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EFFECT OF DISK ANGLE AND TILT ANGLE ON THE PERFORMANCE OF MOUNTED TYPE THREE BOTTOM DISK PLOW

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Abstract

Three disk mounted type disk plow was tested in Silty loam soil. The Disk and Tilt angle settings used were 42°, 43°, 45° and 16°, 18°, 20° respectively. Fuel requirements were increased with the increase in disk angle and tilt angle. Field capacity was increased with the increase in disk angle and tilt angle. The field capacity at disk angle setting of 45° and tilt angle of 20° was improved by 7 % than disk angle setting of 42° and tilt angle 16° and 2 % more than disk angle setting of 43° and tilt angle 18°. The use of disk plow is also recommended for rocky and problem soils where other tillage Implements could not perform job satisfactorily. Optimal disk and tilt angles not only enhance operational efficiency but also reduce soil compaction, promoting better crop growth. Optimal disk and tilt angles not only enhance operational efficiency but also reduce soil compaction, promoting better crop growth. Further research is recommended to refine these settings for varying soil types and conditions. Additionally, adjusting the disk and tilt angles according to soil moisture and texture can further optimize performance and reduce fuel consumption. Implementing these adjustments can lead to more sustainable and cost-effective farming practices. Moreover, operator training on proper adjustment of disk angles can significantly impact the overall effectiveness and durability of the equipment. Regular maintenance and timely replacement of worn disks also contribute to maintaining optimal field performance. In conclusion, integrating optimal disk plow settings with operator expertise and maintenance protocols ensures enhanced soil preparation and sustainable agricultural productivity.

INTRODUCTION:

Delving into the early days of civilization, historians have found a great deal of evidence to support the belief that plowing was one of the first gainful occupations of mankind. Primitive man broke the soil with rocks, or with tough roots and crooked sticks. The muscles of his own back and legs and arms supplied the power pull these crude implements through the earth so that he could assist Nature in providing food for himself and his family. Later oxen and then horses were used with improved tools and finally within the range of OUT own memory, mechanical power was introduced to reduce once and for all the drudgery and long hours of tilling the soil. Those unfamiliar with the plow are likely to regard it as a simple and common place tool of little importance. They little realize that it is still a basic farm implement, with the vital function of preparing a deep seedbed, mellowing the soil, covering vegetation and providing air and moisture to the tilled earth. The increase of any crop production in both quantity and quality depends mainly on the improvement of soil and plant conditions. This can be achieved by using the suitable tillage tool so Engineers are concerned to investigate into performance parameters of all machines used on farm. It is important to identify and quantify physical performance of parameters of farm machines so that appropriate machine can be selected with regard to conditions of soil. Tillage is a process of creating soil conditions for seed germination and growth of crop. The tillage of soil is considered one of the biggest farm operations as the tillage operation requires the most energy on the farm in most traditional farming system. The disk plow is designed to work in all types of soil for functions such as soil breaking, soil raising, soil turning and soil mixing. It is used to open the new fields and to process the stony areas. It can be used easily at rocky and rooted areas. It is especially useful in hard and dry trashy land conditions and in soils where scouring is a major problem. It is directly mounted to the tractor. To achieve the maximum and overall profit from the farm business performance of implement the tractor system need to be evaluated. Disk plow is very versatile as it adapts different conditions and types of existing agricultural soil for uniform fallow at required depth Among the tillage implements the disk plow is most conventional and popular primary and secondary tillage tool and widely used on Farm. It is very popular among farmers. Those are used as a primary tillage implement in the ordinary course of land preparation for most of the summer, winter and fodder crops and most suitable for soils such as hard, dry and sticky, where moldboard plough will not scour work. The disk blades are set at an angle, known as disk angle from the forward line of travel and also at a tilt angle from the vertical; the disk angles vary from 42° to 45° whereas tilt angles vary from 16° to 20°. Tractor drivers usually use an angle close to maximum for decreasing the tillage depth, consequently decreasing power requirements, without regard to the tillage quality and the impact that occurs on the soil properties. The experiment was conducted on three types of soils with 9 different moisture levels for 3 different disc angles tilt angles of the disk plough. The depth of penetration decreased with the decrease in soil M.C. and increased with the decrease in tilt angle.

OBJECTIVE:

1. To experience and record effect of disc angle and tilt angle on field capacity and power requirement of disk plow.
2. To study fuel consumption, wheel slippage and field capacity of disk plow.

REVIEW OF LITERATURE:

Recent studies using FEM modelling have shown that disk and tilt angles strongly affect plough performance and soil disturbance. Ibrahmi and Bentaher et al., (2025) found that higher tilt angles with smaller disc angles reduced draught and lateral forces, lowered energy consumption, and improved tractor stability, while increasing vertical forces for better penetration. Optimal performance occurred at DA=30° and TA=15°, with tilt angle having a greater influence on soil disturbance and force components than depth or speed, highlighting the importance of proper implement geometry in efficient tillage.

