Current Research in Agricultural Sciences
2014 Vol. 1, No. 3, pp. 83-94
ISSN(e): 2312-6418
ISSN(p): 2313-3716

EFFECT OF DISC AND TILT ANGLES OF DISC PLOUGH ON TRACTOR PERFORMANCE UNDER CLAY SOIL

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ABSTRACT

The three- bottom, fully mounted disc plough (DP) is widely used as a primary tillage implement in the irrigated sector in Middle and Northern Sudan. In the DP, two angles (tilt and disc) affect tractor performance and ploughing quality. This research was conducted at the Demonstration Farm of the Faculty of Agriculture, University of Khartoum to study the effect of two disc angles (43° and 45°) and three tilt angles (15°, 20° and 25°) on tractor effective field capacity, rear wheel slippage, fuel consumption, ploughing depth and width of cut. Soil of experimental area was clay loam. The experiment was arranged in a split-plot design and replicated three times. Disc angles were assigned to the main plots whereas tilt angles were distributed in the subplots. Tractor forward speed was maintained at the most commonly used ploughing speed (9 km/h). Effective field capacity was increased by 16% with the decrease of disc angle, while the width of cut, was decreased by 15%. The decrease of tilt angle improved penetration of discs into the soil, the highest ploughing depth was recorded for the tilt angle °15 with the disc angle °45, which consequently led to an increase of both rear wheel slippage and fuel consumption rate.

Keywords: Crop production, Seed bed, Effective field capacity, Land preparation.

Contribution/ Originality

This paper contributes in the existing literature by providing data and information concern with field capacities, field efficiency and fuel consumption using different disc and tilt angles on tractor performance in the clay soils of Shambat in Sudan

1. INTRODUCTION

Crop production requires a number of operations like seed bed preparation, seeding, fertilizing, spraying, dusting, irrigation, harvesting and threshing. The first operation in production of crop is tillage. Tillage is a mechanical manipulation of soil to provide favourable

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conditions for crop production. Soil tillage consists of breaking the compact surface of earth to a certain depth and to loosen the soil mass, so as to enable the roots of the crops to penetrate and spread into the soil. Tillage may be called the practice of modifying the state of soil to provide favourable conditions for plant growth. Tillage operation is the most labour consuming and difficult operation compared to all subsequent operations in the field. Farm machinery is an important element for agriculture development and crop production in modern agriculture of many countries. The main objective of the machinery is to reduce number of labor, the difficulties of farm operations and maximize production. Agricultural mechanization has been receiving a considerable interest in recent years due to increasing demand for food due to the expansion of world population [1].

The use of machines for agricultural production has been one of the outstanding developments in the global agriculture during the last century. The benefits of the application of the farm machinery can be seen in many aspects of human life as million of workers to be released for other activities in developed countries. The main source of power in agriculture is the tractor, which is now available in different sizes. Tractor power utilization is achieved through the driving wheels as traction to provide the drawbar power required for draught implements and to provide mobile support for attached machines.

Field efficiency reported by Abu [2] and Theoretical and effective field capacity mentioned by Smith and Wilkes [3] are the main performance parameters, therefore, it is important to select the suitable machine or machines to carry out the specific operation with minimum cost of energy and in the required time under suitable field condition. Disk plows, which are primarily suitable for the tillage of virgin, stony and wet soils, cut through crop residues and roll over the roots. Blades on disk plows are concave, usually representing sections of hollow spheres. The action of a concave disk blade is such that the soil is lifted, pulverized, partially inverted, and displaced to one side. 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 15° to 25°.Kepener, et al. [4] and Al-Hashimy [5]concluded that the increase of tilt angle decreased discs penetration in the soil which led to an increase in the effective field capacity due to the increase of the actual cutting width. Bukhari, et al. [6] and Osman, et al. [7] found that as disc and tilt angles increased, the field capacity and fuel consumption rate increased.

