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Determination of Draft Power, PTO Power and Fuel Consumption of Single Acting Disc Harrow Driven from PTO

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HIGHLIGHTS

- Measurement of fuel consumption of applications
- -Determination of the draft force and draft power of applications
- -Determination of the PTO torque and PTO power of applications
- -Determining the power requirement of applications
- -Determination of the ratio of disc circumference speed to tractor forward speed of applications

Abstract

In this study; A single-acting disc harrow was used, which takes its movement from the tractor PTO. PTO driven single-acting disc harrow was tested with disc diameters of 610 and 660 mm, disc direction angles of 16^0 - 23^0 and 30^0, and disc revolutions of 104.97 - 119.97 and 143.96 min^{-1}. Single-acting disc harrow moving from PTO was compared in terms of disc diameter, directional angle and disc revolutions. The lowest draft force requirement was obtained from $D_1N_1Y_1$, $D_2N_1Y_1$ and $D_1N_1Y_2$ applications, with values of 0.48 kW, 0.61 kW and 0.79 kW, respectively. The highest draft power requirement was obtained from $D_2N_3Y_3$, $D_2N_3Y_2$ and $D_1N_3Y_3$ applications with 7.80 kW, 6.97 kW and 5.25 kW values, respectively. The lowest PTO power take-off power requirement from the applications was obtained from the $D_1N_1Y_1$, $D_1N_2Y_1$ and $D_1N_3Y_1$ applications, with values of 22.80 kW, 22.88 kW and 24.82 kW, respectively. The highest PTO power take-off power requirements were obtained from the $D_2N_3Y_3$, $D_1N_3Y_3$ and $D_2N_3Y_2$ applications, with power requirements of 41.15 kW, 39.40 kW and 38.62 kW, respectively. In terms of fuel consumption, the lowest fuel consumption was determined in $D_1N_1Y_3$, $D_1N_1Y_2$ and $D_1N_1Y_1$ applications with 11.40 L ha^{-1} 11.63 L ha^{-1} and 11.95 L ha^{-1} values. The highest fuel consumption was obtained from 18.34 L ha^{-1}, 17.78 L ha^{-1} and 17.58 L ha^{-1}, respectively, and $D_2N_3Y_3$, $D_2N_3Y_2$ and $D_2N_3Y_1$ applications.

Keywords: Draft power, PTO power, Fuel consumption, Disc direction angle

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1. Introduction

The PTO-driven disc machine has less wheel slip due to the need for less draft force, which allows the use of lower- power tractors, which can directly help with less soil compaction and reduce tractor purchase costs Salokhe et al. 1994; Hann and Giessibl,1998).

Upadhyay and Raheman (2019) reported that the effect of increasing the working depth on the draft force is less pronounced in PTO driven disc harrows compared to free rotating disc harrows. They explained that the reason for this is that in cases where the working depth is high, the cutting soil strip section of the disc harrows moving from the PTO increases as the working depth increases and the forward thrust force increases due to the fact that the convex part of the disc contacts the incisal wall more with the increase in the working depth. In addition, in their study with PTO driven disc harrow and free moving disc harrow at different working depths and u/v ratios, they reported that the fuel consumption of PTO driven disc harrows is higher than free moving disc harrows. They stated that the reason for this may be the use of additional PTO power in the PTO driven disc harrow and its effect on more soil.

Nalavade et al. (2013) in their study with PTO and free-moving disc harrows, determined that at different working speeds, PTO-driven disc harrows achieve higher working depth, carry higher soil volume, and consequently consume higher draft power than free-running harrows. When both disc harrows were compared, they reported that the PTO - driven disc harrow gave lower draft force values per unit working depth.

Salokhe et al. (1994) reported that the battery direction angle, the number of passes, and the feed rate were determined by the specific determined that the torque requirement was significantly affected and explained that the specific torque requirement at the 28° battery direction angle was lower than the 33° group angle.

