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The Effect of Tillage Parameters on the Performance of the Heavy Duty Offset Disk Harrow

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Abstract: For mulch tillage burrying the residue is very important. Especially recently heavy-duty disk harrow is often used for breaking the soil and incorporating the residue into the soil. In this study, the performance of the heavy-duty offset disk harrow in a soil bin was examined. The objective of this study was to investigate the effect of forward speed, angle and weight of the disk harrow on draft and soil conditions in the soil bin. Heavy-duty disk harrow with 11 disks (reduced to the half size) was operated in a soil bin without stubble to see the effect of the tillage parameters alone on the soil conditions. The disk harrow was operated at speeds of 5.2, 7.9 and 9.8 km h^{-1}. The angles of the disk harrow were 10, 14 and 22°. The weight, speed and the angle of the disk harrow were found statistically significant for draft. Also the interactions of three factors were significant. The increasing angle, weight and speed increased the draft. Especially increasing the angle of the disk harrow dramatically increases the draft. The bulk density of the soil was only affected from the angle of the disk harrow. The weight and the speed did not have any effect on bulk density of the soil. Soil size changed with only changing the angle; increasing the angle increased the clod size.

Key words: Heavy duty disk harrow, mulch tillage, draft

INTRODUCTION

Increasing number of tillage detorietes the structure of the soil and causes the excessive fuel consumption. For this reason, it is essential to prepare the soil for seeding with minimum pass to conserve the soil and water. So the residues to be left on the soil surfaces should be practiced to minimize the erosion. Heavy-duty disk harrows are used recently for this purpose; the aim was to use the implement for mulch tillage and prepare the soil for seeding maximum by one or two passes.

The development of the large tractors permits the use of wide, large diameter disk harrows that can perform primary tillage while leaving plant residues on the surface of the field to conserve soil and water[1].

Dursun *et al.*[2] studied the stubble burying ratios of moldboard and disk ploughs. According to their findings, increasing the speed, disk angle and the depth of tillage increases the stubble burying ratios.

Hoki *et al.*[3] studied the effects of the pto driven powered disk tiller. They found the powered disk harrow is more effective comparing the unpowered disk tiller. Increasing the ground speed increased the total power requirements of the tiller.

Singh *et al.*[4] operated one-way plough at forward speeds of 2.77, 4.31, 5.14 and 6.88 km h^{-1} with peripheral disk velocity to ground speed ratios of 2.62, 1.9, 1.77, 1.42. They found the ratio of 1.42 produced 50.76% less energy and reduced operation time by 48.64%.

It appeared that the draft and tillage energy of a disk harrow could be reduced by changing disk spacing and other gang geometry[5]. Schafer and his friends concluded that reducing the disk spacing from 500 to 100 mm reduces draft to the lowest level.

Most effort was made through the understanding of the disk harrow tillage parameters and its effect on the soil conditions. This research was intended to examine the performance of the disk harrow in a soil bin before operating in the field. By getting the tillage performance parameters, one can better operate and control the performance of the disk harrow.

MATERIALS AND METHODS

The tests were conducted in a soil bin having clay-loam soil with a texture of 33.6% clay, 39% silt and 27.4% sand. The soil was prepared before each test in a similar way that first chiesel was used to level the soil and aerate the soil and then the soil was tilled with rotary tiller. Final step of the preparing the soil was to compact the soil by a roller with three passes. The moistures of the soil were 7.48% for dry and 12.5% for wet soil.

