

EFFECTS OF CHISEL PLOW SHANKS DISTRIBUTION ARRANGEMENTS AND FORWARD SPEED ON MACHINE PERFORMANCE INDEX IN CLAY SOIL

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ABSTRACT: *In Khartoum states –Sudan, the farmer currently seemed to start more widely use the chisel plow for many considerations, such as the rough soil surface and/or surface residue left by these tillage practices have been found to reduce sediment concentrations and in some cases the volume of runoff water; and the performance data for the ploughing operation is essential to reduce cost of ploughing operation and make economic decisions. The effect of two shank distribution arrangements and two tractors forward speed (4.5km/hr. and 7.5km/hr.) on machine effective field capacity, fuel consumption, travel reduction, draft, drawbar power and Percentage of Plowed Area versus Non – plowed were therefore examined in a bid to establish their optimum operating conditions. The study was performed at the Demonstration Farm; College of agricultural studies; Sudan University of Science and Technology - Sudan, The soil type in the study site is predominantly clay. The results showed that, the mean of Effective field capacity for Sp1 and Sp2 at shank arrange 1 were 0.36 ha/hr and 0.62 ha/hr. Pooled data of fuel consumption showed that forward speed of Sp2 was having the highest fuel consumption of 12.93 Lit./ha at shank arrange2, The treatments of shank arrange 2 produced higher draft of 10.95 kN while the lowest draft of 9.14 kN was obtained by treatment of shank arrange1, A statistically, there were significant influences of shanks distribution arrangements on machine draft, while no significant difference ($P<0.05$) was observed in total power requirements among the two shanks arrangements (arrange1 and arrange2) for the two different forward speed (Sp1 and Sp2). Statistical analysis ($P<0.05$) showed that increasing the forward speed, increased effective field capacity, fuel consumption and wheel slippage significantly while there was no significance effect on machine draft.*

KEYWORDS: chisel plow, shanks distribution arrangements, machine draft, drawbar power

INTRODUCTION

Due to the global demand for food items, the increased costs of mechanization on the farm and the current disposition of financial institutions towards agricultural credits, it became very critical for existing farmers, farm managers, and agricultural investors to make informed decisions based on figures, and to improve the management of mechanization operations. In Sudan, agricultural mechanization is one of the greatest contributions of technological advancements to agricultural production. The appropriate choice and subsequent proper use of mechanized inputs into agriculture has a direct and significant effect on the achievable levels of land productivity, labour

productivity, the profitability of farming, the environment and the quality of life of people engaged in agriculture.

The tillage of soil is considered to be one of the biggest farm operations as it requires the most energy on the farm. One of the criteria used to assess the suitability of a tool for soil manipulation is the force required in pulling the tool through the soil (McLaughlin et al., 2008; Olatunji et al., 2009; Mamman and Oni, 2005; Gill and Vanden Berg, 1967; Arvidsson et al., 2004). The tillage operation requires the most energy and power spent on farms. Therefore, draft and power requirements are important in order to determine the size of the tractor that could be used for a specific implement. The draft required for a given implement will also be affected by the soil conditions and the geometry of the tillage implement (Taniguchi et al., 1999; Naderloo et al., 2009; Olatunji et al., 2009).

Tillage activities in Khartoum State-Sudan especially for large scale farmers are achieved through the use of farm tractors and relevant equipment. AL-Suhaibani and Ghaly (2010) defines tillage as the process of creating a desirable soil condition for seed germination and growth. Tillage provides good weed control with low herbicide cost; allows the control of disease and insects by destroying them through burying of crop residues. Three things are involved in soil tillage which includes the power source, the soil and the implement (Olatunji, 2007).

Al-Suhaibani and Ghaly (2010) investigated the effect of ploughing depth and forward speed on the performance of a medium size chisel plow operating in a sandy soil but the effect of shanks arrangement and ploughing speed on the draft and power requirements and average fuel consumption and other machine performance in the same zone such as Khartoum State Sudan where there is high concentration of tractors and equipment as well as a large number of arable farmers has not been fully investigated or explored. Previous studies have indicated that it is possible to improve the performance of the chisel plow as well as reduce the cost of tillage by choosing the right type of arrangement and distribution of shanks and the appropriate speed for tillage.