Hoki et al. (1988) observed a reduction in overall power requirements as well as a reduction in draft requirements during a preliminary test of an electric disc harrow. In addition, it was noted that the draft and power requirements were affected by the feed rate, PTO speed, tillage depth and soil condition.

Salokhe and Quang, (1995) reported that the slower the shear rate, the higher the soil's resistance to shearing, so higher torque is required.

Khadr (2000), stated in his research that fuel consumption, overall processing efficiency and specific energy increase with increasing agricultural processing speed. He also stated that the fuel consumption of the tractor depends on the draft force of the machine and the working depth.

Resarchers reported that in disc harrows, by enabling the discs to rotate by driving, the ratio of the circumferential speed of the discs to the forward speed and the appropriate adjustment of the disc angle, the draft force requirement and penetration resistance decreased significantly with the improvements in the physical properties of the soil (Hoki et al., 1988; İslam et al., 1994; Salokhe et al., 1994; Salokhe and Quang, 1995; Nalavade et al., 2010; Upadhyay and Raheman, 2018).

The researches made with the PTO driven disc tillage machines are based on the studies made using a single disc and in the soil channel. There is very limited information about the comparative field performance of tillage implements and machines with disc moving from the PTO. It is thought that it is important to determine the draft force requirement, draft power, torque requirement, PTO power and fuel consumption of the single-acting disc harrow driven by the PTO under field conditions, and to compare it with the single-acting disc harrow that takes its movement from the soil.

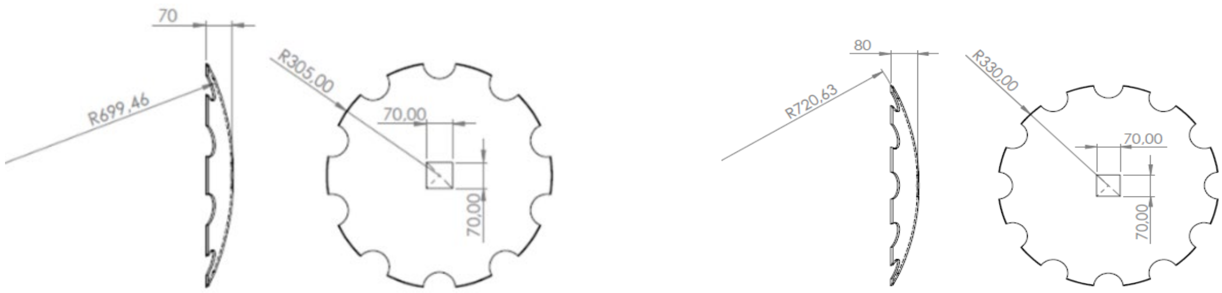
2. Materials and Methods

The specifications of the PTO driven single acting disc harrow used in the trials are given in Table 1 and Figure1. New Holland TD110 tractor was used in the trials. It is used as a disc harrow that takes its movement from the soil, by removing the sprocket mechanism connected to the movable single acting disc harrow disc shaft from the PTO shaft. The discs used in the trials are given in Figure 2.

Figure 1. PTO driven the single-acting disc harrow used in the trials

Table 1. Features of PTO driven single acting disc harrow

Features	D1	D2
Number of discs	8	8
Disc diameter (mm)	610	660
Direction angle (Y1-Y2-Y3)	16^0 -23° - 30^0	
Disc speed (N1-N2-N3) ($1.min^{-1}$)	104.97 – 119.97- 143,96	
Distance between discs (mm)	260	260
Working depth (mm)	210	210
Machine weight (kg)	950	1000



(a) (b)

Figure 2. Features of the discs used in the trials. (a) D1:610mm (b) D2:660mm

The movement taken from the tractor PTO with the help of the articulated shaft is transmitted to the shaft to which the discs are connected by means of the chain-gear system (Figüre 3). Different disc speeds applied in the trials, in the sprocket system given in Figures 3.5 and 3.6, the gears with 10, 12, 14 and 16 gear were changed and the disc revolutions were N1= 104.97 min^{-1} N2 = 119.47 min^{-1} and N3= 143.97 min^{-1} has been obtained.

