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The effect of comboplough on some soil physical properties of Universiti Putra Malaysia Research Park

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A disk plough combined with a set of rotary blades (comboplough) for land preparation has been designed, fabricated and tested. The concave disk cut and inverted layers of soil to bury surface material. The soil in contact with the surface of disk would be cut and pulverized by the rotary blades. Normal multiple tillage operations were reduced to a single pass and thus reduced the number of field trips as compared to conventional tillage practices resulting in a potential reduction of soil compaction, labor, fuel cost and time. The comboplough was tested in the Serdang sandy clay loam soil texture at Universiti Putra Malaysia Research Park. The treatments consisted of three types of blade (straight type or S blade, C-shaped and L-shaped) and three rotary speeds (130, 147 and 165 rpm). Mean Weight Diameter Dry basis (MWD_d), mean weight diameter wet basis (MWD_w), stability index (SI), instability index (II), 2 to 8 mm aggregate size distribution (ASD_{d8}) and 0 to 100 mm aggregate size distribution (ASD_{d100}) were determined and analyzed. The results indicated that no significant differences were noted between types of blade. However, the rotational speeds had significant effects on selected parameters.

Key words: Tillage, combined implement, disk plough, rotary blade.

INTRODUCTION

The plough is as old as agriculture which originated from 10 to 13 million years ago in the fertile crescent of the Near East, mostly along the Tigris, Euphrates, Nile, Indus and Yangtze River valleys, and were introduced into Greece and Southeastern Europe 8000 years ago (Lal et al., 2007). Tillage is one component in any system of soil management for crop production and is a process of applying energy to the soil to change its physical condition by disturbing it. Tillage processes are used in crop production for different reasons, such as loosening soil to create a seedbed or soil pulverization for better root zone, moving soil to change the micro topography, or mixing soil to incorporate amendments (Zhong et al., 2010). Lobb et al. (2007) reported that tillage has been and will always be an integral part of crop production. They further stated that tillage can result in the degradation of soil, water and air quality. Tillage is the most important primary activity for crop production. In addition, it is one of the highest power-required processes of the agricultural production and the high cost of energy has encouraged farmers to find alternative economic tillage methods (Bayhan et al., 2006). Tillage operation is also defined as a procedure for breaking up soil; the soil failure depends largely upon the soil

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Figure 1. A comboplough.

(a) (b) (c)

Figure 2. Straight blade, S (a), C-shaped blade (b) and L-shaped blade (c).

properties, tool parameters and cutting speed (Zhong et al., 2010). The cost and the timeliness of operation assume critical importance while deciding the type of tillage tools. Godwin (2007) said that the cost of tillage operation is a vital component to determine farm profitability and recent years have seen a significant move to reduce tillage operation. The great part of energy consumption in mechanized agriculture is related to tillage operation. Operations simultaneously utilizing two or more different types of tillage tools or implements to simplify, control or reduce the number of operations over a field are called combined tillage. Machines for tillage operation usually pass the farm four times or more which causes soil compaction, increases cost of labour and energy. The compression of soil causes reduction of the moisture penetration, soil oxygen capacity, penetration of root in the soil, organic materials capacity in soil and increasing energy consumption (Tebrügge and Düring, 1999).

Most of the primary tillage operation is for unsettling the compression of soil and root growth. In this regard, Ruci and Vilde (2006) on their research stated that ploughing is one of the most power-consuming and expensive processes in agricultural production. Craciun et al. (2004) on their research reported some advantages about combined machines for seedbed preparation and sowing. Using conventional technologies, with successive tillage implements across the land, it takes a lot of time, the loss of the soil moisture and sometime because of heavy rains, snow and bad weather, could impede sowing and crop establishment. Cesnieks et al. (2001) and Vilde (1998, 1999) evaluated the possibilities and efficiency of soil tillage minimization and they concluded that, it is one of the most power-consuming and expensive processes in agricultural production. They reported that tillage requires 180 to 320 kWh/ha, which corresponds to 50 to 80 kg of fuel per hectare of the land tilled and makes 20 to 25% of its total consumption in agriculture. With the present technologies, the cost of soil tillage operation ranges between 45 to 58 USD/ha. In terms of draft, Javadi and Hajiahmad (2006) reported that draft and clod mean weight diameter (MWD) significantly decreased when combined tillage operation is done compare to single operation with many pass. The past research work did not consider the combined effect of disk plough and rotary blades on farm. In this regard, Ahmad and Amran (2004) studied the energy prediction model for disk plough combined with a rotary blade in wet clay soil. In order to produce cheaper agricultural products, it is necessary to reduce expenditure. The concept of disc plough combined with rotary blade machine has the following advantages; higher degree of soil crumbling, better mixing of soil and mineral fertilizer, improved parameters of work on heavy soils, the guarantee of complete preparation of the field, reduction of draft and wheel slip, reduces soil compaction, energy consumption, fuel consumption, decreases labour and machinery cost.