Fiat 80-66 4WD (Engine Power 59 kW) tractor and heavy-duty disk harrow with 11 disks (reduced to the half size of the original Heavy-duty disk harrow) were used in the experiments (Fig. 1). Some technical specifications of

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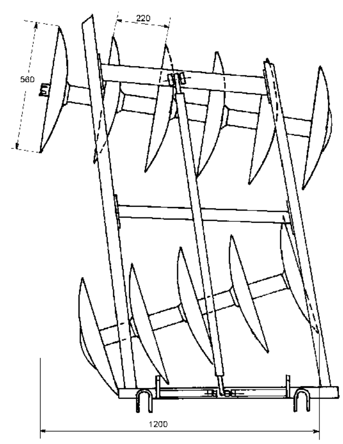

Fig. 1: General view and the dimensions of the disk harrow

Table 1: Specifications of the disk harrow

Dimensions:	
Overall length	1765 mm
Overall width	1310 mm
Overall height	1197 mm
Working width	1200 mm
Mass without additional weight	385 kg
Number of the disk	11
Diameter of the disk	560 mm
Disk spacing	220 mm

the disk harrow were given in Table 1. The disk harrow was operated at speeds of 5.2 km h^{-1} (H1), 7.9 km h^{-1} (H2) and 9.8 km h^{-1} (H3). The disk angles of the disk harrow were 10° (A3), 14° (A2) and 22° (A1). Aditional weight of 100 kg was added to the disk harrow to examine the effect of the weight that is designated G2 in the figures and tables. A three-point hitch dynamometer was used to measure the draft of the implement. The dynamometer is suitable for mounted implements for category I and II. The measurement set consists of three strain gauge load cells (Biaxial Clevis Pin), six converters (HBM-MC3), one A/D computer board (ME26) and a laptop computer (Halikan LA 5040) to store the data.

Computerized instrumentation consists of a vertical and horizontal load cells and each of these has a maximum capacity of 33 kN. The calibration results of the force measurements were realized using load cells and indicated a linear relationship with a coefficient of determination of 99.9% (r^2). In the field test, the measurement system was used to obtain draft force of a disk harrow with 11 disks. The instrumentation consists of four parts; 1. frame, 2. load cells, 3. converters and 4. lap-top computer (Fig. 2). At different disk angle and weight of the disk harrow was tested with three different forward speeds in dry and wet soil conditions. The soil bin that is 3 m wide and 50 m long was divided into three sections. The tractor was run in the soil bin in each section using different variation of disk harrow parameters and forward speed. Each test was replicated three times. After tillage operation, the soil samples were taken from 0-5, 5-10, 10-15 and 15-20 cm depths to calculate the bulk density and porosity of the soil. The completely randomized block design and Duncan's multiple range test was used to examine the data.

RESULTS AND DISCUSSION

Disk harrow parameters were found significant along with forward speed for draft and soil conditions. The statistical results were given in Table 2 and 3. The weight, speed and the angle of the disk harrow were found statistically significant for draft. The interactions of three factors were also significant. The increasing angle, weight and speed increased the draft. Especially increasing the angle of the disk harrow more affects the draft comparing the weight and the forward speed of the disk harrow.

Figure 3 and 4 show the draft requirement of the disk harrow regarding changing the parameters. As it is seen from the figures, increasing speed from H1 to H3 increases the draft.

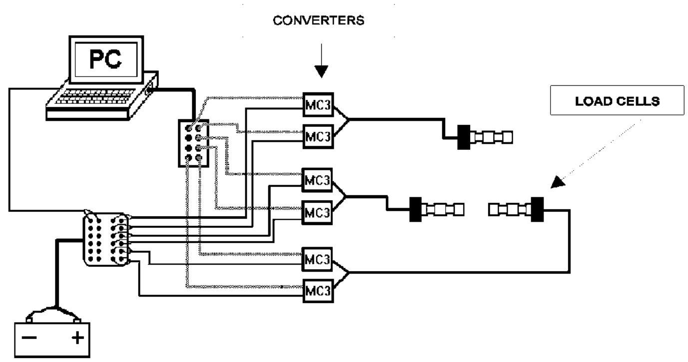

Fig. 2: Schematic view of the instrumentation system[6]