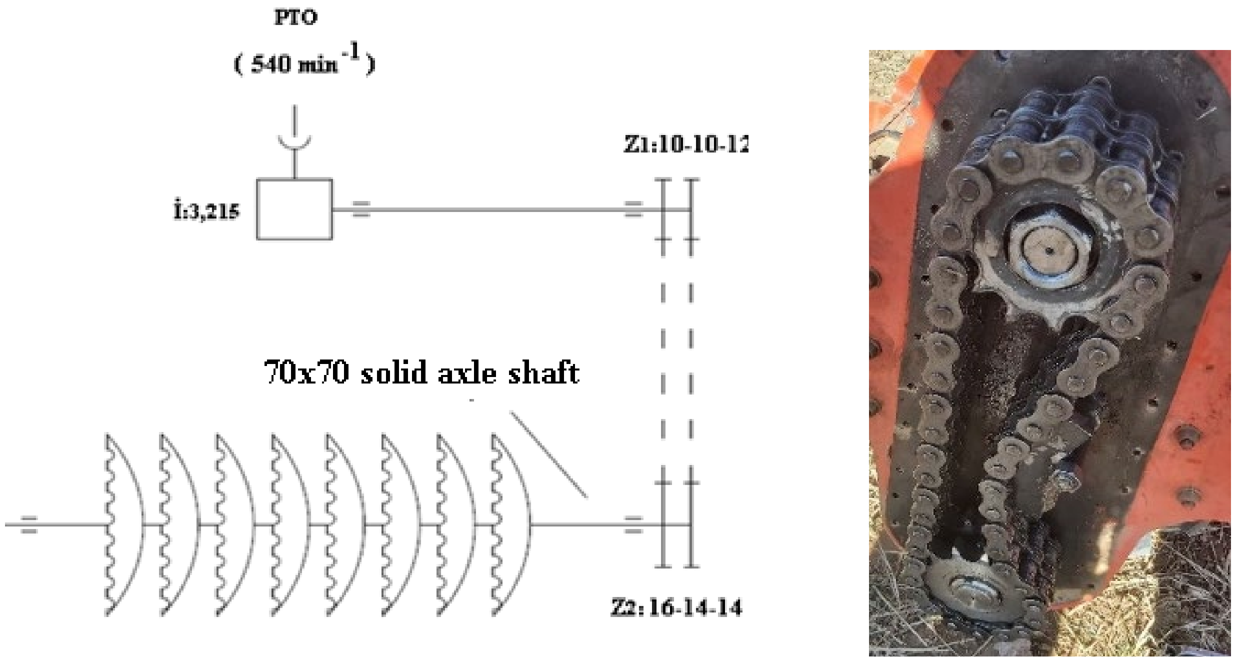


Figure 3. PTO driven single acting disc harrow motion transmission diagram chain-gear system

The soil properties of the area where the trials were carried out are given in Table 2.

Table 2. Soil properties of the field area

Parameters	Units	Values
texture class	loamy	
Hair	(%)	17.73
Plate	(%)	30.37
Annual	(%)	51.90
Volume Weight	($g\ cm^{-3}$)	1.35
Porosity	(%)	48.98
Organic matter	(%)	1.05
Moisture	(%)	16.8

Determination of draft force

The draft resistance values were measured in each application by connecting the single-acting disc harrow driven from the PTO to the three-point linkage system connection points of the tractor with three drafts (Figure 4). During the trials, the draft resistance values taken from three points were recorded in the data collector in kg. Datataker, which is used as a data collector, is set to record 2 data per second. The recorded results were then transferred to the Microsoft Excel program in the computer environment, and the results were evaluated and the draft power needs were calculated.