Disc ploughs are simultaneously utilized to prepare an adequate seedbed and bury crop residues. They are particularly adapted for use in hard-dry soils, shrubby or bushy land. They are also utilized in clay soil for reduction of energy consumption in tillage, soil compaction and structural degradation due to vehicular traffic. This paper describes a study on the design, development and performance of a comboplough to replace current two-pass or three-pass tillage treatments with one-pass. The potential benefit with current one-pass tillage treatment would be saving in fuel, labour and machinery cost.

MATERIALS AND METHODS

Tractor and tillage apparatus

A comboplough has four essential parts which include a chassis, a disk plough (Figure 1), a set of rotary blades (Figure 2) and a transmission system (Figure 3). The comboplough is attached to a tractor three point linkage system and driven by the tractor power-take-off shaft (PTO). Power is transferred from the PTO to the gearbox (Figure 2). The drive direction is changed by 90° at the horizontal shaft to the rotary blade shaft. A clutch safety system is placed between the universal joint and the gearbox to prevent overload. The disk implement consists of standard disk having 61 cm diameter (Tooth, 1998). The position of rotary blade was determined according to the upward soil movement at the end of the disk (Ahmad and Amran, 2004). The rotary shaft has three kinds of blades: straight (S), C-shaped and L-type (Figure 2). A

Figure 3. Transmission system.

Figure 4. Adjustment and positioning of tractor travel speed.

63.4 kW John Deere 6405 (PTO power 51 kW) was used for the tillage experiments. The tractor has static weight distribution of 40% front and 60% rear with total mass of 3891 and 180 kg balancer (6 × 30 kg). The front tires were type radial 12.4 to 24 single operated at 220 kPa inflation pressure while the rear tires were radial 18.4 to 34 single operated at 160 kPa inflation pressure.

Tillage site

The experiments were carried out at the University Putra Malaysia Research Park, Serdang Selangor, Malaysia, on three different plots with 675 m^2 size in the year 2010/2011, on a clay loam soil with average texture of 28.73% sand, 28.32% clay and 43.7% silt, longitude 101°, 42.912´E, latitude 2°, 58.821´N and an altitude of 40 m above sea level. The experimental site has an average annual rainfall of 2548.5 mm with maximum and minimum temperatures of 33.1 and 23°C, respectively. The soil penetration resistance in each experimental plot was determined using a Penetrograph (80 mm long and 10 mm cone diameter) at depth between 0 to 80 mm.

Test procedure

The test was performed based on 2 × 3 factorial treatment in Randomized Complete Block Design (RCBD) with three replications. Block dimensions were 25 × 27 m^2. Clod mean weight diameter was determined using different sieve sizes (8, 4.75, 2.8, 2, 0.5, and 0.3 mm) in three replications after operation. The main plots were allocated to rotary speeds (130,147 and 165 rpm) and sub plots were allocated to the three types of blades namely, straight blade (S), C-shaped and L-shaped. Aggregate stability or stability index (SI) was measured using a wet-sieving apparatus to determine the mean weight diameter, wet basis (MWD_{w}) and dry-sieving to determine the mean weight diameter, dry basis (MWD_{d}). The method of wet-sieving was adapted from Kemper and Rosenau (1986). The wet-sieving apparatus duration was 10 min and 50 oscillations per minute and SI was calculated using the following formula:

Instability Index (II) = $MWD_d - MWD_w$

Stability index (SI) = 1÷ instability index (II)

Experiments were conducted to determine the influence of various types of blades and rotational speeds on selected soil physical properties. The soil physical characteristics investigated were MWD_d, MWD_w, to find out the SI, II and percentage of aggregate size distribution for aggregates between 2 and 8 mm (ASD_{d8}). Clod mean weight diameter (MWD_{d100}) was determined using different sieve sizes (100, 50, 14, 6.3 mm) in three replications after operation using sieve size of 100 mm and below. The tillage depth for disk plough was 20 cm. The tractor PTO speed of 540 rpm was reduced to 216.5 rpm using a gearbox. The rotary blade speeds of 130,147 and 165 rpm were obtained by changing the adjustable gear sprockets (13:23, 14:22 and 15:21) in the transmission system (Figure 3). The travel speed used for all treatments was 7.2 km h^{-1}. This travel speed was achieved by adjusting engine throttle (1500 rpm) and gearbox position (A-2) at fixed setting (Figure 4). The analysis of variance (ANOVA) and protected Duncan's new multiple range test were used to analyze the data using the statistical analysis systems (SAS) 2005 software.