Table 2: Statistical results of the draft in dry soil

Source	SS	Df	Ms	F	P
Main Effect					
G	14.57	1	14.570	2497.19	***
H	6.12	2	3.060	524.71	***
A	224.41	2	112.210	19234.71	***
Interaction					
G x H	0.64	2	0.320	54.62	***
G x A	5.39	2	2.690	461.76	***
H x A	7.61	4	1.900	326.29	***
G x H x A	1.95	4	0.490	83.62	***
Error	0.11	18	0.006		
Total	260.80	35			

Table 3: Statistical results of the draft in wet soil

Source	SS	Df	Ms	F	P
Main Effect					
G	16.00	1	16.000	3200.00	***
H	3.22	2	1.610	321.56	***
A	497.39	2	248.700	49738.89	***
Interaction					
G x H	1.82	2	0.910	182.00	***
G x A	2.53	2	1.260	252.67	***
H x A	9.22	4	2.300	460.89	***
G x H x A	1.73	4	0.430	86.67	***
Error	0.09	18	0.005		
Total	532.00	35			

Table 4: Forward speed and disk harrow parameter effects on the percentage of soil clod size in dry soil

		Percentage of clod size, %								
Clod size (mm)		Ø (20-80)			Ø (5-10)			Ø (2.5->2.5)		
forward speed (km h^{-1})		5.2	7.9	9.8	5.2	7.9	9.8	5.2	7.9	9.8
	A1	12.0	12.3	15.1	22.5	25.6	21.5	65.5	62.1	63.4
G1	A2	22.6	19.0	23.6	22.7	24.9	21.6	49.7	56.1	54.8
	A3	31.0	19.5	39.5	23.9	26.1	29.7	45.0	54.4	38.9
	A1	29.9	19.0	14.9	13.6	22.2	18.9	62.0	58.8	66.2
G2	A2	24.4	23.7	21.9	28.9	24.5	23.2	41.2	51.8	54.9
	A3	57.5	27.1	29.5	22.5	23.1	18.8	20.0	49.7	51.6

Table 5: Forward speed and disk harrow parameter effects on the percentage of soil clod size in wet soil

		Percentage of clod size, %								
Clod Size (mm)		Ø (20-80)			Ø (5-10)			Ø (2.5->2.5)		
forward speed (km h^{-1})		5.2	7.9	9.8	5.2	7.9	9.8	5.2	7.9	9.8
	A1	29.3	26.9	25.2	21.6	33.7	29.3	49.1	39.4	45.5
G1	A2	31.7	28.9	31.3	41.2	37.1	23.8	27.1	34.0	44.9
	A3	48.1	40.6	34.0	40.1	36.1	31.7	11.8	37.0	34.3
	A1	25.9	28.6	25.9	14.6	31.9	30.5	59.5	30.8	43.6
G2	A2	32.9	37.4	31.9	31.1	26.1	28.1	43.0	36.5	26.4
	A3	57.5	44.9	45.5	28.6	40.2	29.6	13.9	14.9	24.9

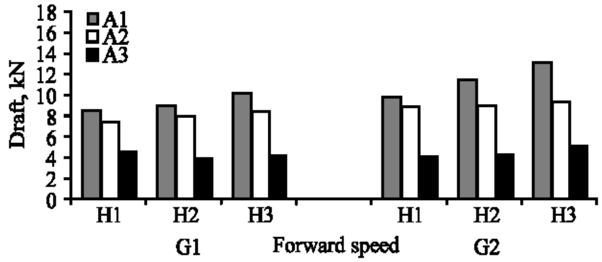

Fig. 3: Draft vs. forward speed with changing disk angle and weight of the disk harrow in dry soil conditions

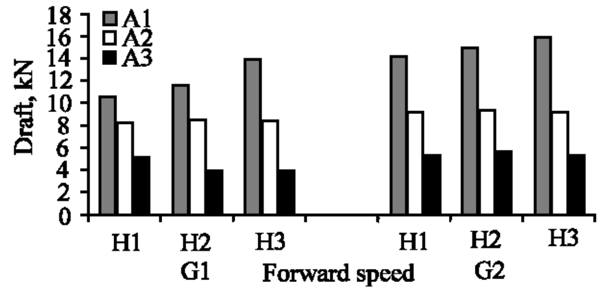

Fig. 4: Draft vs. forward speed with changing disk angle and weight of the disk harrow in wet soil conditions

Similarly the weight increase has the same effect on the draft. But the angle has greater effect on the draft. Increasing angle from A3 to A1 increases the draft to the considerable level.

