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THE EFFECTS OF COMBOPLOW ON SOME SOIL PHYSICAL PROPERTIES OF UNIVERSITY PUTRA MALAYSIA RESEARCH FARM

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ABSTRACT

A disc plough combined with a set of rotary blades (Comboplow) for land preparation has been designed, fabricated and tested. The Comboplow includes two units of tillage tool comprising of a disc plough and several rotary blades. The disc plough cuts, partially or completely inverts a layer of soil to bury surface material. The soil in contact with the surface of disk would be cut and pulverized by the rotary blades. Multiple tillage operations are reduced to a single pass , resulting in a potential reduction of soil compaction, labour and fuel cost .The Comboplow was tested at Universiti Putra Research Farm having sandy clay loam soil texture. The treatments were three types of blades (straight type,curved and L- shaped) and three rotary speeds (130,147 and 165 rpm) . The parameters measured were Mean Weight Diameter (dry basis) , Mean Weight Diameter (wet basis) , and soil bulk density. The mean weight diameters of the soil aggregates (dry basis) were 3.54, 3.28 and 3.12 mm at rotational blade speeds of 130, 147 and 165 rpm, respectively. The mean weight diameters of the soil aggregates (dry basis) were 3.21, 3.36 and 3.38 mm for the straight type blade, curved type blade and L-shaped blade, respectively. An increase in rotary speed reduced the mean weight diameter (dry basis). The mean weight diameters of soil aggregates (wet basis) were found to be 1.39, 1.66 and 1.73 mm at rotational speeds of 130, 147 and 165 rpm, respectively. The mean weight diameters of soil aggregates (wet basis) with the straight type blade, curved type blade and L-shaped blade were 1.63, 1.59 and 1.56 mm, respectively. An increase in the rotational speed from 130 to 165 rpm decreased the mean weight diameter (wet basis) by 0.34 mm. In comparison to the control treatment, the straight type blades, L-shaped blades and curved type blades decreased soil bulk density by 23.6%, 23.2% and 21.5%, respectively. The L-shaped blade had maximum and minimum values of percentage bulk density (dry basis) at rotary blade speeds of 165 and 130 rpm, respectively.

***Keywords**: Combined machine, Tillage, Comboplow, Bulk density, Mean Weight Diameter*

INTRODUCTION

The disc plough combined with rotary blades is simultaneously utilized to prepare an adequate seedbed and bury crop residues. It is particularly adapted for use in hard-dry soils, shrubby or bushy land. It is utilized in clay soil for reduction of energy consumption in tillage, soil compaction and structural degradation due to vehicular traffic; therefore, current multiple-passes tillage operation could be replaced with one-pass. The outstanding benefit with this newly developed one-pass tillage operation implement is to save fuel, labour and machinery cost.