Measurements of soil characteristics

Twenty-seven soil samples were collected from the field during the tillage experiments from each plot at depths of 0 to 15 and 15 to 30 cm. Soil samples were classified by mechanical analysis using the pipette method.

RESULTS AND DISCUSSION

Table 1 presents the result obtained from the mechanical analysis for the soil sample using pipette principles. The soil classification was achieved by USDA textural classification system. The experimental soil sample was found to be sandy loam (Table 1 and Figure 5). Figure 6 shows the soil penetration resistance of different experimental plots at different depths. The maximum soil resistance of 380 N/cm^2 was found in plot "A" at the 75

Table 1. Soil particle size of the field at the University Research Park for a Serdang clay loam.

Site	Clay (%)	Sand (%)	Silt (%)
A	33.74	40	26.82
B	25.64	14.53	59.83
C	25.77	31.67	42.56
Average	28.38	28.73	43.07

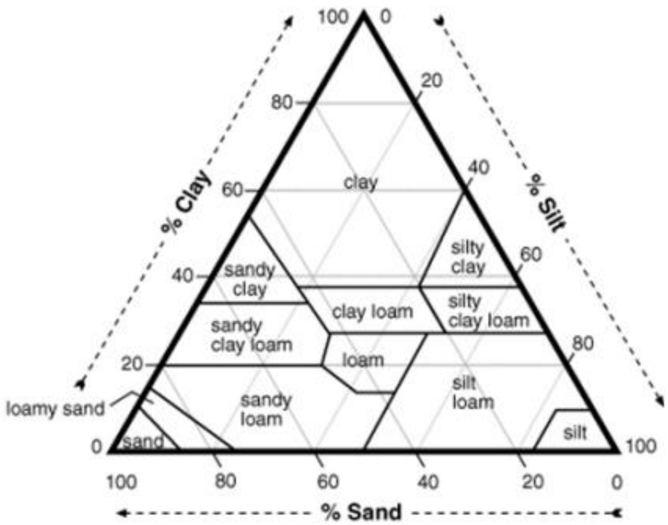

Figure 5. USDA textural classification system (percent sand ≥2 to 0.050 mm, percent silt = 0.050 to 0.002 mm, and percent clay is finer than 0.002 mm) (Teh and Jamal, 2010).

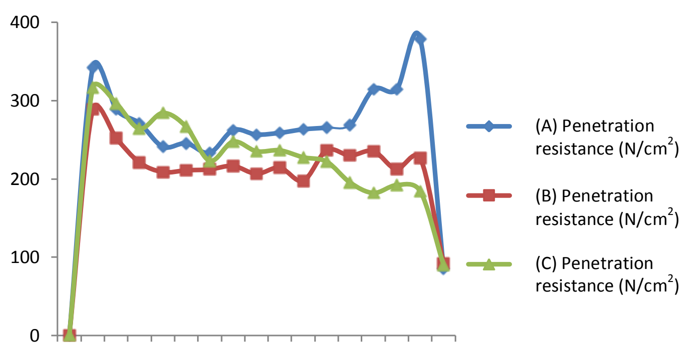

Figure 6. Soil penetration resistance at different sampling plots.

mm depth. Tables 2 and 3 show the relationships between types of rotary blades, rotational speeds and physical characteristics of soil. Statistical analysis presented indicates that there were no significant differences between types of blades on MWD_d. The effects of different blades were not significant on MWD_w; however, it was noted that the C-shaped blade had minimum MWD_w and the straight blade, S, had maximum MWD_w (Table 3). The effect of different blades were not significant on SI however it was noted that the S and L-shaped blades had maximum and minimum SI values, respectively. The effects of different types of blades were not significant on II however it was noted that L-shaped and the straight blade (S) had maximum and minimum values of II respectively. Aggregate size distribution (ASD_8) could also be expressed as the percentage of aggregates greater than 2 to 8 mm. The results also showed that types of blades had no effect on ASD_8, however it was observed that the C-shaped and straight type blades had highest and lowest ASD_8 respectively.