Mckyes and Maswaure [8] and Kheiralla, et al. [9] found that tensile force increase with the increase of the width of agricultural implements. The increase of tilt angle increases rear wheel slippage percentage. Abu-Hamdeh and Reeder [10] stated that the reason of increasing slippage when tilt angle increased may be attributed to the increase of the tensile force.

The general objective of this research was to study the effect of changing a three bottom disc plough angles (tilt and disc angles) on tractor performance.

The specific objectives were:

i. To measure the effect of changing disc and tilt angles on the effective field capacity and field efficiency of a disc plough.

ii. To study the effect of using different disc and tilt angles on tractor rear wheel slippage and fuel consumption.

iii. To study the effect of changing disc and tilt angles on ploughing depth and width of cut.

2. MATERIALS AND METHODS

2.1. The Experimental Site

The experiment was carried out at the Demonstration farm of the Faculty of Agriculture, University of Khartoum in Shambat. The experiments were conducted during the December of 2013. The total of the area of the experiment was 1440 m^2. The soil of experimental area was generally clay loam. Some physical and chemical characteristics of value soil are shown in Table 1

Table-1. Physical and chemical characteristics of the soil

Depth (cm)	Mechanical analysis(%)			pH	Soil class	Moisture content	Bulk density	Particle density
	Sand	Silt	Clay					
0 – 15	-	-	-	-	-	3.30	1.30	2.65
0 – 30	37.1	13.9	49.0	7.9	Clay loam	4.14	1.29	2.65

2.2. Experimental Design and Layout

Theexperiment included six treatments (two disc angles 45° and 43° with three tilt angles15°, 20° and 25°), which were replicated three times. The experimental area was divided into three blocks; each block was subdivided into six plots with an area of 10 m × 8 m. Each experimental unit was not separated by an area due to the short length and width of experimental area. The distribution of treatments within the plots was random. The experiment was arranged in a split plot design with disc angles assigned to the main plots while tilt angles were distributed to the sub-plots. The experiment implement medium size standard disc plough. The specifications of the implement are presented in Table 2

Table-2. Disc plough specifications

Parameter	Specifications
Make	Baldan
Country	Brazil
No. of discs	3
Hitching	Fully tractor mounted on the three poinlinkage
Disc	3 each of 60cm in diameter and 70cm cutting
Width	75 cm
Model	AF

Standard disk plough was pulled by Massey Ferguson (440) tractor.

2.3. Measurements

2.3.1. Measurement of Field Capacities

For calculation field efficiency by Abu Zaid [2]

$$FE\ (\%) = \frac{TFC(fed/h)\times 4.2}{s(km/h)\times w(m)} \times 100$$

For calculation Theoretical field capacity the following equation as stated by Smith *et al.* [3] was used.

$$TFC = \frac{S \times W}{C} \ldots$$

For calculation Effecting filed capacity

$$EFC = TFC \times FE\% \ldots$$

Where:

EFC = Effective field capacity (fed/h).

FE = field efficiency (%).

TFC = Theoretical field capacity (fed/h).

S = Speed (km/h).

W = Rated width of the implement (m) .

C = Constant (8.83).

2.3.2. Rear Wheel Slippage

The tractor rear wheel slippage(S) was calculated as percentage follows:

$$\text{Wheel slippage (\%)} = \frac{D1-D2}{D1} \times 100$$

Where:

D1=distance traveled without load in(m).

D2=distance traveled with load in(m)

2.3.3. Measurement of Fuel Consumption

Fuel consumption rate for each implement in operation was measuring by starting working the plot with full tank capacity. After finishing the plot the fuel tank was refilled with a graduated cylindering .the amount of fuel with was used for refilling the tank was recorded and the time taken to finish specific plot was also recorded. The fuel consumption rated in (l/fed) was calculated as follow:

$$\text{Fuel consumption (l/fed)} = \frac{Reading\ of\ cylinder\ (ml)}{Area\ of\ plot(fed)}$$

2.3.4. Measuring Width of Cut and Plough Depth

A measuring tape 50 m long was used for calculation of width of cut and ploughing depth at selected randomized points along study area. The average of the width of cut and plough depth were then calculated.