Tillage is one component in any of the soil management system 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 [1]. Lobb *et al* [2] reported that tillage can result in the degradation of soil, water, and air quality. Tillage is the most important primary activity for crop production. Godwin [3] reported 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 cost. Ruci and Vilde [4] in their research stated that, ploughing is one of the most power-consuming and expensive processes in agricultural production. Using conventional technologies, with successive tillage implements across the land, it takes a lot of time, loss of the soil moisture and sometime because of heavy rains, snow and bad weather that limits duration of tillage, this could obstruct sowing and crop establishment. Vilde [5] evaluated the possibilities and efficiency of minimizing soil tillage and he concluded that, it is one of the most power-consuming and expensive processes in agricultural production. he reported that tillage requires 180-320 kWh ha^{-1}, which corresponds to 50-80 litres of fuel per hectare of the land tilled and makes about 20-25% of its total crop production inputs in agriculture. he further reported that with the present technologies, the cost of soil tillage operation ranges between 45-58 USD/ha. According to Javadi and Hajiahmad [6] , MWD before tillage operation and after tillage operation with combination of disc harrow and Cambridge roller, disc harrowing once and disc harrowing twice, were 1.49 , 1.23 mm; 1.39 , 1.32 mm 1.37 and 1.17 mm, respectively. They also reported all tillage operation implements decreased the values of MWD. Boix-Fayos *et al.*, [7] studied the soil aggregation in relation to other soil properties along a climatologically transect in the Southeast of Spain. They reported the large aggregates >10, 10-5, 5-2 mm were present in highest proportions in the most arid of the studied areas. Aggregates 1- 0.105 mm were positively correlated to medium, fine, very fine sand, silt fractions and to organic matter. Aggregates < 0.105 mm were positively correlated to organic matter and clay content. Small aggregate sizes 1-0.105 and <0.105 mm had a positive influence on soil water retention and they seem to be a good indicator of soil degradation. Boydafi and Turgut [8] studied the effect of tillage implements and operation speeds on soil physical properties in Ataturk university. They reported that after primary tillage; the air dried soil samples were sieved using a 63, 32, 16, 8, 4 and 2mm set of sieves with a shaking time of 30s. Finally aggregate size distribution was determined based on the weight of soil in each class with respect to the total soil sample weight. They concluded that primary tillage implements and operating speeds significantly affected the mean weight diameter values. The average MWD values for disc plough and disc plough with harrow was 25.64 and 18.76 mm, respectively. The MWD values with the tillage implements without rotary harrow higher than implements followed by rotary tiller. An increased in implement speed from 1.25 to 1.5 m/s decreased MWD with1.18 mm and an increased in speed from 1.5 to 1.75 m/s also decreased MWD with 1.18 mm. Operating speeds significantly affected the MWD values, as the operation speed increased MWD decreased. Ponjican, *et al.,* [9] investigated that the effects of working parameters on rotary tiller specific work requirement. They reported average bulk density before tillage operation and after tillage operation were 1.27 and 1.07, respectively. It means that the bulk density was affected with rotary tiller working and decreased after tillage operation with rotary tiller.

The effects of tillage treatments (mouldboard ploughing, chisel ploughing, and disc ploughing) on soil water holding capacity and on soil physical properties were investigated by Abu Hamdeh [10]. He reported that dry bulk density from 0 to 20 cm was affected by tillage treatments and from 20 to 40 cm by axle load. Tillage systems generally affect the soils' ability to hold moisture and the available water capacity. 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 [11].

The past research works did not consider the combined effects of disc plough and rotary blades on soil tillage. In this regard Ahmad and Amran,[12] studied the energy prediction model for disc 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; improve 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.

MATERIALS AND METHODS

The experiments were conducted at Universiti Putra Malaysia Research Farm, Serdang, Selangor, Malaysia. Three different plots having 675 m^2 sizes each during the year 2010/2011 were used. The site was located at longitude 101˚, 42.916΄E, latitude 2˚, 58.812΄N and an altitude of 46 to 48 m above sea level with an average annual rainfall of 2549 mm with maximum and minimum temperatures of 33.1˚C and 23˚C respectively. The experiment was conducted using a randomized complete block design with a factorial arrangement of treatments (three types of blades with three speeds) in three replications. Data were statistically analyzed and significant differences were separated using Duncan's multiple range tests ($p \leq 0.05$). Regression analysis was also conducted separately for each treatment. Regression analysis of bulk density responses over type and speed of blades was generated using standard procedures (SAS, 1996), in order to calculate slope,

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intercepts and regression coefficients (R^2).A 63.4 kW John Deere 6405 tractor (PTO power 51 kW) was used or the tillage experiments. The tractor has static weight distribution of 40% front and 60% rear with total mass of 3891 kg and 180 kg balancer (6×30 kg).The front tires were radial 12.4-24 single operated at 220 kPa inflation pressure and the rear tires were radial 18.4-34 single operated at 160 kPa inflation pressure.
A disc plough combined with rotary blades consists of the following components; chassis, three point hitch, transmission system (universal joint with safety clutch, gear box, input shaft, output shaft, chain, sprockets, main shaft, and holder of blades), disc, coulter, rotary tillers and adjusting mechanism. The Comboplow consists of two units, a disc plough and rotary blades. The disc plough cuts partially or completely inverts layer of soil, and the rotary blades simultaneously pulverised the cut soil layer from the disc. As such multiple tillage operations are reduced to a single pass thus reducing the number of field trips as compared to conventional tillage practices.

In this machine power is transferred to the rotary tiller from the tractor via the power-take-off (PTO) drive by means of safety clutch. A shaft containing blades is located at 90°to the line of travel and rotates in the same direction as the forward travel of the tractor. Since the shaft turns at a rate considerably faster than the corresponding tractor speed, soil cutting and pulverisation is effectively accomplished.