Wandusim et al., (2025) used response surface methodology (RSM) to model how disc angle and forward speed (with a constant tilt angle) affect draught, wheel slip, fuel consumption, cutting depth, and width for a double-row disc implement in loamy soil. Though focused primarily on disc angle and speed rather than multiple tilt settings, the study found that a disc angle of ~42.5° at 7.5km/h provided ideal compromise performance with lower draught and wheel slip, demonstrating the geometric influence on performance metrics. The findings support the broader concept that implement geometry (including disc angle and tilt considerations) directly influences energy requirements and field efficiency.

Upadhyay, Raheman, and Dubey (2025) investigated the specific draft (SD) and torque requirements of an active–passive disk harrow using soil bin trials and regression modelling, considering operational factors including gang/disc angles, speed ratio, and working depth. Although focused on a harrow rather than a plough, these results are relevant because disk angle (gang angle) significantly influenced energy requirements (specific draft) and torque demands in soil engagement, supporting the broader conclusion that cutting geometry profoundly affects soil cutting forces and implement efficiency in disk-based tillage tools.

Tarasenko et al. (2025) tested a reversible ripper-type plough to examine how blade rotation angle, speed, and soil density affect fuel consumption. They found that fuel use was minimized at a blade angle of ~45° and speed of 8.39 km/h under 1.26g/cm³ soil density. Although the study used a ripper plough, it shows that implement geometry strongly influences energy requirements and field performance, highlighting the importance of optimizing blade or disc angles in soil-engaging tillage tools.

Peng Wu, Ying Chen et al., (2024) used DEM modelling and laboratory experiments to study the effects of disc and tilt angles on soil cutting forces and residue incorporation with a concave disc. They found that draught force and residue incorporation decreased with higher tilt angles (10°–30°) and increased with larger disc angles, with disc angle having a stronger effect. Optimal geometry (tilt 20°, disc 25°) minimized draught and maximized residue incorporation, highlighting that adjusting disc and tilt angles can improve tillage efficiency and soil mixing.

Aydın, Çelik, and Malaslı et al., (2024) evaluated single-disc furrow openers in no-till seeders, showing that disc geometry significantly affects soil cutting forces and furrow properties under varying soil moisture and compaction. Plain, notched, and fluted discs had the lowest vertical, draft, and lateral forces, while wavy discs produced the highest. Disc type also influenced furrow size, with wavy discs creating the largest furrows. Forces increased with soil compaction and moisture. These results highlight that disc shape and angle strongly impact soil-tool interactions, providing insights relevant for optimizing disk and tilt angles of mounted three-bottom disk ploughs.

Sharma et al. (2024) studied fuel consumption of disc plough and cultivator in loam soil, showing that disc plough used more fuel (16.08 L/ha) than cultivator (7.53L/ha). Differences in soil bulk density and moisture indicated that implement design and soil interaction affect energy use, highlighting the importance of optimizing disc and tilt angles to improve performance.

Ucgul et al., (2023) used DEM with multi-body dynamics to simulate soil–disc plough interactions, showing that disc geometry affects soil flow, resistance, and draft forces. While disk angle and tilt were not explicitly tested, the study highlights that implement geometry is a key factor in soil–tool interactions and operational efficiency.

Al-Jarrah, Aljuboori, and Al-Jawadi et al., (2023) evaluated a triple-disk plow under varying soil moisture, scraper position, and speed, showing that soil adhesion, lateral transfer, and energy use were significantly affected by these factors. While disk and tilt angles were not tested, the study highlights that implement geometry and operational settings strongly influence soil–tool interaction and plough performance.

Kheiry and Elnougomi et al., (2022) investigated the response of mounted disk plough operating variables—specifically disc angle (40° and 45°) and tilt angle (15° and 25°)—on tractor and implement performance in light clay soil. Through field experiments conducted at the College of Agricultural Studies Farm, Sudan University of Science and Technology, they assessed effective field capacity, field efficiency, tractor rear wheel slip, and fuel consumption across these geometric settings. The results showed that increasing both disc and tilt angles significantly increased effective field capacity and field efficiency. However, larger disc and tilt angles also led to higher rear wheel slippage and greater fuel consumption rates, while the combination of a lower tilt angle (15°) and moderate disc angle (40°) produced the lowest slippage and optimal fuel use.

Hoseinian, Hemmat, Esehaghbeygi, Shahgoli, and Baghbanan et al., (2022) used DEM modelling to analyse how tillage tool geometry (including rake and tilt angles) affects draught, vertical forces, specific resistance, and soil disturbance in a dual sideway-share subsurface tillage implement. Their results showed that tilt angle significantly influenced specific draft resistance, with a minimum at about 20°, indicating that tool geometry parameters such as rake and tilt angles can alter soil reaction forces and soil disturbance behaviour.

Although the study did not focus on a three-bottom disk plough, it highlights the broader principle that implement geometry strongly affects soil–tool interaction and energy requirements in mechanized tillage tools.

Al-Jburi, Mahmood, and Subhi et al., (2021) studied the effect of tilt angle (15°–25°) on a disk plough in silty-clay soil and found that increasing tilt angle enhanced soil bulk density, draft force, and field productivity, while wheel slippage was not significantly affected. This highlights that disk geometry, particularly tilt angle, strongly influences soil response and implement performance in mounted three-bottom disk ploughs.