Disc plough is widely used by Khartoum states but farmer Currently the farmers seemed to start more widely use the chisel plow for many considerations, such as the rough soil surface and/or surface residue left by these tillage practices have been found to reduce sediment concentrations and in some cases the volume of runoff water; and the performance data for the ploughing operation is essential to reduce cost of ploughing operation and make economic decisions. This study places a particular attention on farm tractors for ploughing operation being the most explored primary tillage operation mode by farmers in the Khartoum State Sudan among several alternatives and, also it is considered as the most significant element of the total crop production systems with the largest fixed and operational costs. Therefore, the research has been conducted for measuring the effect of two shank distribution arrangements and two tractors forward speed (4.5km/hr. and 7.5km/hr.) on machine effective field capacity, fuel consumption, travel reduction, draft, drawbar power and Percentage of Plowed Area versus Non – plowed with five-shanks of chisel plow.

In addition, there are no detailed studies in Sudan related to the consideration of machine performance in tillage operations using Chisel plow at various Shanks arrangements and ploughing

speeds despite the fact that cost of tillage constitutes the highest cost of the total agricultural operational costs.

MATERIALS AND METHODS

Experimental Site

Field experiments of this study were performed at the Demonstration Farm: College of agricultural studies; Sudan University of Science and Technology - Sudan, The experimental site was located at 15.40 N Latitude, 32.32 E Longitude and altitude 380 meters above mean sea level (msl). (Oliver 1965). The soil of the experimental site is clay (fine montmorillonite, hyper thermidentic chromusterts. Initial chemical and physical characteristics of the soil (0-60 cm) were collected from the experimental site. The soil recorded Ece above 4.4 ds / m slightly saline soil. The climate of the locality is classified under tropical semi-arid with low relative humidity, The mean monthly maximum temperature in summer and in cool season was 40 0C and 20 0C respectively, but night temperatures are lower (Oliver, 1965). The mean annual rainfall is about 160 mm. However, there is considerable fluctuation in annual rain fall from year to year (Adam, 2005). There was no crop growth and the field was left fallow prior to performing the experiments.

Experimental Design and Treatment Applications

There was no crop growth and the field was left fallow Prior to performing the experiments, The split plot experiment with 2 levels of operating forward speed (4.5km/h and 7.5km/h) and shanks distribution arrangement was applied on clay soil with forward speed as the main plot and shanks distribution arrangement sub-plots, replicated in 3 times, resulting in a total of 12 plots. The size of each plot was 900 m² (6 × 150). The plots were separated by a distance of 2m between each sub plots and by distance of 10m at the end of two sub plot for the tractor turning. Each plot had buffer areas at two ends for tractor acceleration and deceleration to ensure the tractor travelled at a specified constant speed within the plot. The shanks arrangement used in this study were two shanks in front row and three shanks in rear row of the chisel plow frame for Arrange 1, while the Arrange 2 were three and two shanks in front and rear rows, respectively. The speeds of ploughing were determined using the tractor hand throttle and constant gear ratio (monitored on the tractor's dash board). The ploughing depth used for each tillage system was 0.2 m the ploughing depth and it selected and fixed using the tractor depth controller. Amounted Chisel plow was used for all tests.

Measurements

Effective field Capacity (EFC)

The time lost in the field such as turning, adjustment and change of gear along with the time used for actual work were recorded in the field test area. The field capacity was calculated by using the equation given by (Ranam, 1995).

$$EFC = \frac{A}{T_p + T_n}$$

Where:

EFC = Effective field capacity, ha.h-1

A = Area covered, ha

TP = Productive time, h

T1 = Non-productive time, h (Time lost for turning, excluding refueling and machine trouble).

Fuel consumption:

The fuel tank of tractors was filled to capacity at the commencement of each run of the ploughing operation experiments. Quantity of diesel consumed by each tractor for the ploughing operations were estimated at the end of each run by measuring the amount of fuel required to refill the fuel tank to capacity using measuring cylinders. Three replications of each runs were recorded at the varying plough depths and shanks arrangements.

Wheel slippage (Travel Reduction) (%)

The travel reduction (Slippage) of the tested machine was determined by marked the rear wheel at a portion tangent to the ground surface, then distance travel in 10 revolutions with load and without load were marked and measured. The travel reduction was calculated using the formula:

$$\text{Travel Reduction (Slippage\%)} = \frac{(L_1 - L_2)}{L_1}$$

Where:

L_1 = actual distance with no load (m).

L_2 = actual distance with load (m).