Determination of PTO power

Torque values of the single-acting disc harrow driven from the PTO were measured in Nm with a torquemeter connected to the PTO shaft of the tractor in each application (Figure 4). The torque and power consumption values obtained from the torquemeter during the trials were recorded in the data collector.

Datum brand digital display data collector was used as a data collector. The values recorded in the data collector were then transferred to the computer environment and evaluated.

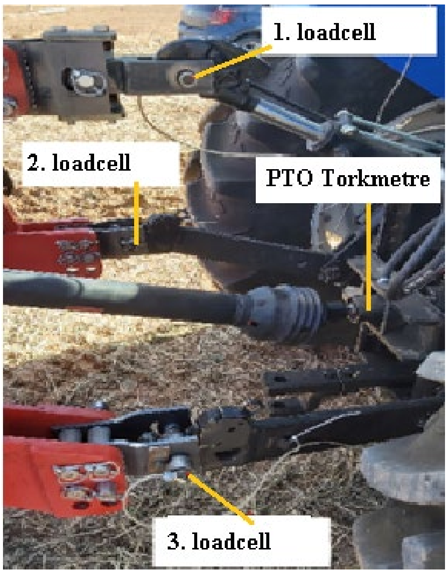


Figure 4. Connecting the draft pins and torque meter used in the trials to the tractor

Measuring Fuel Consumption

In order to clearly measure the instantaneous fuel consumption of the tractor during operation, one of the connections of the fuel meter is connected to the fuel line from the fuel tank to the engine and the other to the return line from the engine to the fuel tank (Figure 5). The fuel meter measures the amount of fuel going to the engine fuel line and from the return line to the fuel tank separately, and the net amount of fuel consumed by the tractor was measured instantaneously in L h^{-1}. The obtained hourly fuel consumption was calculated as L ha $^{-1}$.

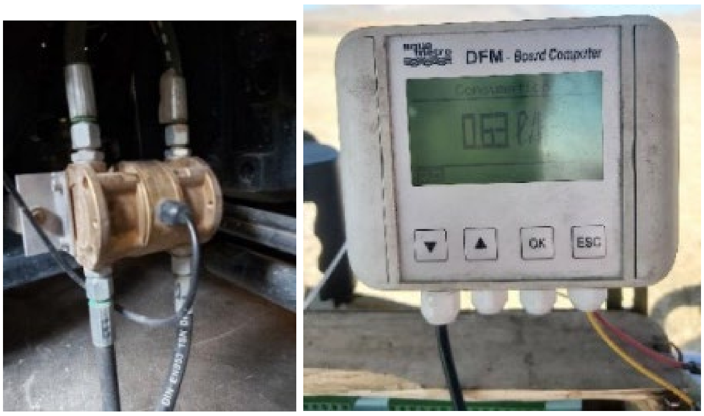


Figure 5. Fuel meter and data collector

3. Results and Discussion

The draft power values obtained for the D_1 diameter disc were obtained between 0.48 – 5.25 kW. The highest draft force value was obtained from the $D_1N_3Y_3$ application with 5.25 kW, followed by $D_1N_3Y_2$ with 4.10 kW and $D_1N_2Y_3$ with 2,32 kW, respectively. The lowest draft power values were obtained from $D_1N_1Y_1$,$D_1N_1Y_2$ and $D_1N_2Y_1$ applications with 0.48 kW, 0.79 kW and 0.93 kW, respectively Figure 6.