Sadek, Chen, and Zeng et al., (2021) used a discrete element method (DEM) model to examine the effects of disc (gang) angle and tilt angle on draft force in a high-speed disc tillage implement. Their results showed that draft force increased with disc angle but decreased with tilt angle, confirming that disc geometry strongly influences soil resistance and tillage performance, a principle relevant to mounted three-bottom disk ploughs.

Aridhee et al., (2020) investigated the impact of tractor slip and forward velocity on soil properties, fuel consumption, and energy efficiency at varying tillage depths. Their findings revealed that as forward velocity increased, both draft force and drawbar power rose significantly, while traction efficiency declined beyond optimal slip limits. Moderate operating speeds (2.5–3.0 km/h) minimized fuel consumption and improved traction stability.

Okoko and Ajav et al., (2020) found that increasing tillage depth and forward speed significantly raised draft force for a three-bottom disc plough in sandy loam soil, demonstrating that implement geometry and operating conditions are key determinants of soil resistance and energy requirements in primary tillage tools like mounted disc ploughs.

Damanauskas, Velykis, and Satkus et al., (2019) studied how disc angle, speed, and tillage depth affect stubble tillage quality and fuel consumption in loam and clay loam soils. They found that higher disc angles increased draft and fuel use, while lower angles with higher speeds improved soil structure and residue incorporation with less energy. The study confirms that disc geometry significantly influences draft, fuel consumption, and soil engagement, highlighting the importance of disc and tilt angles for mounted three-bottom disk plough performance.

Jakasania, Yadav and Mohnot et al., (2018) reviewed numerical methods (DEM and FEM) used to model soil–tillage tool interaction, demonstrating that tool geometry, including angles analogous to disc angle and tilt, substantially affects soil cutting forces and draft resistance. Their synthesis highlights that implement geometry parameters are important determinants of tillage tool performance and energy requirements in agricultural soil-engaging systems, providing theoretical support for studies on the effects of disk and tilt angles in mounted three-bottom disk ploughs.

Saeed Ranjbarianet et al., (2017) focused that increase of forward velocity results in increase of implement draft, wheel slippage, drawbar power and overall energy efficiency but results in decrease of traction efficiency. Furthermore, fuel consumption decreased by increase of velocity from 1.5 km/h to 3 km/h but increased by increase of velocity from 3 km/h to 4 km/ha Moreover, it was observed that draft requirement for implements in tests ranged from 8.2 kN for the disk plow to 13 kN for the chisel plow and fuel consumption ranged from 10.72 L/ha for the chisel plow to 26.5 L/ha for the moldboard plow. The ranges in mentioned parameters indicate that energy saving can be readily done by selecting energy-efficient implements and by proper matching of the tractor size and operating parameters to the implements.

Yun Zhang et al., (2016) The larger the disc angle resulted larger draft force. However, disc angle cannot be zero, because it is responsible for the width of the furrow. In order to keep the draft as low as possible, the smaller disc angle should be chosen. With the depth of 3in and speed of 3mph, the most reasonable compound angle (non-zero disc angle) for the lowest draft force is disc angle and 25 tilt angle. The average of the minimum draft force is 299N.

Tayel et al., (2015) investigated the combined effects of plowing depth, tractor speed, and soil moisture content on wheel slippage and fuel consumption under sandy soil conditions. Field experiments were conducted at the National Research Centre experimental farm in El-Nubaria, Egypt, over two consecutive seasons. The study revealed that both wheel slippage and fuel consumption increased significantly with greater soil depth, higher tractor speed, and elevated soil moisture levels. The highest values of slip and fuel use were observed at 30 cm plowing depth, 9.6 km h^{-1} tractor speed, and 11.6 % moisture content, while the lowest occurred at 10 cm depth, 1.79 km h^{-1} speed, and 8.6 % moisture. The results indicated that efficient plowing can be achieved by maintaining moderate soil moisture and shallow working depths, which minimizes energy losses and improves traction efficiency. Tayel's findings provide a clear operational guideline for optimizing tractor–implement performance through careful adjustment of soil and speed parameters during tillage operations.

Smith et al., (2015) conducted an extensive investigation at the University of Nebraska–Lincoln to model tractor fuel consumption and power performance under partial drawbar loading conditions. His research emphasized that tractor energy efficiency is strongly influenced by variations in forward velocity, drawbar load, and wheel slip, even when the tractor operates below its full rated capacity. Using field and dynamometer tests, Smith established predictive relationships between drawbar power, fuel rate, and tractive efficiency, showing that excessive forward velocity and high slip values significantly increase fuel consumption per unit of work. The study also highlighted the non-linear behavior of tractive efficiency, which peaks at intermediate slip levels (approximately 8–12%) and declines rapidly beyond that threshold. Smith's findings confirmed that optimal energy use occurs when tractor velocity and implement load are properly matched to soil and traction conditions. His model provided a quantitative framework for estimating specific fuel consumption and power utilization efficiency, serving as a valuable reference for subsequent studies on tractor-implement matching and tillage energy optimization.

Omer A. et al., (2014) researched that indicated the tilt angle of 20° is the most appropriate for ploughing with the disc plough as it recorded the highest field capacity, field efficiency, low draft, recorded moderate value of the required power, rear wheel slippage and fuel consumption.