Machine draft and drawbar power requirements

Draft requirement of the plows was measured with a hydraulic dynamometer was attached with a horizontal chain between two tractors to measure the draft. Two wheel drive tractor (Massy Ferguson model 440), of 80 hp was used as a rear (towed) on which the implement was mounted; whereas the front tractor (Massy Ferguson (4x4), 120 hp was used to pull the towed tractor with the attached implement through the strain gauge dynamometer. The towed tractor was working on the neutral gear but the implement in the operating position; Dynamometer readings were averaged over a distance of 200 to 300 meters (two runs across the field). On the same field the implement was lifted from the soil and the rear tractor was pulled to record and save the idle draft. Difference between the two measurements was the net drawbar pull for the implement under study condition. The power could be estimated according to the following formula:

$$\text{Drawbar power (kW)} = \frac{\text{Draft (kN)} \times \text{plowing speed } \left(\frac{\text{km}}{\text{h}}\right)}{3.6}$$

Percentage of Plowed Area versus Non – plowed (%)

Percentage of Plowed Area versus Non – plowed (%) been calculated using the following equation:

$$\begin{aligned} &\text{Percentage of plowed area versus Non plowed (\%)} \\ &= \frac{\text{Non – plowed area between each plow blade (cm}^2\text{)}}{\text{Plowed Area between each plow blade (cm}^2\text{)}} \end{aligned}$$

RESULT AND DISCUSSION

The summary of the analysis of variance results related to the effects of shanks distribution arrangements and forward speed on the machine draft, power requirements, Effective field Capacity, Travel Reduction, Fuel consumption and the Percentage of plowed and unplowed areas of the Chisel plow, are presented in Table 1.

Table 2: ANOVA description for all observed parameters at different forwards speed, harvesting depth and conveyer inclination and their interactions.

Observed parameters	EFC		Fuels consume.		Wheel slip.		Draft		Drawbar power		Plowed Area	
Source	P	SS	P	SS	P	SS	P	SS	P	SS	P	SS
Shank arrange	0.15	0.009	0.03	5.49	0.008	44.4	0.03	22.3	0.03	70.3	0.99	0.2
Speed	0.00	0.106	0.03	26.8	0.03	134	0.52	1.0032	0.00	567.3	0.82	304
Speed × Shank arrangement	0.1	0.012	0.88	0.012	0.02	22.6	-	-	-	-	0.33	1465

Effect of shanks arrangement distribution and forward speed on EFC:

The statistical analysis of data on the Effective field capacity (EFC) was highly significantly affected by forward speed ($P < 0.05$). While, the shanks distribution arrangements and their interaction did not affect this parameter significantly at 5% level of significance as shown in (Table 2).

The mean values of (EFC) at different shanks distribution arrangements and forward speeds are shown in Fig. 1. From Fig. 1, it can be seen that as the forward speed of the chisel plow increased from Sp1 (4.5 km/hr) to Sp2 (7.5km/hr), the EFC increased from 0.36 ha/hr to 0.62 ha/hr at shanks distribution arrangements one. Similarly the (EFC) increased from 0.37 to 0.50 as the forward speed increased from Sp1 to Sp2 at shanks distribution arrangements 2, respectively. In line with this, Kepner et al (1982); Kheiry and Dongxing, 2016; kheiry et al., 2018. This increase in the EFC with increase in the forward speed might be due to that fact; field capacity is mainly affected by speed travels in the field, time losses and width of machine)

From Fig. 1, it can also be seen that with changing of the shanks distribution arrangements from Arrange 1 to arrange 2, the EFC closed to be same at speed Sp1, while there was a slightly decreased from 0.62 to 0.50 ha/hr at Sp2.

The treatment of shanks distribution arrangement + Sp2, may be considered as best optimized value for effective field capacity of the tested machine in the tested soil. Fig. 1.