Bulk Density

Undisturbed soil samples were collected from the topsoil layer of 0-15 cm and subsoil layer 15-30 cm depth at nine different locations before tillage operation [13]. The samples were collected to determine the bulk density of the soil. The samples were taken in 3 replications using 100 cm^3 volume core rings. The materials used for the experiment were: Hammer, weighing balance, with an accuracy of 0.001%, Vanier calliper, core ring, drying oven and knife Vanier calliper was used to determine the volume dimensions of the core ring. Bulk density was computed as the ratio of the mass of the oven-dried sample to the volume of the wet sample taken from the field. An experiment was conducted to determine the influence of various types of blade and rotational speeds on aggregate size distribution. A randomized complete block design (RCBD) with a 2×3 factorial arrangement, 3 blade types, straight, curved and L-Shaped blade, and 3 speeds, 130,146,165 rpm in three replications were used for the experiment.

Mean Weight Diameter

The method of wet-sieving was adopted from Kemper and Rosenau [14]. The materials used for the research were: Set of sieve sizes (8, 4.75, 2.8, 2, 1, 0.5 and 0.3 mm); aluminium containers; weighing balance, with 0.001% accuracy; shaker; water; funnel; wet sieving apparatus and drying oven.To determine the mean weight diameter, soil samples were randomly taken from the tilled plot. Eighty one samples were collected (for straight, curved and L-shaped blade types) at three speeds (130,147 and 165 rpm) with three replications after tillage operation. The moist soil samples were allowed to air dry at room temperature for six weeks. The air dried soil samples were sieved using a set of sieves (mesh opening 8, 4.75, 2.8, 2, 1, 0.5 and 0.3mm) with a shaking time of 30 s. Table 1 shows the sample table that was used to determine the mean weight diameter. The average sizes of sieves ($\bar{X}_i$) that shows the mean diameter of each aggregate size friction was calculated using ($\bar{X}_1 = \frac{8+4.72}{2} = 6.4$). Soil in the sieves 4.75, 2.8, 2, 1, and 0.3 mm (W_i) were weighted with weighting balance. The proportion of the total sample weight (W_i) occurring in the corresponding size friction ($\bar{X}_i$) were calculated. The summation is carried out over all *n* size fractions 1563 as shown in Table 1. Mean weight diameter was calculated using equation 1 Arvidsson [15], Boydas and Turgut[16] and Teh and Jamal [17].

$$MWD_{dry} = \frac{1}{W_t}\sum_{i=1}^{n} \bar{X}_i W_i \qquad (1)$$

where,

MWD_{dry} = mean weight diameter (dry basis) in mm;
W_i = weight of each size fraction (g);
W_t = total weight of soil sample (g);
$\bar{X}_i$ = mean diameter of each aggregate size fraction (mm).

For all 81 samples, table 1 were used and for every block the average of MWD_{dry} were calculated and analysed. Aggregate size distribution can also be expressed as percentage of aggregates that are greater than 2 mm. in calculating the percentage of aggregate greater than 2 mm, the weight of all aggregate greater than 2 mm was calculated and divided to total weight of all aggregates and multiplied 100. Table 1 shows percentage of aggregates >2mm which is equal to

$$\left(\frac{150.95+102.05+47.63}{1653} \times 100\right) = 16.3\% \quad \text{and} \quad MWD_{dry} = \frac{1563}{515.79} = 3.2049$$

Table 1: Sample table for measuring mean weight diameter (dry basis)

Sieve size (mm)	$\bar{X}_i$ (mm)	W_i (g)	$\bar{X}_i \times W_i$
8 - 4.75	6.4	150.95	966.08
4.75– 2.8	3.8	102.05	387.79
2.8-2	2.4	47.63	114.312
2-1	1.5	85.43	128.145
1-0.5	0.75	51.18	38.385
0.5-0.3	0.4	25.56	10.244
0.3-0	0.15	52.99	7.9485
Total	-	**515.79**	**1563**

In measuring the mean weight diameter (wet basis), same soil samples used for mean weight diameter (dry basis) were used. The method of wet-sieving was adopted from Kemper and Rosenau [14]. Percentage of each soil in the related sieve $\bar{X}_{i1}$ was calculated (Table 2). Particles less than 0.3 mm (clay) were removed from the test procedure [17].The percentage of each soil in related sieve (W_{i2}) based on total weight minus clay was computed and prepared for wet sieving apparatus. Each sample in sieve was wetted and transferred in the wet sieving apparatus, for 10 minutes duration at 50 oscillations per minute. It was then oven dried at 105°C for 24 hours. Dried soil samples after transfer from the oven (W_{i3}) were weighed and MWD_{wet} was calculated.

