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The Effect of Tillage Depth, Tillage Speed, on Tillage Operation Using Disk Plough in silty-clay Soil

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Abstract
A number of tillage tests were set up in this research to explore the influence of tillage depth and tillage speed alterations on disk tillage of a silty-clay soil at 2 distinct tillage depths (20,30 cm) and forward velocities (2.5,3,5 km/h).The findings reveal that raising tillage depth increases bulk density, slippage ratio, and fuel usage while decreasing field efficiency value.**Furthermore, as speed rose, so did bulk density, slippage ratio, fuel consumption, and field efficiency.**
Keywords: disk plough, wheel slippage, field efficiency, tillage Depth, tillage Speed.

1.Introduction

Agriculture is primarily done to cultivate various plants native to various parts of the planet's entire ecosystem. This wide range necessitates original, inventive agricultural improvement that is appropriate for each community. Various inventions and mechanical models that are appropriate for the state of agricultural practice should be provided. Agriculture mechanization has been described in a variety of ways. The most comprehensive and correct description is that it includes all degrees of producing and developing inventions, from basic and vital hand instruments to more complex and automated ones.
Tillage tractors, along with numerous loading equipment, are key tools used in varied or distinct field operations in the farming industry. Due to rising fuel prices, power efficiency in farming has been a growingly important concern. Soil preparation is the biggest power user in a typical farming structure. In comparison to typical land farming preparation and development using plough, no-till designs might reduce fuel consumption for tillage by 3 to 4 times [1]. Transitioning from ploughing to low or no-tillage systems need specific adaption assessments and training. The effectiveness of traction, which is determined by slip and rolling resistance, influences the transmission of drawbar power across the interface wheel and soil surface.Traction efficiency is primarily determined by tractor-related elements (tractor size, number of driving axles, type of wheel, inflation pressure) and soil-related elements (surface hardness, soil moisture content). An increase in the surface area between the driven wheel and the dirt surface might enhance drawbar transmission. Four-wheel drive (4WD), which is often used, or employing an additional powered axle through PTO (Power Take-Off) [2] is one practical implementation of this element.
The concept of tractor wheel slippage has consistently been one of the most important productive variables affecting tractor fuel consumption, for both on-field and off-field agricultural jobs [3]. According to Olatunji and Davies in 2009, soil wetness and shear quality increase tillage energy requirements. Operations which entail mechanical mobility and soil pulling equipment, such as cultivation and seeding, on agricultural soil are considered tractable if they can generate enough shear strength to avoid tire slippage and soil damage while also delivering soil tilth without the formation of blocks [4]. By reducing soil moisture content, the total traction of the tractor was reduced, as was the movement resistance.
Furthermore, soil-related variables, such as soil structure and grain and organic material concentration, influence fuel usage in soil cultivation [5]. Depending on the soil quality, fuel consumption rises by 0.5 to 1.5 litres for every hectare per cm of plow depth [6]. The influence of ploughing conditions on tractor tyre slippage and fuel usage in loose soil was investigated, and it was determined that the optimum condition for ploughing of the soil utilized in the study were 8.6 percent (w/w) soil moisture content at ploughing, 10 cm ploughing depth, and 1.79 kmhr-1 tractor speed[3]. In comparison to a two-wheel drive, the development in drawbar pulling capability via all-wheel drive reduced wheel slippage during ploughing by half and during tillage by 67 percent, resulting in a fuel savings of 2 L ha-1, [1].
The operational depth in the plowing method has a significant influence on fuel usage and tire slippage. There is a range of wheel slippage for each soil condition, with the highest gripping efficacy. As a result, it is absolutely necessary to monitor and show slip in order to acquire the maximum drawbar output from the tractor and instrument mesh. With the importance of slippage in mind,

only few attempts have been made to assess this state. Diverse approaches suggested by previous scholars, like the Doppler radar effect, photo-transducers, and so on, were sophisticated and expensive. An study was performed at IIT, Kharagpur, [7] with the ultimate use of a chip or microcontrollers, where a 2WD tractor wheel slippage sensor was constructed that is microcontroller-based to boost drawbar yield.

