RPM)	Drawbar pull		Drawbar power		PTO power		Total power	
			kN	Avg	kW	Avg	kW	Avg	kW	Avg
Subsoiler	1.8		11.14	11.38 b	5.56	6.96 b			5.56	6.96 b
	2.6		11.62		8.36				8.36	
Rotary harrow	1.8	323	3.36	3.93 a	1.68	2.44 a	7.47	11.62 a	9.15	14.05 a
	2.6	323	4.04		2.91		9.63		12.54	
	1.8	598	4.55		2.04		14.13		16.16	
	2.6	598	4.34		3.12		15.24		18.36	
Summation	1.8	323	14.50	15.21 c	7.24	9.40 c	7.47	11.62 a	14.71	21.01 c
	2.6	323	15.67		11.27		9.63		20.90	
	1.8	598	15.21		7.60		14.13		21.73	
	2.6	598	14.96		11.48		15.24		26.72	
Forward speed (Average)	1.8		9.85 a		4.82 a		10.80 a		13.46 a	
	2.6		9.93 b		7.43 b		12.44 b		17.38 b	
Harrow speed (Average)		323	9.39 a		5.77 a		9.12 a		15.82 a	
		598	9.64 a		6.06 a		14.78 b		21.00 b	

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

Table 3 Performance parameters of combine tillage implement.

Condition	Forward speed (kmh^{-1})	Harrow speed (RPM)	Drawbar power		PTO power		Total power	
			kW	Avg	kW	Avg	kW	Avg
Combined tillage implement (No 1)	1.8	323	6.21	7.55 b	9.35	12.62 a	15.56	20.17 c
	2.6	323	10.90		11.18		22.07	
	1.8	598	4.73		11.70		16.43	
	2.6	598	8.38		18.23		26.61	
Subsoiler (No 2)	1.8		5.56	6.96 b			5.56	6.96 a
	2.6		8.36				8.36	
Rotary harrow (No 3)	1.8	323	1.68	2.44 a	7.47	11.62 a	9.15	14.05 b
	2.6	323	2.91		9.63		12.54	
	1.8	598	2.04		14.13		16.16	
	2.6	598	3.12		15.24		18.36	
Subsoiler + Harrow (No 4)	1.8	323	7.24	9.40 c	7.47	11.62 a	14.71	21.01 c
	2.6	323	11.27		9.63		20.90	
	1.8	598	7.60		14.13		21.73	
	2.6	598	11.48		15.24		26.72	
Forward speed (Average)	1.8		5.01 a		10.71 a		14.19 a	
	2.6		8.06 b		13.19 b		19.37 b	
Harrow speed (Average)		323	6.70 a		9.12 a		15.82 a	
		598	6.22 a		14.78 b		21.00 b	

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

The result of combined tillage implement recommended that the total power requirement of a tractor to operate the tilling work was in the range between 15.56 – 26.61 kW, as shown in Table 3.

Statistical analysis of the results presented in Table 3 revealed a significant effect of forward speed on total power. It was found that an increase in forward speed made the total power requirement increased considerably. Also, there was a significant difference in the total power at different rotational speed. Average value of total power at 323 and 598 rpm rotational speeds were 15.82 and 21.00 kW, respectively. As the rotational speed of rotary harrow increased, the total power also increased.

4 Conclusions

The combine tillage implement reduces power requirement when compared to separate working of subsoiling and harrowing. The combined tillage implement needed total drawbar pull of 9.47–15.15 kN and total power of 15.56-26.61 kW. The combine tillage implement operated at the rotational speed of rotary harrow of 598 rpm and forward speed of 1.8 kmh-1 used less total power than a summation of separate work by 24.39%.

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