Table 2: Sample table for measuring the mean weight diameter (wet basis)

Sieve size (mm)	$\bar{X}_i$ (mm)	W_i (g)	$\bar{X}_i \times W_i$	[1] $\bar{X}_{i1}$ (%)	[2] W_{i1} (g)	[3] W_{i2} (%)	[4] W_{i3}	MWD_{wet}
8 - 4.75	6.4	150.95	966.08	29.27	29.27	32.62	23.15	148.16
4.75– 2.8	3.8	102.05	387.79	19.79	19.79	22.05	22.21	84.02
2.8-2	2.4	47.63	114.312	9.23	9.23	10.29	9.38	22.51
2-1	1.5	85.43	128.145	16.56	16.56	18.46	16.17	24.26
1-0.5	0.75	51.18	38.385	9.92	9.92	11.06	11.28	8.46
0.5-0.3	0.4	25.56	10.244	4.96	4.96	5.52	6.80	2.72
0.3-0	0.15	52.99	7.9485	10.27	[2] 0	0	[4] 11.11	1.67
Total	-	**515.79**	**1652.886**	100.00	89.73	100	100	[5] **291.8**

1. $percentage\ \frac{\bar{X}_{i1} W_i}{W_{total}} \times 100;$

2. For testing MWD_{wet} clay particles were not used (Teh and Jamal 2010); . $W_{i2} = \frac{W_{i1}}{\sum_{i=1}^{n} W_{i1}} \times 100;$

4. This weight of clay was calculated (100-88.99 total weight without clay);

$$MWD_{wet} = \frac{total\ MWD_{wet}}{100} = 2.918,\ MWD_{wet} = \frac{291.8}{100} = 2.918$$

RESULTS AND DISCUSSIONS

Effect of Type of Blade and Rotary Speed on Soil Bulk Density (Dry Basis)

The results on bulk densities (dry basis) before and after tillage operations at depths of 0-30 cm are presented in Table 3. Mean values obtained were, 1.538, 1.537 and 1.539 g/cm^3 at depth 0-30 cm in blocks A, B and C, respectively. The table also illustrates the means of bulk density in response to blade type and speed of rotary. The mean values of bulk density were 1.206, 1.181, and 1.177 g/cm^3 for the curved type blade, L-shaped blade and straight type blade, respectively. The mean values of bulk density were 1.297 g/cm^3, 1.172, and 1.095g/cm^3 at for speeds of 130, 147 and 165 rpm, respectively. The analysis of variance on bulk density (dry basis) at the depth of 0-30 cm from the soil surface in blocks A, B and C are presented in Table 4. The analysis showed that there were no significant differences between treatments in each case. The responses in bulk density in the field, for blocks, type of blade and rotary speed at the depth 0-30 cm are illustrated in Fig.1. Table 5 shows the relationship between types of rotary blades, rotational speeds and bulk density (dry basis). Soil bulk density (dry basis) was significantly ($p<0.0001$) affected by the rotational speed and type of blades ($p<0.05$). Results also showed a significantly ($p<0.01\%$) higher value at 130 rpm than at the other speeds. This was attributed to be due to clod breaking and loosening of soil surface layer at the lowest speed (130 rpm). Interaction effect of rotary speeds × type of blades revealed no significant effects on bulk density ($p<0.05$). However it was noted that the highest bulk density (dry basis) and lowest bulk density (dry basis) were obtained from L-shaped blade at 130 rpm and 165 rpm rotational speeds, respectively. This was in agreement with Javadi and Hajiahmad [6] who reported that the bulk density generally decreased after tillage operation. These results were similar to the findings by Abu Hamdeh [10], Javadi and Hajiahmad [6] and Ghazavi [18] who reported that the bulk density was affected by tillage implements and generally decreased after tillage operation.