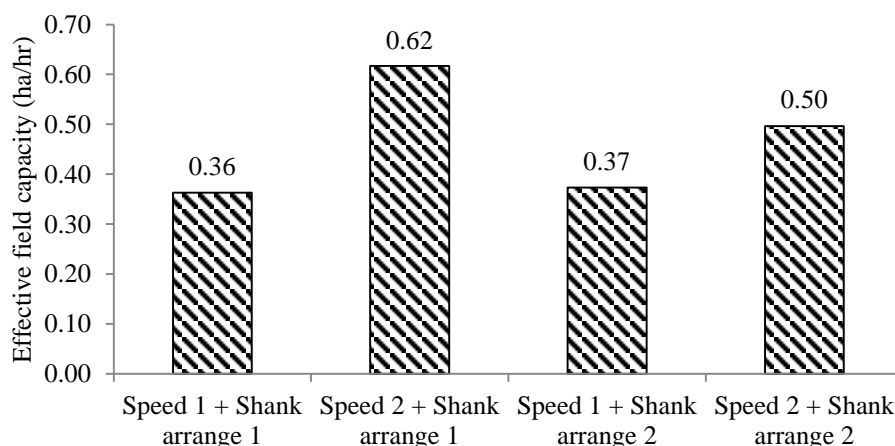


Fig. 1: Effect of shanks distribution arrangements and forward speed on EFC (ha/h)

Effect of shanks arrangement distribution and forward speed on fuel consumption:

Variation in the shanks distribution arrangements and forward speeds showed a significant impact on fuel consumption at ($P < 0.05$) (Table 1), while the values of fuel consumption were not significant for interaction of shanks distribution arrangements and speed as indicated in Table 1. The mean values of fuel consumption at two shanks distribution arrangements and forward speeds are shown in Fig. 2. There was a consistent increase in the fuel consumption with increase in forward speed from Sp1 to Sp2. Pooled data of fuel consumption showed that forward speed of Sp2 was having the highest fuel consumption of 11.64 Lit./ha which was nearly 26.2% more than that at (Sp1) at shank arrangement 1 (Fig.2). Similarly, with increase in forward speed, the fuel consumption goes on increasing, highest fuel consumption of 12.93 Lit./ha was recorded due forward speed at highest forward speed of 7.5km/hr as compared to first speed of 4.5 km/hr and at shank arrangement 2 (Fig. 2).

From Fig. 2, it could also be seen that as the shanks distribution arrangement of chisel plow changed from arrange 1 to arrange 2, fuel consumption increased by 14.2% and 9.97% at Sp1 and Sp2, respectively. This increase in the fuel consumption with increase in the forward speed agrees with Kheirry., et al (2018); Kheiry and Dahab (2017); Kheiry and dongxing (2016) who found that, there was a positive relation between forward speed and fuel consumption.

The treatment of Sp1 + shank arrangement 1 may be considered as best optimized value for fuel consumption in the field condition of the tested machine. Fig. 2.

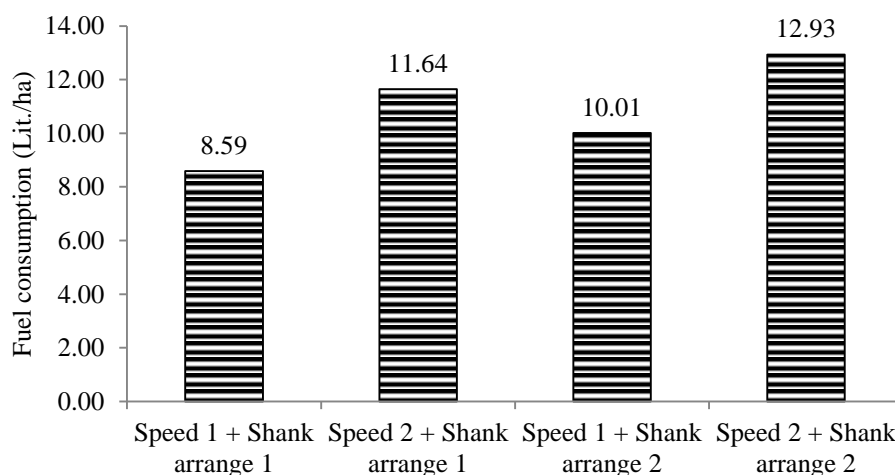


Fig. 2: Effect of shanks distribution arrangements and forward speed on fuel consumption (Lit./ha)

Effect of shanks arrangement distribution and forward speed on wheel slippage:

Table (2) indicates that, there was a highly significant difference on wheel slippage when it was influenced by the shanks arrangement ($P > 0.05$), and there was a significant effect by different speeds at 5% level of significance (Table 1). While, the interaction of shanks arrangement and forward speed was non- significant ($P > 0.05$) as shown in (Table 1). The summary of obtained data of the wheel slippage of the commonly used chisel plow in experiment side at the various shanks distributions arrangement and plowing speeds is presented in Fig. 3.