Disc angle is the angle between the plane of cutting edge and the line of travel. It is normally $42^0 - 47^0$.

. Reducing this angle increases the disc rotation with respect to ground speed and reduces the tendency of the plough to over cut. Increasing the disc angle improves the disc penetration.

Tilt angle is the angle between the plane of the cutting edge and the vertical line. It ranges from 15^0 - 25^0 in heavy, sticky soils. Decreasing the tilt angle improves disc penetration in loose and brittle soils.

3. RESULTS AND DISCUSSION

3.1. Effect of Disc and Tilt Angles on Tractor Effective Field Capacity

It can be observed Fig.2 and Table.3 that the disc angle 45° with tilt angle 25° recorded low effective field capacity (0.80 fed/h) as compared to the disc angle 43° with tilt angle 25°, which recorded the highest effective field capacity (0.93 fed/h). This result agrees with the result of Kepener, et al. [4] and Al-Hashimy [5] 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.

Table-3. Effective field capacity

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	0.046[a]	5	0.009	4.764	0.012
Intercept	13.676	1	13.676	7114.916	0.000
Angle A	0.042	1	0.042	21.876	0.001
Angle B	0.001	2	0.000	0.165	0.850
Angle A * Angle B	0.003	2	0.002	0.806	0.469
Error	0.023	12	0.002		
Total	13.745	18			
Corrected Total	0.069	17			

a. R Squared = .665 (Adjusted R Squared =0 .525)

A = disc angle.

B = tilt angle.

3.2.Effect of Disc and Tilt Angles on Tractor Field Efficiency

Fig.3 and Table.4 show that the disc angle 45° with the tilt angle 25° recorded the lowest filed efficiency (67%) while the disc angle 43° with the tilt angle 25° recorded the highest field efficiency (78%). These results agrees with the results of Kepener, et al. [4] and Al-Hashimy [5] who reported that increasing the effective filed capacity increases the field efficiency because of the proportional relationship between them.

On the other hand, the results disagree with the results of Bukhari, et al. [6] and Osman, et al. [7] who stated that the field capacity increases with the increase of disc and tilt angles.

Table-4. Field efficiency

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	304.500^a	5	60.900	5.454	0.008
Intercept	95484.500	1	95484.500	8550.851	0.000
Angle A	280.056	1	280.056	25.080	0.000
Angle B	2.333	2	1.167	0.104	0.902
Angle A * Angle B	22.111	2	11.056	0.990	0.400
Error	134.000	12	11.167		
Total	95923.000	18			
Corrected Total	438.500	17			

a. R Squared = .694 (Adjusted R Squared = 0.567)

A = disc angle.

B = tilt angle.

3.3.Effect of Disc and Tilt Angles on Tractor Rear Wheel Slippage

It is clear that the disc angle 43° with tilt angle 20° recorded the highest slippage (14.9 %), while the disc angle 45° with the tilt angle 20° recorded the lowest value of slippage (5.7%) Fig.4 and Table.5.

These results disagree with Bukhari, et al. [6] who stated that increasing disc and tilt angles led to an increase in the wheel slippage .

The increase in the disc angle results in an increase in the wheel slippage due to the increase of tensile force, Mckyes and Maswaure [8] and Kheiralla, et al. [9] found that tensile force increase with the increase of the width of agricultural implements .

The increase of tilt angle increases rear wheel slippage percentage. Abu-Hamdeh and Reeder [10] stated that the reason of increasing slippage may be attributed to the increase of the tensile force.