Ahmed M. El Naim et, al. (2014) researched and found decreasing ploughing depth led to increasing effective field capacity and field efficiency. Increasing the disc angle increases the width of cut. Decreasing tilt angle increases ploughing depth. This result agrees with the result of Kepener et al., (1978) and El Naim et al., (2014) who reported that the increase of tilt angle led to decrease discs penetration in the soil which led to an increase in the effective field capacity due to the increase of the actual cutting width.

In the research conducted by Hamid Reza Ghanbaryan Alavijeh et al., (2013) at the Islamic Azad University, Varamin-Pishva Branch, Iran, the authors evaluated the effects of four tillage methods and two maize cultivars on soil physical properties and plant yield under field conditions. Their experiment used a split-plot randomized complete block design with three replications. The study demonstrated significant differences ($p \leq 0.01$) among tillage treatments and between maize cultivars in terms of soil physical characteristics and yield performance. Specifically, the highest grain and forage yield (88.18 t/ha) was associated with the Single Cross 704 cultivar under twice disc tillage at 10-15 cm depth. Additionally, the study reported that cultivator with blade combined with light disk tillage at 8-10 cm depth produced the greatest soluble sugar and protein contents in maize, indicating improved physiological performance. These findings highlight that moderate and well-timed soil disturbance can enhance both soil conditions and crop productivity, particularly when combined with cultivar selection adapted to local conditions.

The performance of agricultural tractors during plowing is strongly affected by plowing depth and soil moisture, which influence draft, drawbar power, wheel slip, and energy consumption. Karimi Inchebron et al., (2012) evaluated a light tractor under varying depths and moisture levels to assess these effects. Their field experiments showed that increasing depth and moisture raises soil resistance and energy requirements. Proper selection of depth and moisture can optimize traction and reduce power losses. This study highlights the importance of soil physical conditions in tractor performance and field efficiency.

Machinery selection and draft measurement are central to efficient agricultural field operations, as they determine the appropriate match between tractors and implements to optimize power use and minimize energy losses. The ASAE/ASABE et al., (2011) Agricultural Machinery Management Data (D497.7) provides standardized draft and power requirement values for a wide range of implements and soil conditions, offering essential data for machinery managers to estimate draft forces, drawbar power, and matching tractor capabilities for various tillage and planting tasks, thereby reducing fuel consumption and enhancing operational efficiency.

The ASAE/ASABE D497.7 et al., (2011): Agricultural Machinery Management Data standard provides empirical values for tractor and implement performance, fuel consumption, draft requirements, and operating costs. It is widely used in agricultural mechanization studies to estimate field capacity, energy use, and efficiency under varying soil and implement conditions. This standard supports consistent and comparable evaluations of machine performance and economic efficiency across research studies.

Olatunji et al., (2011) evaluated the performance of a disc plough on sandy loam soil across different soil moisture levels and found that depth of cut increased with both draught and soil moisture content, with minimum penetration at 4.9% moisture and maximum at 9.4%, and that the draught-speed relationship and increased soil shear strength and bulk density after tillage can inform power prediction and implement performance under varying moisture conditions.

Safa, Samarasinghe, and Mohssen et al., (2010) investigated fuel consumption in wheat production in the Canterbury region of New Zealand, estimating an average of 65.3 L/ha for total fuel use and highlighting that tillage (≈45 %) and harvesting (≈28 %) consumed the largest fuel shares, while also identifying several indirect socio-technical factors (e.g., number of implement passes and farmers' education) that significantly affect fuel use and provide avenues for optimizing energy efficiency in farm operations.

Al Suhaibani and Ghaly et al., (2010) examined the influence of ploughing depth and forward speed on the performance of a medium-sized chisel plough in sandy soil. Their results indicated that increasing ploughing depth substantially raised draft force and energy consumption, whereas forward speed had a smaller, though measurable, effect on draft. Interestingly, specific draft initially decreased with increasing depth before reaching a plateau, suggesting a non-linear relationship between soil resistance and plough depth. The study emphasized that optimizing both depth and operational speed is critical for enhancing tractor efficiency, minimizing energy use, and improving soil–implement interaction during tillage. These findings provide practical guidance for designing tillage operations that balance implement performance with energy efficiency in sandy soils.

Naderloo et al., (2009) investigated the effects of forward speed and tillage depth on draft force for three primary tillage implements (mouldboard plow, disk plow, and chisel plow) operating in clay loam soil. Their results showed that draft increased significantly with both increased forward speed and greater tillage depth for all implements, and that the highest draft values were observed under the combination of highest speed and depth. These findings confirm that tractor speed is a key determinant of draft and energy use during plowing operations, consistent with broader trends in tillage mechanics research.

Godwin et al., (2007) comprehensively reviewed how tillage implement geometry (such as depth–width ratio, rake angle, and tool shape) influences soil failure patterns and the resulting soil forces during tillage operations, highlighting that geometry strongly affects draft, vertical forces, and soil disturbance by altering the mechanism of soil shear and movement ahead of the implement, and that understanding these relationships is essential for optimizing tool design to balance effective soil engagement with reduced draft and energy requirements.