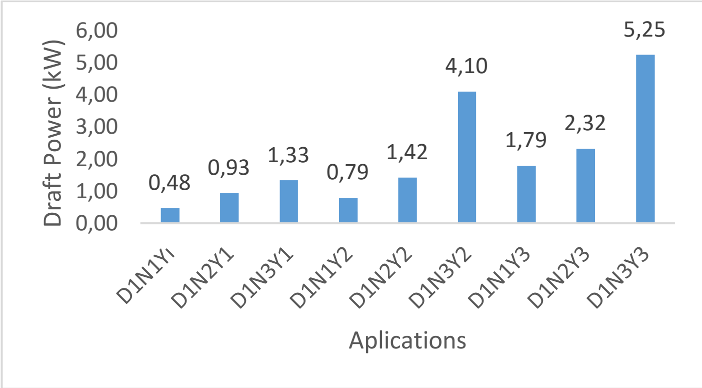


Figure 6. Draft force values of D_1 applications

The draft power values obtained for the D_2 diameter disc were obtained between 0.61 – 7.80 kW. The highest draft power value was obtained from the $D_2N_3Y_3$ application with 7.80 kW, followed by $D_2N_3Y_2$ with 6.97 kW and $D_2N_2Y_3$ with 3.68 kW, respectively. The lowest draft power values were obtained from $D_2N_1Y_1$, $D_2N_2Y_1$ and $D_2N_1Y_2$ applications with 0.61 kW, 1.27 kW and 1.57 kW, respectively Figure 7.

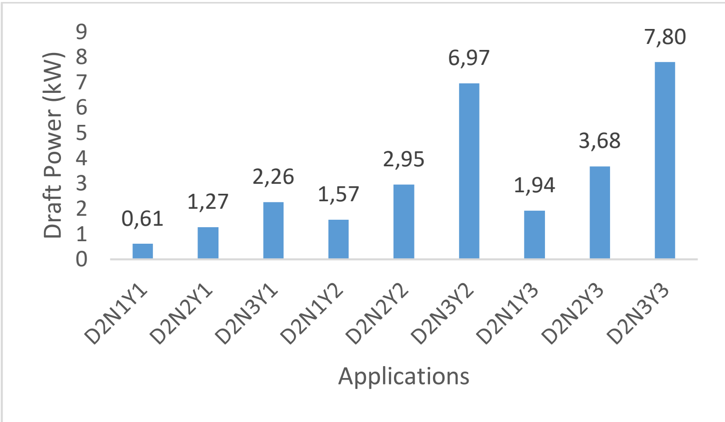


Figure 7. Draft force values of D_2 applications

PTO power values obtained for the D_1 diameter disc were obtained between 22.80 – 39.40 kW. The highest PTO power value was obtained from the $D_1N_3Y_3$ application with 39.40 kW, followed by $D_1N_2Y_3$ with 34.17 kW and D1N1Y3 with 31.54 kW, respectively. The lowest PTO power values were obtained from $D_1N_1Y_1$, $D_1N_2Y_1$ and D1N3Y1 applications with 22.80 kW, 22.88 kW and 24.82 kW, respectively Figure 8

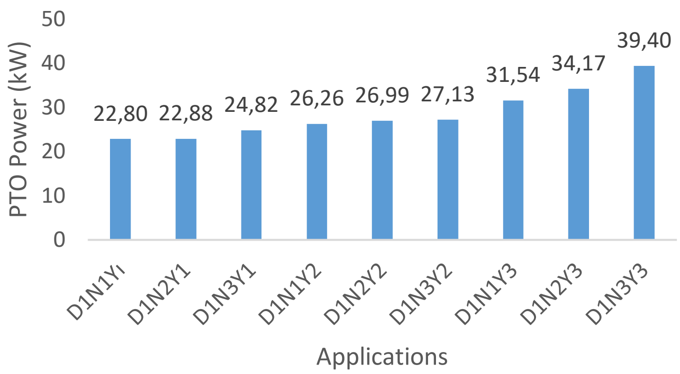


Figure 8. PTO power values for D_1 applications

PTO power values obtained for the D_2 diameter disc were between 28.33 – 41.15 kW. The highest PTO power value was obtained from the $D_2N_3Y_3$ applicationwith 41.15 kW, followed by $D_2N_3Y_2$ with 38.62 kW and $D_2N_2Y_3$ with 34.98 kW, respectively. The lowest PTO power values were obtained from $D_2N_1Y_1$, $D_2N_1Y_2$ and $D_2N_1Y_3$ applications with 28.33 kW, 28.51 kW and 29.49 kW, respectively Figure 9.