Table 3: Duncan's multiple range tests for soil bulk density (dry basis) before and after tillage operation

Before tillage operation (dry basis)		After tillage operation (dry basis)			
Block	MBD (g/cm^3)	Type of blade	MBD* (g/cm^3)	Speed (rpm)	MBD** (g/cm^3)
A	1.538^A	L-shaped	1.181^A	130	1.297^A
B	1.537^A	Straight	1.177^A	147	1.172^B
C	1.539^A	Curved	1.206^A	165	1.095^C

Means followed with the same superscript letter within a same column are not significantly different at p<0.05 according to Duncan's multiple range test (SAS1996); MBD=Mean of bulk density, MBD*=Mean of bulk density for a given blade at all speeds, MBD**=Mean of bulk density at a given speed for all blades.

Table 4: Analysis of variance table for soil bulk density (dry basis) before tillage operation

S.O.V	D.F	MS	F Value	Pr>F
Model	10	0.00036	8.52**	0.0001
Treatment	2	0.000013	0.37^{ns}	0.7438
Replication	8	0.00045	10.5**	<0.0001
Error	16	0.00004		

****** Significant at 1% level,* significant at 5% level and ns not significant at 5% level;
C.V = 0.42% and R^2=84.18%;S.O.V = Source of variance;DF = Degree of freedom;
M.S= Mean square.

Table 5: Analysis of variance table for the effect of type of blades and speed of rotary blade on soil bulk density (dry basis) after tillage operation

S.O.V	D.F	M.S	F Value	Pr>F
Block	2	0.002	1.06^{ns}	0.3699
Speed	2	0.094	44.49**	<.0001
Blade	2	0.018	8.31**	0.0034
Blade*speed	4	0.004	1.93^{ns}	0.1537

****** Significant at 1% level,* significant at 5% level and ns not significant;

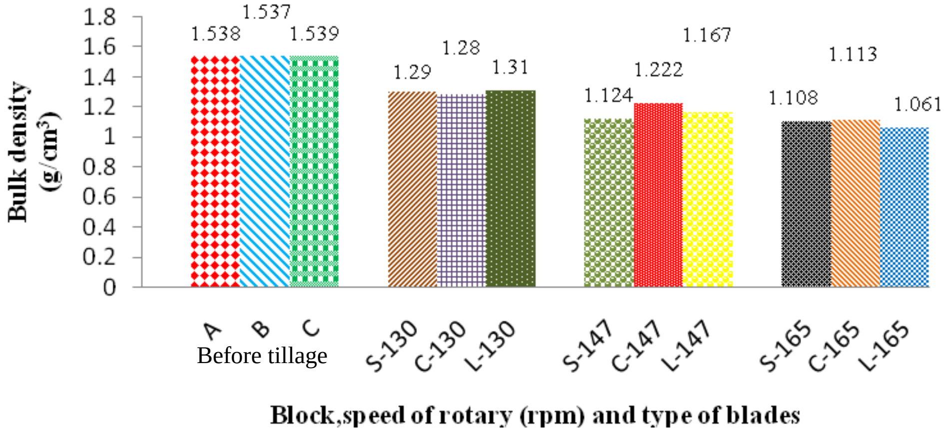

Fig.1: Effect of Blocks, Blade Type and Rotary Speed on Soil Bulk Density (Dry Basis) (S= Straight type blade, C=curved type blade and L= L-shaped blade)

Effect of Blade Type and Comboplow Rotary Speeds on Mean Weight Diameter (Wet and Dry Bases) of Soil Aggregates