Moitzi, Weingartmann, and Boxberger et al., (2006) investigated the influence of tillage systems and tractor wheel slip on fuel consumption in agricultural operations. Their study, presented at the Energy Efficiency and Agricultural Engineering conference, found that wheel slip is a critical determinant of fuel use during tillage: higher wheel slip leads to markedly increased diesel consumption, reduced effective field capacity, and lower overall operational efficiency. The authors demonstrated that minimizing wheel slip through appropriate tillage system selection and tractor–implement matching can lead to substantial fuel savings, highlighting how deep tillage practices and heavy implements increase total energy input per hectare but may reduce energy input per unit of soil displaced. This research emphasizes the importance of integrating tractor performance parameters such as wheel slip and fuel consumption into the design and selection of tillage systems to improve energy efficiency, reduce operating costs, and mitigate the environmental impact of field mechanization.

Moitzi, Weingartmann, and Boxberger et al., (2006) assessed how tillage systems and wheel slip influence tractor fuel consumption, finding that wheel slip is a critical determinant of diesel use and field capacity, with reduced slip (e.g., through four-wheel-drive) lowering fuel consumption by up to about 2 L/ha in ploughing and heavy cultivation; additionally, while deeper tillage increases total energy input per hectare, it decreases energy input per unit of soil moved, underscoring the complex interaction between operational depth, slip, and fuel efficiency in tillage systems.

Frank M. Zoz et al., (2003) Research shows that about 20% to 55% of the available tractor energy is wasted at the tractive device/soil interface. This energy wears the tires and compacts the s oil to a degree that may cause detrimental crop production.

Gill et al., (1980) showed that ground driven rotation of disk with back pressure is greater than that of comparable spherical disk with higher back pressure operating in same soil and operational conditions. Since disk rotation helps to lift invert soil the inter relating factors that affect performance of new disk design should be examined to evaluate whether they cause less burial of plant residue and less soil compaction than normal spherical disk and whether the energy requirements for new design will be reduced.

Agriculture Engineers year book et al., (1982) gave the draft requirements of disk plow for 66cm diameter disk, 0.38 radian tilt, 0.785 radian disk angle and speed(s) in km/hr. The draft/unit cross section of furrow slice recorded in clay and loam soils was 5.2 + 0.0398 square, 2.4+0.0455 square respectively.

(5). Experimental Materials and Methods:

The performance of tillage implements required determination of soil manipulation and forces acting on the tillage machines. The machine should accomplish the necessary soil manipulation with a minimum of energy input and final soil condition must be acceptable when compared with the desired conditions.

To evaluate performance of mounted type disk plow it becomes absolutely essential to analyses the soil and field conditions which are the major components of the tillage implements performance is a function of soil physical properties.

(5.1). Experimental Location:

The field experiment was conducted at the Department of Farm Power and Machinery, Sindh Agriculture University, Tandojam, Sindh, Pakistan to evaluate the performance of a mounted-type three-bottom disk plow under controlled conditions. A rectangular plot measuring 30 × 8 meters was selected for testing. The field had not been plowed for two consecutive cropping seasons to ensure undisturbed soil structure.

The performance parameters studied included tillage speed, tillage depth, working width, wheel slippage, fuel consumption, effective field capacity, and time losses due to turning and adjustments. All measurements were recorded following the RNAM Test Codes and Procedures for Agricultural Machinery (Technical Series No. 12, 1983), Agricultural Engineers Yearbook (1981–82), and Bukhari et al. (1981) recommendations.

Photo 1: While measuring Effective cutting width

(5.2). The instruments and machines used in research work are:

1. Tractor (Al Ghazi 65 Hp).
2. Mounted disk plow (3 disks).
3. Combination square.
4. Measuring tape (50 m).
5. Measuring tape (3.5 m).
6. Ranging poles.
7. Stop watch.
8. Soil Sampler (Core).
9. Soil sample containers.
10. Half meter scales.
11. White chalk.
12. Graduated cylinder.
13. Electronic balance.
14. Oven.
15. Camera.

S. No	Texture Classes			
	Sand %	Silt %	Clay %	Texture
1	23.72	56.04	20.24	**Silt Loam**
2	27.76	49.96	22.28	**Silt Loam**
3	25.80	53.96	20.24	**Silt Loam**

Table 1: Soil Moisture Content (%)

(5.3). Machines:

A mounted disk plow with three disks manufactured by Massey Ferguson Co. was selected for field tests. The power source for operating disk plow in the field was Al Ghazi wheel type tractor with maximum drawbar power of 65 Horsepower. The disk and tilt angles used in the study were 42°,43°,45° and 16°,18°,20° respectively.

The experimental field was unplowed since two cropping seasons.

(5.4). Soil Type:

Soil type available at Experimental Field near Department of Farm Power and Machinery at Sindh Agriculture University, Tandojam, Sindh, Pakistan was selected for testing of disk plow. The Soil was analysed by the soil chemist, Soil and Water Analysis laboratory (Drip Campus Tandojam) The texture of soil was silt loam.