Fig. 3 shows that, the operation of the Chisel plough recorded average of 7.47% and 11.40% of wheel slippage for plowing speeds of Sp1 and Sp2 respectively at the shank arrangement 1, while the Sp1 and Sp2 are recorded 8.57% and 18% of wheel slippage at shank arrangement 2. It's clear that the results of the average wheel slippage in the highest speed was generally higher compared to lower speeds at both shank arrangements. The average wheel slippage of 18% which recorded for the Sp2 at the shank arrangement 2 was observed to be higher than (Sp 1) by 50.7% at the at the shank arrangement 1 and by 58.5% and 36.7% for Sp1 and Sp2 respectively at shanks arrangement2, Similarly an increasing trend was observed for the wheel slippage from 12.8% to 36.6% as the changing in shank distribution arrangement from arrange 1 to arrange 2 at Sp1 and Sp2, respectively (Fig.3).

The treatment of Sp1 + shank arrangement 1 and Shank arrangement 2 may be considered as best optimized value for wheel slippage in the field condition of the tested machine, with a slight superior. Fig. 3.

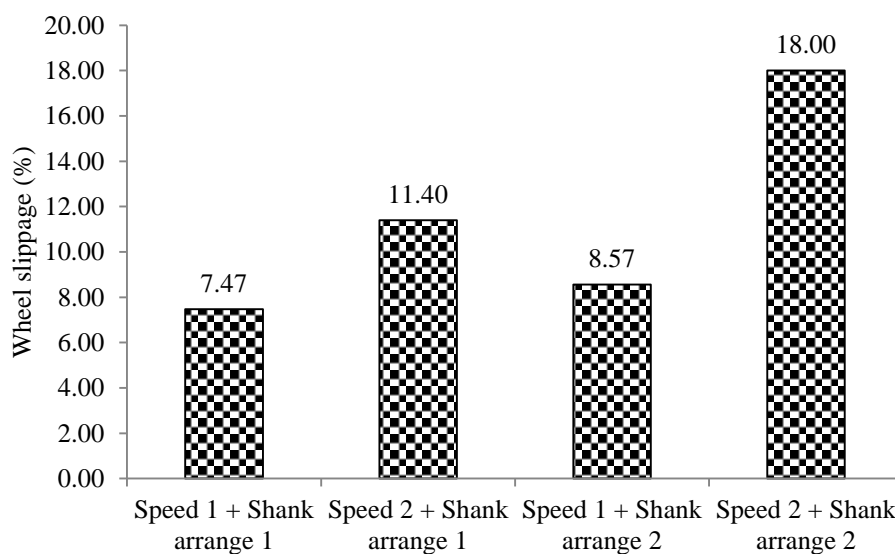


Fig. 3: Effect of shanks distribution arrangements and on wheel slippage (%)

Effect of shanks arrangement distribution and forward speed on machine draft and power requirement:

The statistical analysis performed on machine draft as affected by forward speed showed there is no significant difference ($P < 0.05$). (Table1). The unit draft is defined in this study as the draft per unit width of the worked soil (width of plowed strip). Machine draft at Sp1 was slightly superior to Sp2 by 3.49%. As shown in Fig. 4. The collected data of machine draft indicated that the highest draft of 10.95 kN was recorded by Sp2 of 7.5km/hr., which was 16.5% greater than that at Sp1 of 4.5km/hr., as shown in Fig.4. this result agree with Kheiry and Dongxing, 2016. The data regarding machine draft as affected by change in shank distribution arrangements are given in table and Fig. 5. Table 1 showed that, it is revealed that Machine draft was significantly affected with shank distribution arrangements ($P < 0.05$). The treatments arrange 2 produced higher draft of 10.95 kN while the lowest draft of 9.14 kN was obtained by treatment of arrange1, (Fig. 5).

The average power requirements as affected by the two shank arrangements of chisel plow at experiment location are illustrated in Fig. 5. A statistically no significant difference ($P < 0.05$) was observed in total power requirements among the two shanks arrangements (arrange1 and arrange2) for the two different forward speed (Sp1 and Sp2) at experiment site (Table 1). Generally, it can be observed from this test that, the average power for (arrange 2) greater than that of (arrange 1) by 16.49%. Power requirement was significantly affected and increased in linear fashion with increase in forward speed $P < 0.05$). The average power requirement was recorded at two forward speeds viz., Sp1 and Sp2 are 12.3kW and 21.32, respectively.