Table-5. Rear wheel slippage

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	243.578^a	5	48.716	9.687	0.001
Intercept	1784.036	1	1784.036	354.757	0.000
Angle A	217.709	1	217.709	43.292	0.000
Angle B	1.721	2	0.861	0.171	0.845
Angle A * Angle B	24.148	2	12.074	2.401	0.133
Error	60.347	12	5.029		
Total	2087.960	18			
Corrected Total	303.924	17			

a. R Squared = .801 (Adjusted R Squared =0 .719)

A = disc angle.

B = tilt angle.

3.4. Effect of Disc and Tilt Angles on Tractor Fuel Consumption

The results in of fuel consumption rate are shown in Table 6 and presented in Figure 5. Highest fuel consumption rate (10.8 l/fed) was recorded by the disc angle 45° with tilt angle 20°, while disc angle 43° with tilt angle 15° recorded the lowest rate (6.1 l/fed). These results agree with Bukhari, et al. [6] and Osman, et al. [7] who found that fuel consumption increased as disc and tilt angles were increased.

Table-6. Fuel consumption

Source	Type III Sum of Squares	Df	Mean square	F	Sig.
Corrected Model	56.843[a]	5	11.369	0.667	0.656
Intercept	1198.867	1	1198.867	70.334	0.000
Angle A	7.347	1	7.347	0.431	0.524
Angle B	44.634	2	22.317	1.309	0.306
Angle A * Angle B	4.861	2	2.431	0.143	0.869
Error	204.545	12	17.045		
Total	1460.255	18			
Corrected Total	261.388	17			

a. R Squared = .217 (Adjusted R Squared = -0.109)

A = disc angle.

B = tilt angle.

Table-7. Width of cut

Source	Type III Sum of Squares	df	Mean square	F	Sig.
Corrected Model	0.031[a]	5	0.006	7.274	0.002
Intercept	8.681	1	8.681	10279.605	0.000
Angle A	0.029	1	0.029	34.105	0.000
Angle B	0.000	2	0.000	0.184	0.834
Angle A * Angle B	0.002	2	0.001	0.947	0.415
Error	0.010	12	0.001		
Total	8.721	18			
Corrected Total	0.041	17			

a. R Squared = .752 (Adjusted R Squared =0 .649)

A = disc angle.

B = tilt angle.

3.5. Effect of Disc and Tilt Angles on Width of Cut

It is clear in Fig 6 and Table 7 that the highest width of cut (0.75 m) was obtained under disc angle 45° with tilt angle 25°, while the disc angle 43° with tilt angle 25° recorded the lowest width of cut (0.64 m), this result agrees with the result of Yousif and Elashri [11] who found that increasing disc angle led to an increase in the width of cut ,it also agrees with Kepener, et al. [12] who found direct relationship between disc angle and width of cut. Mahboubi, et al. [13] and

Abdalla [14] found that the increase of tilt angle led to an increase in the rate of soil cut, which led to an increase in the quantity of cut soil thus increasing the actual width of cut.

3.6. Effect of Disc and Tilt Angles on Ploughing Depth

As presented in Fig 7 and Table 8 great ploughing depth (0.32 m) was recorded by the disc angle 45° with tilt angle 15° while the disc angle 43° with tilt angle 20° recorded low value of ploughing depth (0.25 m). These result agree with the result obtained by Abu-Hamdeh and Reeder [10] who observed that a decrease in the tilt angle resulted in an increase in implement penetration. It also agrees with Kepener, et al. [12] who found inverse relationship between tilt angle and ploughing depth.

Gasim [15] reported that the increase in the disc angle up to 45° with tilt angle 15° resulted in an increase in implement penetration. Increasing the tilt angle improves disc penetration in heavy sticky soils. Decreasing the tilt angle improves disc penetration in loose and brittle soils [16]

Table-8. Ploughing depth

Source	Type III Sum of Squares	Df	Mean square	F	Sig.
Corrected Model	0.017[a]	5	0.003	4.770	0.012
Intercept	1.520	1	1.520	2136.945	0.000
Angle A	0.016	1	0.016	21.945	0.001
Angle B	0.001	2	0.001	0.805	0.470
Angle A * Angle B	0.000	2	0.000	0.148	0.864
Error	0.009	12	0.001		
Total	1.545	18			
Corrected Total	0.025	17			

a. R Squared = .665 (Adjusted R Squared =0 .526)

A = disc angle.