(5.5). Soil Moisture:

Soil moisture content on dry weight basis was determined. For measurement of soil moisture content in percent, The Core samples of soil were taken at different position having depth of 15, 30, 45 cm from test plots. The wet soil samples were weighted in an electronic balance and the weight of each wet soil sample was recorded. The samples were placed in a hot air oven maintained at 105°C for 24 hours. The Dried soil samples were re-weighted and weight was recorded. The Soil moisture content in percent is given in table 1. The soil moisture percent (dry weight basis) was calculated by using the formula:

$$Mc\ (\%) = \frac{W - D}{D} \times 100$$

Where:
MC = Moisture content, percent.
W = Weight of wet soil sample, gram.
D = Weight of oven dry sample, gram.

The use of soil sample is shown in table 2 .

S. No	**Depth (cm)**	**Weight of wet sample +Container (gm)**	**Weight of dry sample +Container (gm)**	**Weight of container (gm)**	**Weight of wet soil (gm)**	**Weight of dry soil (gm)**	**Weight of water (gm)**	**Percentage of MC = $\frac{W-D}{D} \times 100$**	**Average (%)**
1	8	36.2	34.4	1.4	34.8	33.0	1.8	5.45	5.94
	11	58.6	55.8	1.4	57.2	54.4	2.8	5.14	
	9	42.9	40.0	1.4	41.4	38.6	2.8	7.25	
2	7	38.2	34.4	1.4	36.8	33.0	3.8	11.51	11.38
	9	44.8	39.4	1.4	43.4	38.0	5.4	14.21	
	9	42.6	39.4	1.4	41.2	38.0	3.2	8.42	
3	6	35.6	33.8	1.4	34.2	32.4	1.8	5.55	4.52
	11	61.0	58.8	14	59.6	57.4	2.2	3.83	
	10	51.2	49.2	14	49.8	47.8	2.0	4.18	

Table 2: Wheel slippage, Fuel Consumption, Cutting width and cutting depth

Photo 2: While weighting soil for Moisture Content

(5.6). Working Depth:

The Working depth was measured with the half meter scale. The depth was measured from the bottom of furrow to the surface level of the soil at seven randomly selected places from test plot. The depth measurement is shown in photograph-2.

(5.7). Working Width:

The effective working width of the disk plow was measured by using the steel tape. The Effective working width was measured by measuring the width five passes of tilled area and dividing it by five to get the average effective working width at seven randomly selected places from test plots. The measurement of width is shown in photograph-3.

(5.8). Wheel Slip:

Tractor drive-wheels slip in all field operations. The distance of the tractor moves forward in a given number of revolutions of the drive wheel decreases when wheels slip. Simple method in determining the amount of wheel slip was used by making a mark with the chalk on the drive wheel of the tractor and a distance the tractor travelled in 10 revolutions with no load (A) and with load (B) was measured. Three observations were taken for measurement of wheel slip. The wheel slip was calculated by using the formula:

$$\mathrm{Tr}\ (\%) = \frac{A - B}{A} \times 100$$

Where:

TR = Wheel slip, percent.
A = Distance travelled with load, meter.
B = Distance travelled with no load, meter.

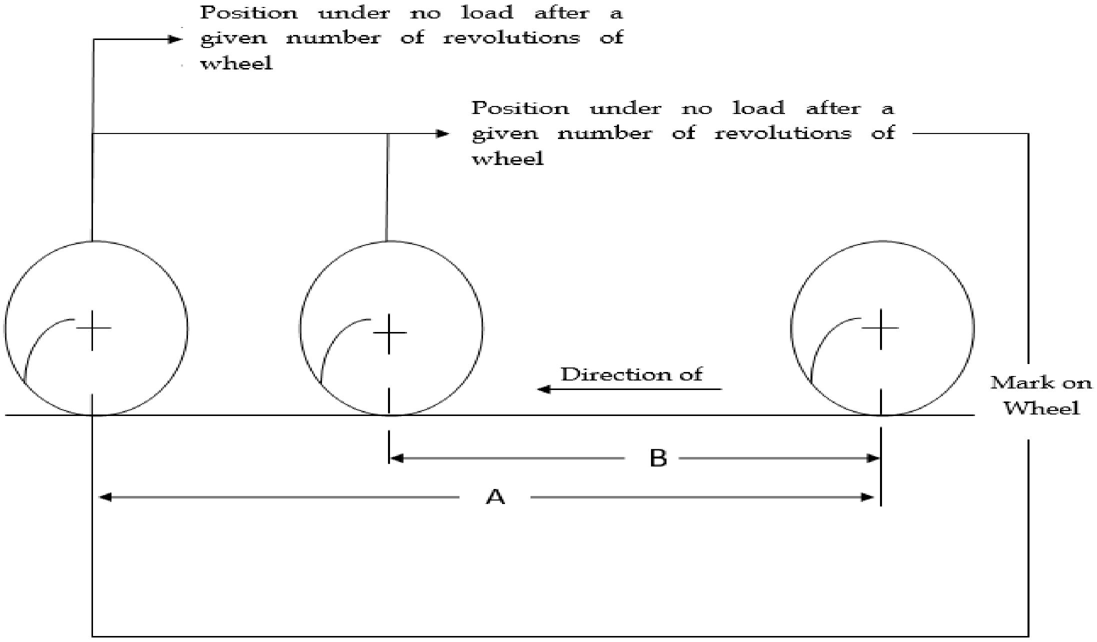

Figure 1. Mounted-type three-bottom disk plow showing disk angle (A) and tilt angle (B) relative to the direction of travel.