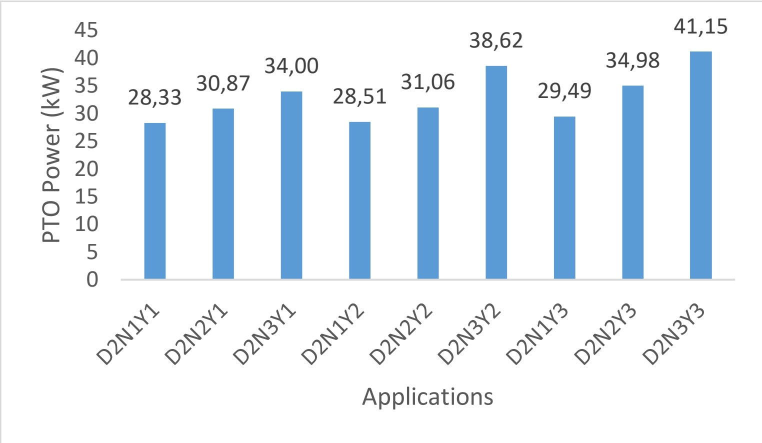


Figure 9. PTO power values for D_2 applications

The fuel consumption values obtained for the D_1 diameter disc were between 11.40 -15.46 L ha $^{-1}$. The highest fuel consumption value was obtained from $D_1N_3Y_3$ application with 15.46 L ha^{-1}, followed by $D_1N_3Y_2$ with 15.11 L ha $^{-1}$ and D1N3Y1 applications with 15.10 L ha $^{-1}$ respectively. The lowest fuel consumption values were obtained from the D1N1Y3, $D_1N_1Y_2$ L ha $^{-1}$ and $D_1N_1Y_1$ L ha $^{-1}$ applications, with 11.40, 11.63 and 11.95 L ha $^{-1}$ respectively Figure10.

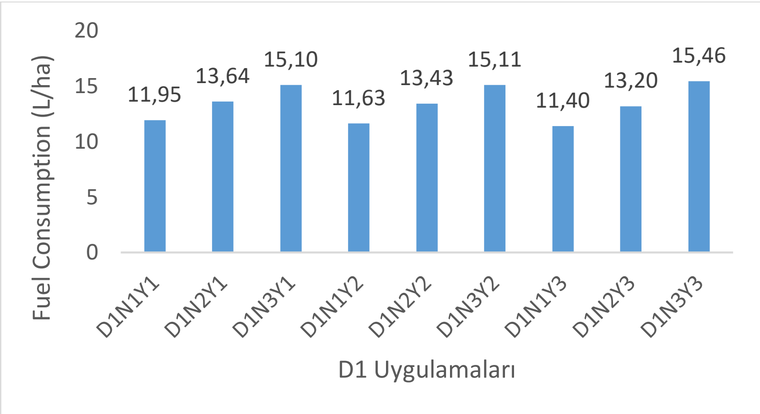


Figure 10. Fuel consumption values for D_1 applicationsThe fuel consumption values obtained for the D_2 diameter disc were between 13.99-18.34 L ha $^{-1}$. The highest fuel consumption value was obtained from the $D_2N_3Y_3$ application with 18.34 Lha $^{-1}$,followed by D_2N_3Y2 with 17.78 L ha $^{-1}$ and D_2N_3Y1 with 17.58 Lha^{-1} respectively. The lowest fuel consumption values were obtained from $D_2N_1Y_2$, $D_2N_1Y_1$ and $D_2N_2Y_2$ applications, with 13.99 L ha $^{-1}$, 14.01 L ha $^{-1}$ and 14.17 L ha $^{-1}$ respectively Figure 11.