B = tilt angle.

4. CONCLUSIONS

From the results of this study the following conclusions can be drawn:

i. Decreasing ploughing depth led to increasing effective field capacity and field efficiency.

ii. Increasing the disc angle increases the width of cut.

iii. Decreasing tilt angle increases ploughing depth.

5. ACKNOWLEDGEMENT

My thanks to Department of Agricultural Engineering, Faculty of Agriculture, University of Khartoum for their help.

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Figure-1. Angle of disc plough

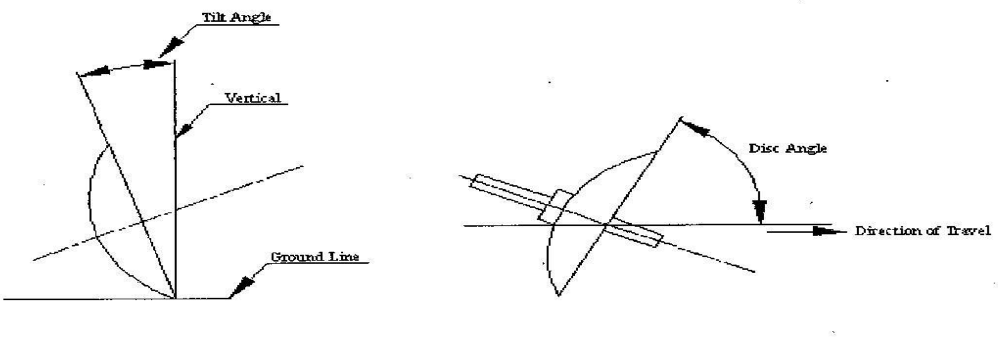

Figure-2. Effect of disc and tilt angles on tractor effective filed capacity

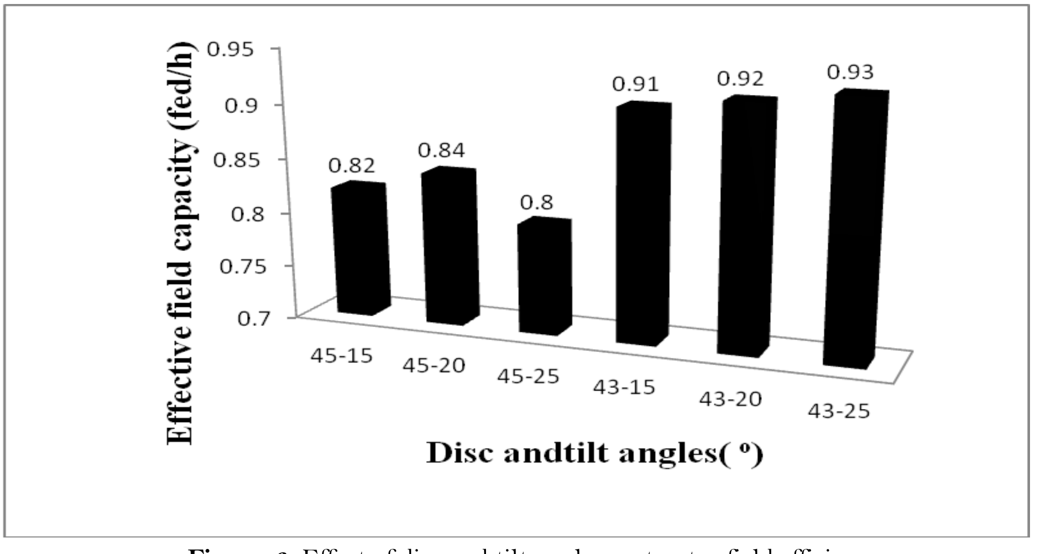

Figure-3. Effect of disc and tilt angles on tractor field efficiency