(5.9). Fuel Consumption:

Fuel tank of the tractor was filled up to its top before testing disk plow in test plot. After plowing the test plot, The Fuel tank of the tractor was refilled up to the same fuel level with 1000 milliliters graduated cylinder. Total quantity of diesel fuel needed to refile the tractor fuel tank up to the same mark was recorded and the total time taken to plow the test plot was also recorded. The fuel consumption per hour and per hectare was calculated from the data so obtained. The measurement of fuel consumption is shown in Figure-2.

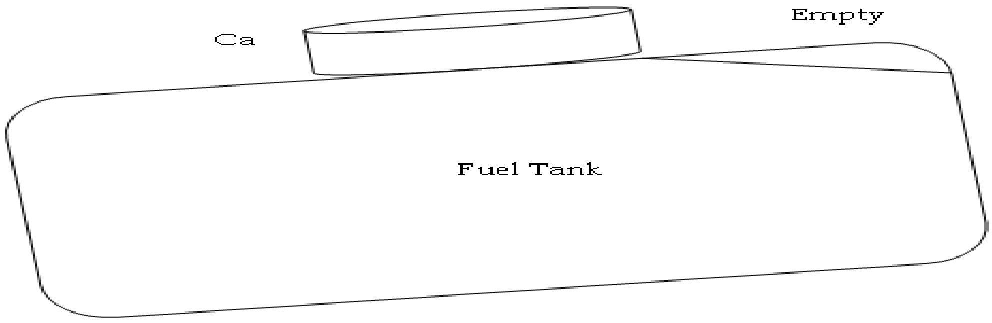

Figure 2: Measurement of Fuel Consumption

(5.10). Effective Field Capacity:
The time lost for every event such as turning and adjustment was recorded. In calculating field capacity, the time consumed for real work and that lost should be used. The effective field capacity is calculated by using formula:

$$C = \frac{A}{Tp + Tt}$$

Where:
C = Effective field capacity, ha/hr.
A = Area tilled, ha.
Tp = Productive time, hr.
Tt = Non-productive time, hr.

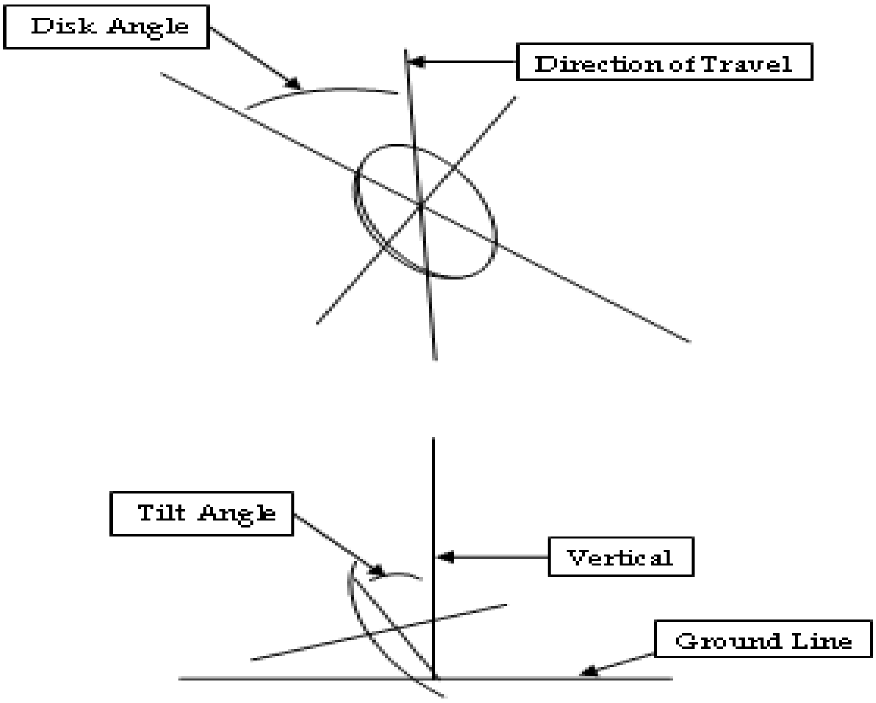

Figure 3: Identification of Disk Angle and Tilt Angle for a Disk

(6). RESULTS AND DISCUSSION: Disk plow performance and operating accuracy differ considerably according to tilt and disk angle, type of soil, moisture percent, weed infestation and plowing pattern. The measurements and examination of disk plow at three disk and three tilt angle settings were made according to RNAM Test Code and Procedure for plows.

- Field conditions
- Machine performance

(6.1). Field Conditions:
The measurements and observations taken for determining the field conditions were:

- Area of test plot
- soil type
- Soil Moisture content

(6.2). Disk plow performance:

The observations and measurements made for evaluation of disk plow performance at different disk and Tilt angles were:

(6.3). Measurement of tilt and disk angle:

The disk angle is the angle in the horizontal plane between the path of travel and the line passing through the plane of disk. When angle is zero, the disk will roll along the path of travel. To measure the disk angle, the disk plow was hitched to the tractor after each setting and the disk angle was measured is shown in Figure 1. The line of pull was drawn on ground by keeping a ranging pole parallel to the direction of travel and the angle was measured with the help of combination square and rafter framing square.