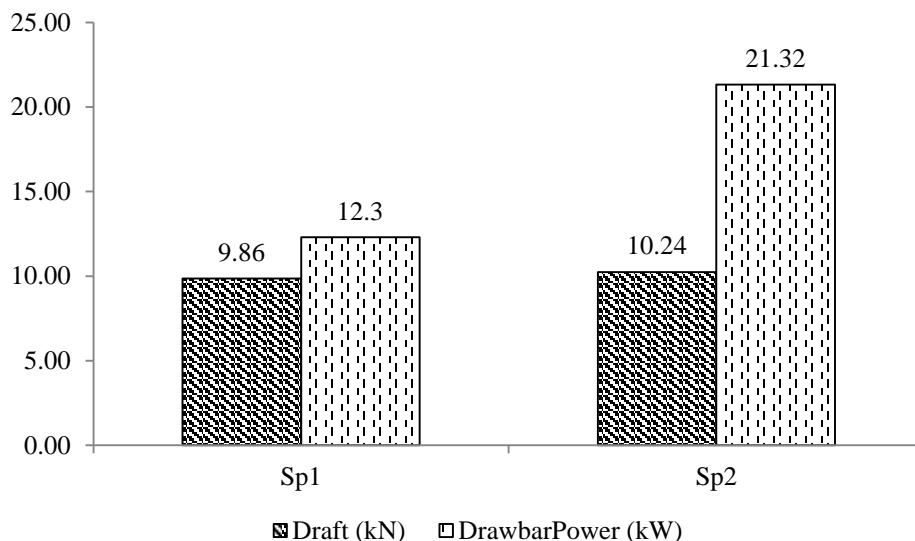


Fig. 4: Effect of forward speed on machine draft (kN) and drawbar power (kW)

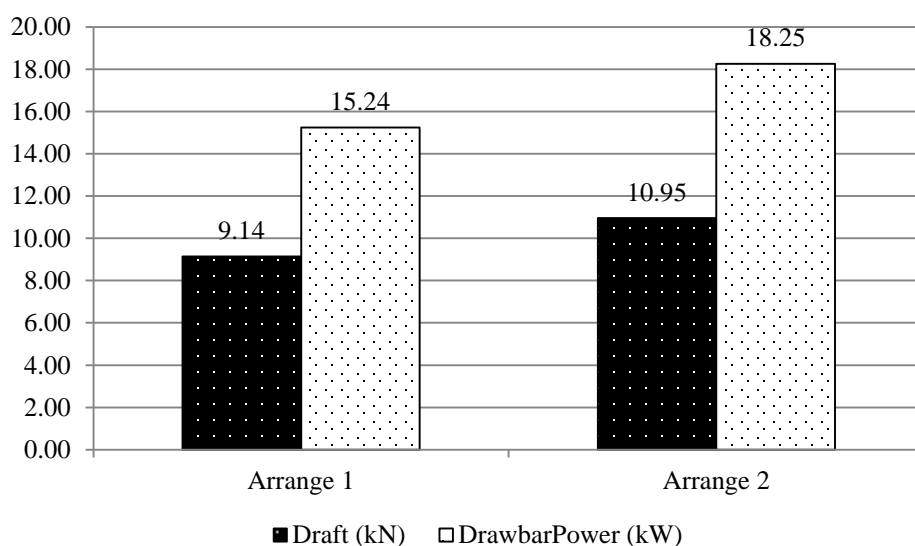


Fig. 5: Effect of shanks distribution arrangements on machine draft (kN) and drawbar power (kW)

Effect of shanks arrangement distribution and forward speed on Percentage of Plowed Area versus Non – plowed:

The dominance of shanks arrangement on Plowed Area versus Non – plowed for the chisel plow is shown in Fig. 6. The ANOVA for the Plowed Area versus Non – plowed for two shanks arrangement distribution and different forward speed are presented in Table 1. The average of Plowed Area versus Non – plowed had no significant difference ($P < 0.05$). Generally, the average of Percentage of Plowed Area versus Non - plowed was found to be same in both arrangements with an area of 285.65 cm^3 and 285.42 cm^3 for arrange 1 and 2 respectively.