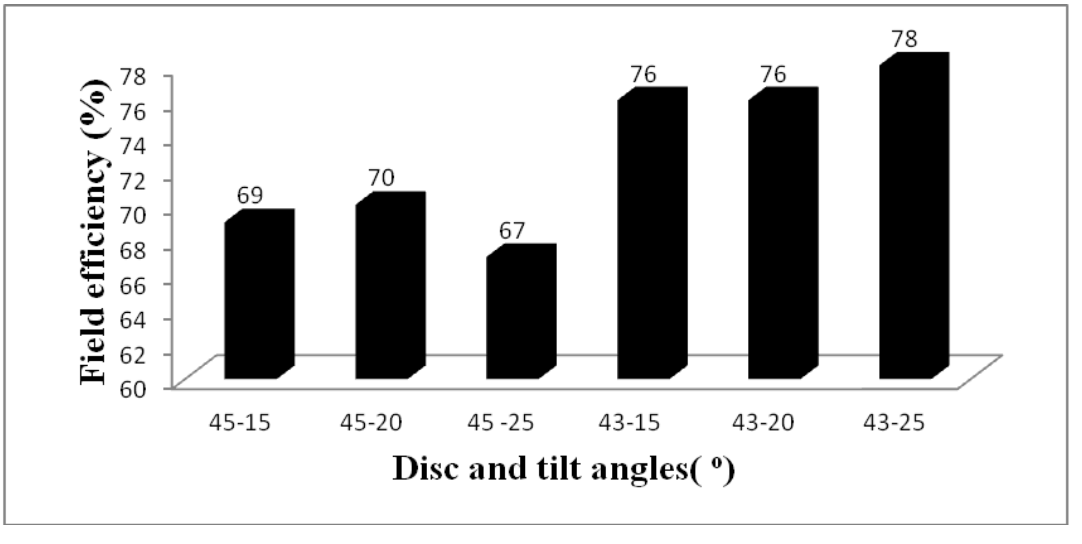

Figure-4. Effect of disc and tilt angles on tractor slippage

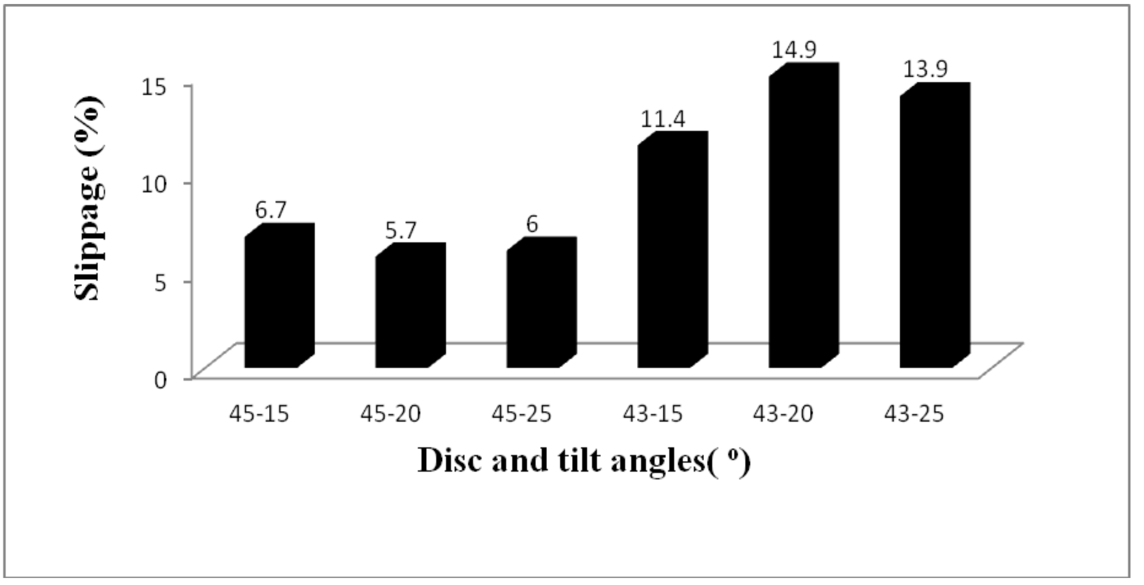

Figure-5. Effect of disc and tilt angles on tractor fuel consumption

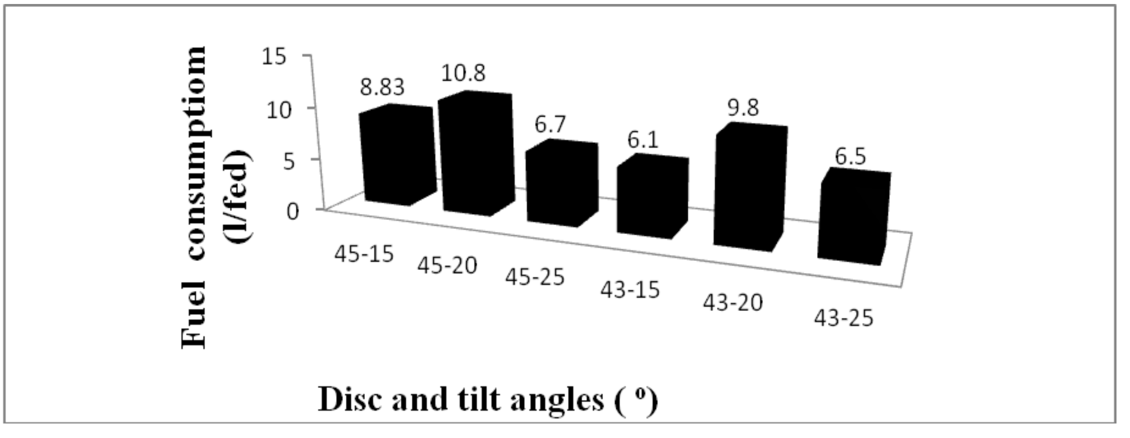

Figure-6. Effect of disc and tilt angle on width of cut

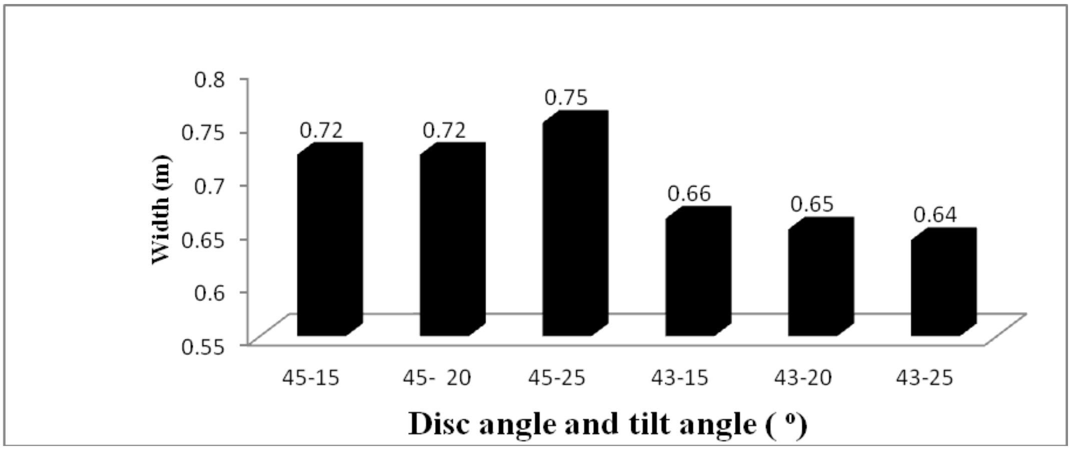

Fig-7. Effect of disc and tilt angle on ploughing depth