Another factor for aggregate size distribution (ASD_{100}) can also be expressed as the percentage of aggregates greater than 2 to 100 mm while mean weight diameter (MWD_{d100}) can also be expressed as the diameter of particle size (dry basis) greater than 2 to 100 mm. Statistical analysis indicate that there were no significant differences between three types of blades and MWD_{d100}. However, the C-shaped blade had greater effect on MWD_{d100} compared to the other two blade types (straight and L-shaped). Rotational speeds of blade had significant effects on physical characteristics of soil. The mean weight diameter dry basis, MWD_d, showed high significant difference ($p < 1\%$) at 130 rpm when compared to the other two speeds. This was considered to be due to clod breaking and loosening of soil surface layer at the lowest speed (130 rpm). The results for mean weight diameter wet basis, MWD_w, proved that the difference was highly significant between the blade rotational speeds. Results revealed that rotary blade speeds had significant effects on instability index (II) and stability index (SI). This may be due to the fact that the rotary blade hit the soil surface with sufficient cutting velocity to produce particle size of soil and II. The highest II was obtained from lowest rotary speed. The result showed that a blade speed of 135 rpm had maximum effect in increasing ASD_8 to 62.714%. It means that lower rotary blade speed would produce higher value of ASD_8. Results obtained also showed that rotary blade at 130 rpm speed had 24.559 mm MWD_{d100}. This indicates that rotary blade speed had high significant effect on MWD_{d100}. This proves that slow hitting soil process by the rotary blade produces larger diameter clods.

From statistical method, the analysis of variance was done to check the significance of interrelationships among obtained data set. Interaction effects of rotary speeds × type of blades revealed significant effects on

Table 2. Analysis of variance (ANOVA) of different factors for traits measured.

S.O.V	DF	MWDd8 (mm)	MWDw (mm)	II	SI	2-8mm (ASD)	MWDd100 (mm)
Blade	2	3.06[ns]	0.14[ns]	1.82[ns]	1.49[ns]	2.86[ns]	3.14[ns]
Speed	2	17.00**	3.87*	19.32**	2.16[ns]	6.48**	1.41[ns]
block	2	18.00**	72.98**	92.76**	5.97[ns]	16.44**	6.05*
Blade × Speed	4	4.3*	0.29[ns]	1.71[ns]	1.39[ns]	4.78**	3.87*

** Significant at 1% level, * Significant at 5% level, ns- not significant, MWD_{d8} - dry mean weight diameter, MWD_{w} - wet mean weight diameter, SI - stability index, IS - instability index, MWD_{d100} - dry mean weight diameter between 0 to 100 mm, ASD - aggregate size distribution.

Table 3. Mean values and comparison of mean for traits measured.

Treatment		MWD_{d8} (mm)	MWD_{w} (mm)	II	SI	2 to 8 mm [ASD (%)]	0 to 100 mm (MWD_{d100})
	S	3.20629[a]	1.6262[a]	1.5801[a]	1.3475[a]	58.456[a]	24.751[a]
Blade	C	3.35139[a]	1.5940[a]	1.7574[a]	0.8979[a]	61.356[a]	24.609[ab]
	L	3.35242[a]	1.5581[a]	1.7943[a]	0.8414[a]	61.221[a]	22.007[b]
	130	3.51080[a]	1.3916[B]	2.1192[a]	0.7896[a]	62.714[a]	24.559[a]
Speed	147	3.28322[b]	1.7280[a]	1.3881[b]	1.4093[a]	57.799[b]	24.197[a]
	165	3.11609[c]	1.6587[ab]	1.6245[b]	0.8880[a]	60.521[ab]	22.612[a]

Means between treatments followed by similar letters do not differ significantly (p>0.05).

ASD_8 (p<0.01), MWD_{d8} and MWD_{d100} (p<5%). These results showed that speed of rotary blades and types of blades were not independent. The rotary speed could have some effects depending on the type of blades used.

Conclusion

A new machine “comboplough” has been designed and developed for combined operations of primary and secondary tillage operations in a single pass. Field experiments were conducted at the Universiti Putra Malaysia Research Park, Serdang, Selangor having sandy clay loam soil texture. The results obtained indicated that no significant differences were noted between types of blades. The blade rotational speeds had high significant effects on selected parameters (MWD_d, MWD_w, II, SI ASD_d and MWD_{d100}). The effects of blade type were similar on MWD_d, MWD_w, II, SI ASD_d and MWD_{d100}. The results on MWD_d, II and ASD suggests that a rotary blade speed of 130 rpm was highly effective than 147 and 165 rpm.

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