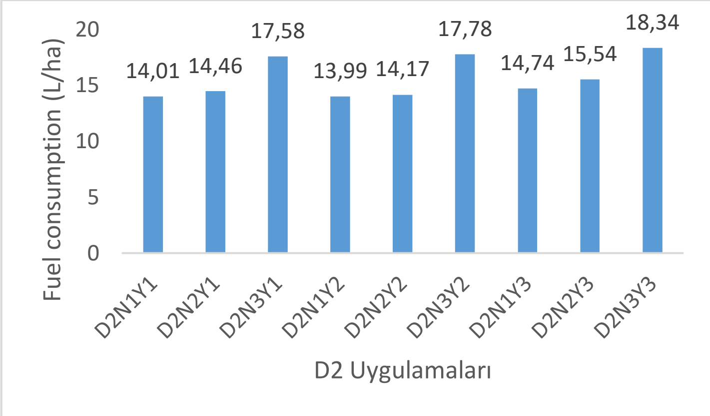


Figure 11. Fuel consumption values for D_2 Applications

4. Discussion

The tillage depth of the disc harrow increased as the disc direction angle and disc speed increase. While the working depth of the machine was determined as at least 95 mm at minimum direction angles, it was observed that it increased up to 205 mm at maximum direction angles.

The machine's gravitational force requirement and accordingly the gravitational force requirement increased at the same rate as the disc direction angles increased. As a result of the drive of the disc harrow discs from the PTO, it was observed that the discs create thrust in the opposite direction, especially at low direction angles where the direction angle is 160, and it was determined that the machine tried to push the tractor. The reason for this is that at low directional angles, as a result of low working depth, the discs encounter soil resistance and create a pushing force by holding onto the soil instead of cutting the soil. As the diameter and speed of the disc increased, the gravitational force increased and accordingly, the need for gravitational force increased. Although sufficient soil cultivation could not be done in Y1 direction angle applications, the efforts of the discs to hold on to the soil due to the notch caused the values to be taken in torque measurements in these applications.

The torque values measured from the PTO also increased with the increase of the machine's disc direction angles, working depth, disc revolutions and disc diameter. It can be said that the reason for this is that when the disc direction angle and disc diameter increase, the volume of the cut soil increases as a result of the increase in the working depth and the high disc speed. In all applications, the minimum PTO power is 22.80 kW and the maximum is 41.15 kW. Abernathy (1976) concluded from laboratory trials on an externally driven disk that the draft requirement can be reduced by 20%, but the total power requirement is 3-6 times greater than the total power requirement of freely rotating disks. Although the machine reduces the traction power by creating forward thrust, it has been observed that the thrust force due to the operation of the discs from the PTO provides an increase in the PTO power.creating forward thrust, it has been observed that the thrust force generated because the discs are actuated from the PTO provides an increase in PTO power.

As a result of the research, it was concluded that as the disc diameter, disc direction angle and disc speed of the disc harrow moving from the PTO increase, the fuel consumption also increases. Among the applications, the highest fuel consumption, direction angle, disc speed and disc diameter were obtained from the applications. Fuel consumption in all applications varied between 11.40 L ha-1 and 18.34 L ha-1. Upadhyay and Raheman (2019) stated that the reason for the high fuel consumption in PTO driven disc harrows may be the use of additional PTO power and its impact on the ground. Damanauskas et al. (2019), in their study with an individual mounted disc harrow, when they increase the forward speed from 1.4 ms-1 to 3.6 ms-1, the fuel consumption is 1 L ha-1, and when the disc angle is increased from 10° to 20°, it is 2 L ha.-1 reported that when the working depth was increased from 5 cm to 8 cm (clay-loamy and loamy soil type), it increased by 0.25 L ha-1.