There was a strong relationship between mean weight diameter (wet basis) and mean weight diameter (dry basis) with respect to rotary blade type and rotational speeds. The rotational speeds was found to have significant effect on the mean weight diameter (wet basis) and Mean weight diameter (dry basis) with the lowest value of 1.39 mm and 3.12 mm at the speeds of 130 and 165 rpm , respectively as shown in Table 6 and Figures 2-3. Results showed significant differences ($p < 0.05\%$) and ($p < 0.001\%$) with the highest value at 165 and 130 rpm rotational speeds compared to the other speeds for mean weight diameter (wet basis) and mean weight diameters (dry basis), respectively (Table 7). The values of the mean weight diameter (wet basis) and mean weight diameters (dry basis) were found to be 1.39, 1.66, 1.73 mm 3.54, 3.28 and 3.12mm at the rotational speeds of 130, 147 and 165 rpm, respectively. The significant ($p < 0.001$) increases with values of the mean weight diameter (wet basis) and decreases in values (significant at 0.001<) of the mean weight diameter (dry basis), this could be attributed to the rotary speed (Figures 2 - 3). The results for mean weight diameter wet basis proved that there were no significant differences between the types of blades; however there was a significant difference between types of blades in mean weight diameter (dry basis). The highest value of the mean weight diameter (wet basis) was obtained with the curved type blade at 165 rpm (Fig.2).The highest mean weight diameter (dry basis) was obtained with the L-shaped blade (Table 4.18). However, the highest value of the mean weight diameter (wet basis) and mean weight diameter (dry basis) were obtained with the curved type blade and L-shaped blade at 165 and 130 rpm, respectively (Figures 2-3). Furthermore, mean weight diameter (wet basis) and mean weight diameter (dry basis) were found to be 1.63, 1.59, 1.56 mm 3.21, 3.36 and 3.38 mm with the straight type blade, curved type blade and L-shaped blade, respectively. Results in mean weight diameter (wet basis) indicated that there was no significant interaction effect between rotary speed and type of blade (Table 6). However there was a significant interaction effect between rotary speed and type of blades (Table 7), it was noted that the L-shaped blade at 130 rpm and straight type blade at 165 rpm recorded the maximum and minimum values of mean weight diameter (dry basis), respectively.

These results were similar to the findings of Boyadas and Turgut [16] , Mahboubi and Lal [19] and Javadi and Hajiahmad [6] who reported that operating speeds of disc plough with harrow, mouldboard plough with rotary harrow significantly affected the mean weight diameter values. An increase in implement speed causes a decrease in mean weight diameter.

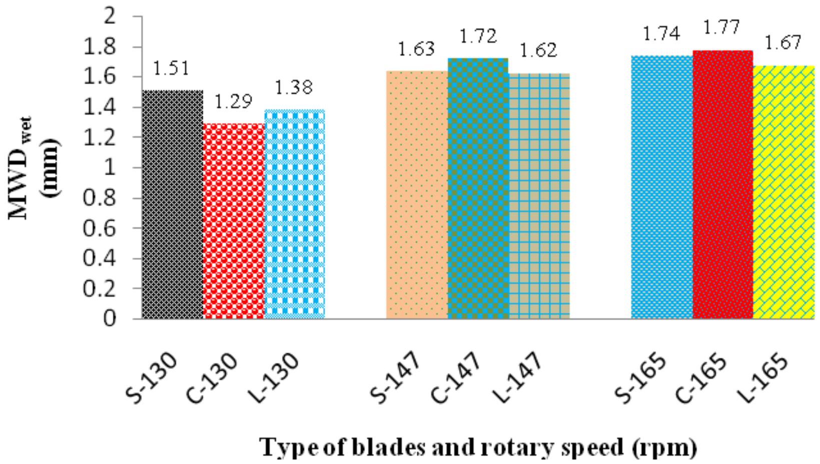

Fig.2: The Effect of Speed of Rotary Blades and Type of Blades on Mean Weight Diameter (Wet Basis) of Soil Aggregates. (S= Straight type blade, C=curved type blade and L= L-shaped blade)