2. Materials and Methods

2.1 The bulk density measures: The mass of dry soil per unit of bulk volume, incorporating air space, is defined as soil bulk density. Soil bulk density varies greatly amongst different soils and is influenced by management strategies (e.g., tillage, livestock grazing, timber harvesting). The fundamental technique is the approach we use to determine the bulk density of soil. A drop-hammer tester with two cylinders and a core is used to extract a cylindrical core of soil. A drop hammer is used to force the sampling head into the earth, which includes an internal cylinder. The inner cylinder, which contains an undisturbed soil core, is later removed and cut to the end with a knife, yielding a core whose volume could be simply determined from its length and diameter. After drying in an oven at 105°C for around 18-24 hours, the weight of this soil core is calculated.

2.2 The slippage ratio: Actual velocity is calculated from the number of leading wheel cycles of the tractor. 100m distance is covered by tractors while the plough blades are close to the soil surface. The related measurements are presented in the following:

$$Dist. = Ti * Tr$$

where *Ti* denotes the number of tire cycles and *Tr* denotes the tire diameter
Thermotical velocity, TEV, is then calculated as follows:

$$TEV = (Dist. / T) * 3.6 \quad km/h$$

T is the duration of the distance collected by the program for each execution cycle for a distance of 100m.
The number of leading wheel cycles of the tractor is used to calculate the Practical velocity. The tractor moves 100m distance while the plough working inside soil surface. The actual velocity, AEV is found as the TEV with time Te.Then the following equation is used to determine the slippage ratio Slip:

$$Slip = \frac{TEV - AEV}{TEV} * 100$$

2.3 Field Efficiency Measurements:
The theoretical field capacity, *TF*is collected by the below formulas:

$$TF = 0.1 * TID * TEV \qquad ha/h$$

TIW represents the tillage implement width for a disk plow, which is 1.23m.
The following formulae are used to calculate EF (Effective Field Capacity):

$$EF = 0.1 * ATIW * AEV * 0.85 \qquad ha/h$$

where ATIW is the real tillage implementwidth for a disk plow
The Field Efficiency, FEc, is calculated using:

$$FEc = (EF/TF) * 100$$

2.4 Fuel consumption:
Fuel consumption is monitored in the fuel system using two integrated flow-meter sensors. The first flowmeter measures the input fuel flow to the injector pump, while the second measures the fuel returning from the injectors and the injector pump to the tank. The variation in fuel usage will be determined by the discharge pumps.

3. Result

The results of the Disk plough and the first level of tillage depth are shown in table 1. The highest value of Bulk density, ratio of slippage **,**consumption of fuelis obtained in speed S3 and the lowest is obtained in speed S1. Finally, for field efficiency, the highest value is obtained in speed S3 and the lowest is obtained in speed S1.

Table 1: Disk Plowresults for the first depth level

Conditions	Bulk g/cm^3	Slip %	Fue l/hl	FE %
	S3	S3	S3	S3
high	1.410	7.69	6.70	74.24
medium	1.300	5.74	5.47	68.81
low	1.190	3.79	4.23	63.39
speed	S1	S1	S1	S1

Table 2 shows the findings of the disk plow and the second level of tillage depth. Speed S3 has the highest value of density of bulk, slippage ratio, consumption of fuel, and efficiency of field, whereas speed S1 has the lowest.

Table2: Disk plough results for the second depth level

Conditions	Bulk g/cm^3	Slip %	Fuel l/hl	FE %
	S3	S3	S3	S1
high	1.72	20.64	13.33	23.45
medium	1.585	14.27	10.36	19.64
low	1.45	7.9	7.39	15.83
speed	S1	S1	S1	S3

According to the two tables, the impact of tillage depth on bulk density, slippage ratio, and fuel consumption increases as tillage depth increases. Therefore, when tillage depth increases, the field efficiency value decreases.