The statistical analysis performed on Plowed Area versus Non – plowed as affected by forward speed showed there is a significant difference ($P < 0.05$) as presented in (Table 1). Chisel plow average Plowed Area versus Non – plowed at ploughing speed of 4.5 and 7.5 km /h were 280.5 cm^3 and 290.57 respectively (Fig. 7). The average Plowed Area versus Non – plowed of chisel plow increased with increase in ploughing speed. An increase of chisel ploughing speed from 4.5 to 7.5 km/h resulted in increase of Plowed Area versus Non – plowed by (3.46%), (Fig. 7).

From the mentioned results the treatment of Sp2 + shank arrangement 1 and Shank arrangement 2 may be considered as best optimized value for Plowed Area versus Non – plowed in the field condition of the tested machine. Fig. 6 and 7.

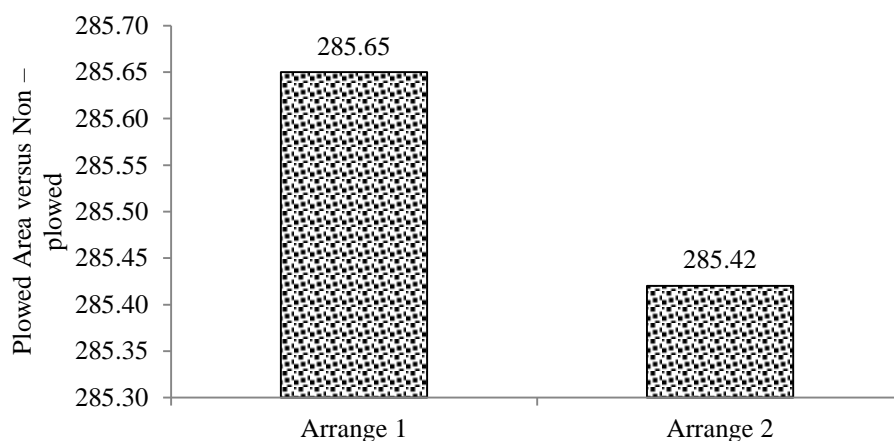


Fig. 6: Effect of shanks distribution arrangements on percentage of Plowed Area versus Non – plowed (%)

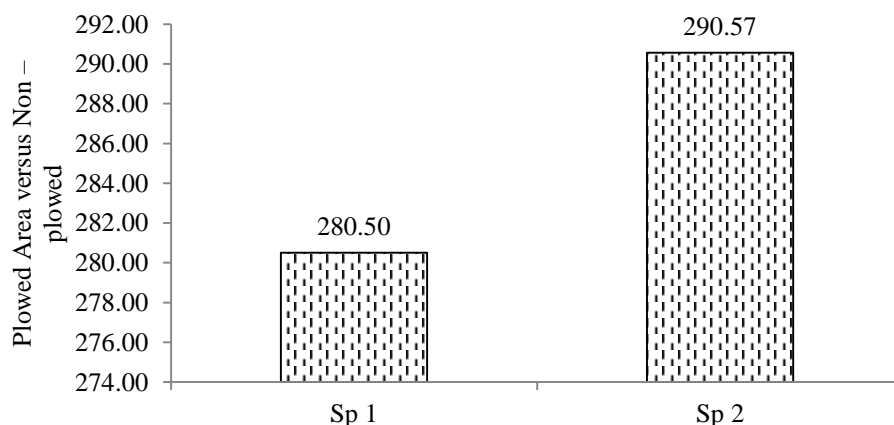


Fig. 7: Effect of shanks distribution arrangements on percentage Plowed Area versus Non – plowed (%)

1- CONCLUSION

- 1) Machine performance such as effective field capacity, fuel consumption, travel reduction (wheel slippage), machine draft and drawbar power and the percentage of plowed versus unplowed area as affecting by shanks distribution arrangements and different forward speed, were measured and evaluated.
- 2) Shanks arrange 2 having the heights mean values of fuel consumption, machine draft, draw bar power and wheel slippage, while the shank arrange 1 recording the heights mean values of effective field capacity and percentage of plowed and unplowed area.
- 3) The treatment of shanks distribution arrangement + Sp2, may be considered as best optimized value for effective field capacity
- 4) The treatment of Sp1 + shank arrangement 1 may be considered as best optimized value for fuel consumption
- 5) The treatments arrange 2 produced higher draft of 10.95 kN while the lowest draft of 9.14 kN was obtained by treatment of arrange1,
- 6) the treatment of Sp2 + shank arrangement 1 and Shank arrangement 2 may be considered as best optimized value for Plowed Area versus Non – plowed

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