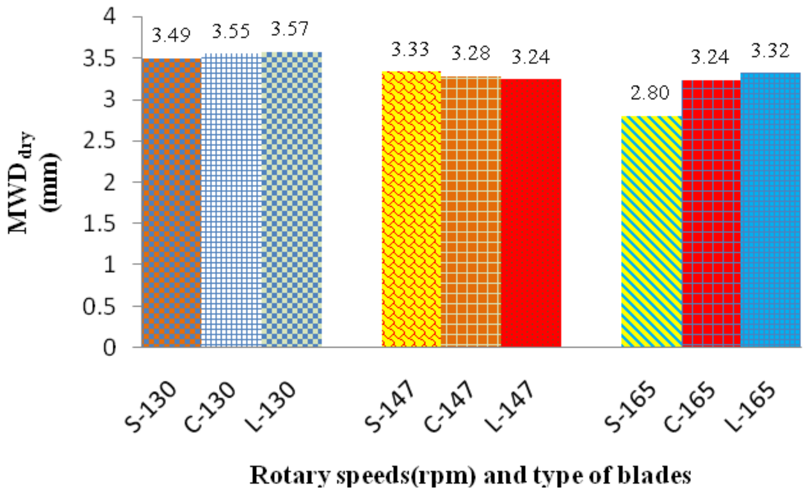

Fig.3: Effect of Blade Type and Rotary Speed on Mean Weight Diameter of Soil Aggregates (Dry Basis) (S= Straight type blade, C=curved type blade and L= L-shaped blade)

Table 6: Duncan's multiple range test on effect of blade type on mean weight diameter of soil aggregates wet and dry bases

Type of blade	$MMWD_{wet}^{*}$ (mm)	$MMWD_{dry}$*** (mm)
Straight type	1.63^{A}	3.21^{B}
Curved type	1.59^{A}	3.36^{A}
L-shaped	1.56^{A}	3.38^{A}

Speed (rpm)	$MMWD_{wet}$** (mm)	$MMWD_{dry}$**** (mm)
130	1.39^{B}	3.54^{A}
147	1.66^{AB}	3.28^{B}
165	1.73^{A}	3.12^{C}

Means followed with the same superscript letter within a same column are not significantly different at p<0.05 according to Duncan's multiple

range test (SAS1996) .$MMWD_{wet}^{*}$= Mean of Mean weight diameter (wet basis) for a given blade at all speeds; $MMWD_{wet}^{**}$= Mean of Mean weight diameter (wet basis) at a given speed for all blades; $MMWD_{dry}^{***}$= Mean of Mean weight diameter (dry basis) for a given blade at all speeds and $MMWD_{dry}^{****}$ = Mean of Mean weight diameter (dry basis) at a given speed for all blades.

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Table 7: Analysis of variance table for effect of blade type and rotary speed on mean weight diameter (wet basis) of soil aggregates

S.O.V	D.F	M.S wet basis	F value wet basis	Pr>F wet basis	M.S dry basis	F value dry basis	Pr>F dry basis
Block	2	5.36	72.98**	0.0001<	0.196	1.03ns	0.379
Speed	2	0.28	3.87*	0.0426	0.701	3.69*	0.048
Blade	2	0.01	0.14ns	0.8687	1.219	6.41**	0.009
Blade×speed	4	0.02	0.29ns	0.8775	0.231	1.21ns	0.343
Error	16	0.07			0.190		

****** Significant at 1% level,* significant at 5% level and ns not significant; S.O.V = Source of variance; D.F = Degree of freedom; M.S= Mean square, C.V = 17.01% and R^2=90.65% (wet basis), C.V = 4.27 and R^2=86.87% (dry basis).

CONCLUSIONS

The following conclusions were drawn from the research. In comparison to the control treatment, the straight type blades, L-shaped blades and curved type blades decreased soil bulk density by 23.6%, 23.2% and 21.5%, respectively. The L-shaped blade had maximum and minimum values of percentage bulk density (dry basis) at rotary blade speeds of 165 and 130 rpm, respectively. The mean weight diameter of soil aggregates (wet basis) was found to be 1.39, 1.66 and 1.73 mm at rotational speeds of 130, 147 and 165 rpm, respectively. The mean weight diameter of soil aggregates (wet basis) with the straight type blade, curved type blade and L-shaped blade was 1.63, 1.59 and 1.56 mm, respectively. An increase in the rotational speed from 130 to 165 rpm decreased the mean weight diameter (wet basis) by 0.34 mm difference. The mean weight diameter of the soil aggregates (dry basis) was 3.54, 3.28 and 3.12 mm at rotational blade speeds of 130, 147 and 165 rpm, respectively. Also the mean weight diameter of the soil aggregates (dry basis) was 3.21, 3.36 and 3.38 mm for the straight type blade, curved type blade and L-shaped blade, respectively. An increase in rotary speed reduced the mean weight diameter (dry basis).

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