Statistical Evaluation

3.1 Bulk Density

The bulk density obtained through different data revealed a strong variation in bulk density value between speed operation and tillage depth at (P 0.05). Table 3 shows the influence of soil depth and pace of operations. Following tillage, the bulk density shifted radically. The linear connection between soil depth and bulk density is discovered to be favorable and grows with depth. Whenever the speed of the tillage process is raised, the bulk density increases. Nevertheless, there is no substantial relationship between tillage depth and speed. This conclusion supports the findings of scholars who measured bulk density. [8–9]

Table 3: The ANOVA Procedure Dependent Variable of Bulk Density

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
depth	1	0.07199748	0.07199748	21.56	0.0009
speed	2	0.45423095	0.22711548	68.01	<.0001
depth*speed	2	0.00190562	0.00095281	0.29	0.7577
Error	10	0.03339209	0.00333921		
Corrected Total	17	0.56461308			

3.2 Slippage Ratio

The slippage ratio obtained through different data revealed significant differences in slippage ratio between speed operation and tillage depth at (P 0.05). Table 4 shows the influence of soil depth and pace of operation. The slippage ratio shifted dramatically. The positive linear association between soil depth and slippage ratio grew with depth. When the pace of the tillage operation is enhanced, the slippage ratio increases. Nevertheless, there is no substantial relationship between tillage depth and speed. This result supports the findings of studies that use slippage ratio to quantify slippage. [3][10].

Table 4: The ANOVA Procedure Dependent Variable of Slippage ratio

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
depth	1	82.5184222	82.5184222	4.74	0.0545
speed	2	266.1290333	133.0645167	7.64	0.0097
depth*speed	2	42.6282111	21.3141056	1.22	0.3346
Error	10	174.1512333	17.4151233		
Corrected Total	17	617.8076000			

3.3 Fuel Consumption

The fuel usage results obtained through different data revealed a significant variance in fuel consumption between speed operation and tillage depth at (P 0.05). Table 5 shows the influence of soil depth and pace of operations. The fuel usage has changed radically. The linear connection between soil depth and fuel usage is discovered to be positive and grows with depth. The fuel consumption rose as the speed of the tillage operation soared, and the association between tillage depth and speed was determined to be substantial. This observation supports the findings of other studies who examine fuel consumption. [11] [12]

Table 5: The ANOVA Procedure Dependent Variable of fuel consumption

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
depth	1	44.6827556	44.6827556	1175.14	<.0001
speed	2	103.6503000	51.8251500	1362.98	<.0001
depth*speed	2	3.7120778	1.8560389	48.81	<.0001
Error	10	0.3802333	0.0380233		
Corrected Total	17	152.4606000			

3.4 Field Efficiency

The statistical analysis of efficient field capacity revealed that the influence of forwarding speed (SP) is quite significant, as seen in Table 6. The depth of tillage has a considerable impact on field efficiency, and the association between tillage depth and pace is shown to be strong. This study is line with the findings of other studies that assess field efficiency. [13].

Table 6: The ANOVA Procedure Dependent Variable of field efficiency

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
depth	1	498.6482000	498.6482000	2809.41	<.0001
speed	2	161.0697444	80.5348722	453.74	<.0001
depth*speed	2	2.1786333	1.0893167	6.14	0.0182
Error	10	1.7749222	0.1774922		
Corrected Total	17	677.4069111.			

4.Conclusion

Results for this study indicated that tillage depth and forward speed impacted tractor fuel usage and thereby costs alongwith productivity rate for disk plough tillage implements.

The influence that depth of tillage poses on bulk density, slippage ratio, and fuel consumption increases as the latter increases. Ultimately, when tillage depth increases, the field efficiency value decreases.Additionally, speed S3 has the maximum value of Bulk density, slippage ratio, fuel consumption, and field efficiency, whereas speed S1 has the lowest.

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