As it seen in Table 4 and 5, the clod size increases with increasing weight of the disk harrow. But clod size decreased with increasing disk angle. In the same disk angle, increasing weight increased the clod size also. Soil size changed with only changing the angle; increasing the angle increased the clod size. The bulk density of the soil was only affected from the angle of the disk harrow (Table 6 and 7). The weight and the speed did not have any effect on bulk density of the soil.

As seen from the results, the disk harrow parameters changes the draft and the soil aggregate size. Heavy-duty disk harrow is used often in Turkey for an alternative tillage to the ploughing. Especially in heavy residue

Table 6: Forward speed and disk harrow parameter effects on bulk density in dry soil

		Bulk density of the soil, g cm^{-3}											
Soil depth (mm)		0-5			5–10			10–15			15–20		
forward speed (km h^{-1})		5.2	7.9	9.8	5.2	7.9	9.8	5.2	7.9	9.8	5.2	7.9	9.8
	A1	1.26	1.16	1.13	1.20	1.16	1.17	1.35	1.41	1.23	1.19	1.21	1.49
G1	A2	1.07	1.18	1.31	1.17	1.28	1.24	1.33	1.40	1.38	1.43	1.49	1.42
	A3	1.21	1.43	1.36	1.39	1.41	1.41	1.22	1.54	1.41	1.42	1.45	1.40
	A1	1.09	1.21	1.23	1.27	1.19	1.15	1.30	1.23	1.22	1.36	1.13	1.29
G2	A2	1.25	1.33	1.36	1.34	1.34	1.39	1.19	1.43	1.49	1.16	1.34	1.59
	A3	1.14	1.14	1.10	1.32	1.13	1.15	1.11	1.38	1.22	1.20	1.15	1.33

Table 7: Forward speed and disk harrow parameter effects on bulk density in wet soil

	Bulk density of the soil, g cm^{-3}											
Soil depth (mm)	0-5			5–10			10–15			15–20		
forward speed (km h^{-1})	5.2	7.9	9.8	5.2	7.9	9.8	5.2	7.9	9.8	5.2	7.9	9.8
A1	0.93	1.08	1.17	1.28	1.19	1.27	1.54	1.41	1.69	1.44	1.46	1.68
G1 A2	1.07	1.27	1.37	1.16	1.44	1.02	1.38	1.12	1.23	1.56	1.04	1.29
A3	1.23	1.09	1.09	1.47	1.48	1.28	1.50	1.67	1.27	1.57	1.53	1.33
A1	0.98	1.13	0.99	1.17	1.31	1.34	1.52	1.37	1.36	1.65	1.37	1.42
G2 A2	1.10	1.34	1.16	1.22	1.15	1.38	1.37	1.36	1.46	1.39	1.62	1.57
A3	1.14	1.23	1.30	1.12	1.31	1.23	1.37	1.17	1.33	1.56	1.25	1.42

conditions disk harrow can work quite effectively so that preserves the soil natural environment by reducing the erosion.

This study was made to examine the effect of the disk harrow in a residue free soil bin conditions. By looking at the results, one can understand the interactive effect of the parameters of the disk harrow. It shows that the angle of the disk harrow had the most effect comparing the speed and the weight of the disk harrow. The depth of tillage increased from 15 to 18 cm by increasing the weight of the disk harrow. Increasing the depth increased the draft. But besides these results, further research should be conducted under residue conditions in the field. The same authors of this study had already begun a study to investigate disk harrow use in the field with cotton and sunflower residues.

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