The tilt angle of disk plow was measured by vertically holding the rafter framing square in front of each disk and the angle was measured by using combination square. The measurement of tilt angle is shown in figure 3.

- Pattern of plowing
- Tilling width
- Tilling depth
- Wheel Slippage
- Fuel requirements
- Field capacity

(6.4). Field Conditions:

Three disks mounted MF-disk plow was tested during 2017-2018 at Experimental field along with Department of Farm Power and Machinery at Sindh Agriculture University Tandojam. The land characteristics are given as follows:

- The field was fallow for two years
- Soil type is silt loam.
- Area of block is 30 x 8 meters
- Soil Moisture content.

The Soil moisture percent on dry weight basis was calculated from the samples taken from test plots is given in Table-1. The three different soil samples were taken from different places of test plot having depth of 15, 30 and 45 cm. The Soil moisture in Hole 1 (0-45 cm depth) varied from 5.45 percent in the top layer to 7.25 percent in the bottom layer. On an average, the soil moisture was found to 5.94 percent.The Soil moisture in Hole 2 (0-45 cm depth) varied from 11.51 percent in the top layer to 8.42 percent in the bottom layer. On an average, the soil moisture was found to 11.38 percent. The Soil moisture in Hole 3 (0-45 cm depth) varied from 5.55 percent in the top layer to 4.18 percent in the bottom layer. On an average, the soil moisture was found to 4.52 percent.

(6.5). Disk Plow Performance:

The experiment was conducted to evaluate the field performance of disk plow at 42°, 43°, 45°, disk angles and 16°, 18°, 20° tilt angles. The data was collected to determine the wheel slippage, fuel consumption and field capacity of disk plow.

(6.6). Pattern of Plowing:

The plowing pattern used was Headland pattern from boundaries. In this pattern non-productive time could be reduced to some extent and the field could be plowed evenly.

(6.7). Fuel Consumption Requirements:

The fuel consumption requirements of disk plow is given in Table-3. The fuel consumption at disc angle 42 and tilt angle 16 was 16 liters per hectare. The fuel consumption requirements of disk plow at disk angle 43° and tilt angle 18° was 18 litters per hectare. The fuel consumption requirements of disk plow at disk angle 45° and tilt angle was 19° litters per hectare. It is concluded that as the disk angle and tilt angle is increased, the fuel consumption requirements were increased due to increase in width of plowing.

(6.8). Field Capacity of Disk Plow:

Field capacity of disk plow is given in Table-4. At disk angle 42° and tilt angle 16°, the time lost was 0.022 hour (81 sec) for the test plot and the field capacity was 0.75 hectare per hour. The time lost at corners and breaking headland was recorded and deducted from the total time taken for plowing to obtain the productive time. At disk angle 43° and tilt angle 18°, the time lost was 0.013 hour (50 sec) for the test plot and field capacity obtained was 0.888 hectare per hour. At disk angle 45° and tilt angle 20°, the time lost in plowing the test plot was 0.011 hour (40 sec) and field capacity obtained was 0.923 hectare per hour. It was concluded that at disk angle setting of 45° and tilt angle 20°, the field capacity was improved 7 percent than disk angle setting of 42° and tilt angle and 2 percent more than disk angle setting of 43° and tilt angle of 18°. The performance at disk angles 43° and 45° and tilt angles 18° and 20° is nearly the same.

Area Tilled (ha)	Productive Time TP (hr)	Non Productive Time Tt (hr)	Effective Field Capacity $C = \frac{A}{Tp+Tt}$ (ha/hr)
Disk Angle 42°, Tilt Angle 16°			
0.024	0.010	0.022	0.75
Disk Angle 43°, Tilt Angle 18°			
0.024	0.014	0.013	0.888
Disk Angle 45°, Tilt Angle 20°			
0.024	0.015	0.011	0.923

Table 3: Field Capacity of Disk Plow at different disk and tilt angles

Treatment	Disc Angle	Tilt angle	Wheel Slippage %	Cutting Depth (cm)	Cutting Width (cm)	Fuel Consumption (L/ha)
1	42°	16°	15	11	123	16
2	43°	18°	17	9	125	18
3	45°	20°	18	8	126	19

Table 4: Soil Texture

CONCLUSIONS AND RECOMMENDATIONS:

(7). CONCLUSIONS:

The conclusions drawn from the present research work on different disk and tilt angle settings of mounted disk plow are:

- At higher disk angles and tilt angles, the travel reduction increased and at lower disk angles and tilt angles, the travel reduction decreased.
- Fuel requirements were increased with the increase in Disk angle and Tilt angle.
- Field capacity was increased with the increase in disk angle and tilt angle.

RECOMMENDATIONS:

Farmers are interested to plow more area in less time it is therefore recommended that disk plow at 45° disk angle and 20 tilt angle may be adjusted to obtain maximum performance.

The use of disk plow is also recommended for Rocky and problem soils where other tillage implements could not perform the job satisfactorily. Further studies in different types of soils should be conducted to evaluate the performance.

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