We can explain the low draft power, PTO power and fuel consumption results in Y1 applications as the low operating depth due to low directional angle and the inability of the discs to cut sufficient soil volume. The increase in the angle of direction ensures that the fragmentation is effective, as at the angles of 230 and 300 degrees, and the discs overlap the soil to leave a more even profile, thus making the tillage more efficient. Soil cultivation in accordance with agricultural technique is achieved by increasing the direction angle, but as a result, it causes higher draft power requirement, PTO power requirement and fuel consumption.

The single-acting disc harrow, acting from the PTO, provides better lateral displacement of the cut soil slice. The increase in the disc direction angle increases the volume of soil to be cultivated, which causes an increase in soil reaction forces.

According to the data obtained from the research results, it is necessary to adjust the desired direction angles in the structure of the disc harrow in order to tillage at different disc direction angles with the single-acting disc harrow driven by the PTO. High disk circumferential velocity and high u/v ratio are required as well as wide directional angles for optimum soil fragmentation. It should not be ignored that the working depth increases with the increase in the direction angles, and accordingly the required draft power and fuel consumption increase. Young (1976) made a pitch evaluation of a disc harrow driven by a power take-off and observed that increasing the disc peripheral speed increases the power requirement and reduces the pull requirement.

In addition to the appropriate working depth, the disc direction angle should be chosen between 230 -30° in order to make a soil cultivation in accordance with the agricultural technique. In general, the results of the research show that the direction angles of the disc harrow discs moving from the PTO should be adjusted with an adjustment scheme that the farmer can change as he wishes. Thus, it will allow working by adjusting the disc direction angles according to different soil conditions and agrotechnical requests.

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References

Abernathy WH (1976). Draft requirements for self-powered disk. *ASAE Paper No. 76-1021, ASAE,St Joseph, MI 49805 (1976).*

Damanauskas V, Velykis A, Satkus A (2019). Efficiency of disc harrow adjustment for stubble tillage quality and fuel consumption. *Soil and Tillage Research, 194, 104311.*

Hann M, Giessibl J (1998). Force measurements on driven discs. *Journal of agricultural engineering research*, 69 (2), 149-157.

Hoki M, Burkhardt TH, Wilkinson RH, Tanoue T (1988). Study of PTO driven powered disk tiller.*Transactions of the ASAE*, 31 (5), 1355-1360.

Islam M, Salokhe V, Gupta C, Hoki M (1994). Effects of PTO-powered disk tilling on some physical properties of Bangkok clay soil. *Soil and Tillage Research*, 32 (2-3), 93-104

Khadr KA (2000). A study some factors affecting the power tiller performance. *Misr J. Agric. Eng,* 17 (3), 636-646.

Nalavade PP, Salokhe VM, Niyamapa T, Soni P (2010). Performance of free rolling and powered tillage discs. *Soil and Tillage Research*, 109 (2), 87-93.

Nalavade P, Soni P, Salokhe V, Niyamapa T (2013). Develop-ment of a Powered Disc Harrow for on-farm Crop Residue Man-agement. *Int. Agric. Eng. J*, 22, 49-60.

Salokhe V, Islam M, Gupta C, Hoki M (1994). Field testing of a PTO powered disk tiller. *Journal of terramechanics*, 31 (2), 139-152.

Salokhe V, Quang NB (1995). Dynamics of a powered disk in clay soil. *Journal of terramechanics*, 32 (5), 231-244

Upadhyay G, Raheman H (2018). Performance of combined offset disc harrow (front active and rear passive set configuration) in soil bin. *Journal of Terramechanics*, 78, 27-37.

Upadhyay G, Raheman H (2019). Comparative analysis of tillage in sandy clay loam soil by free rolling and powered disc harrow. *Engineering in Agriculture, Environment and Food*, 12 (1), 118-125.

Young PE (1976). A machine to increase productivity of a tillage operation. *Transactions of the ASAE*, 19 (6), 1055-1061.