Slippage Study of a Two-Wheel Drive Tractor During Tillage Operations on Different Soil Surface Conditions of The Atabadzi Soil Series of Ghana

Adewunmi TAİWO[1], Joshua Danso OWUSU-SEKYERE[2]

[1]*Ladoke Akintola University of Technology, Faculty of Engineering and Technology, Department of Agricultural Engineering, P.M.B. 4000, Ogbomoso, Oyo State, NIGERIA*

[2]*University of Cape Coast, School of Agriculture, Department of Agricultural Engineering, University Post office, Cape Coast, GHANA*

Abstract-*The objectives of this study were to: determine the wheel slippage of a 2-WD, tractor during primary tillage operations on the Atabadzi soil series (with 1.67% m.c., d.b.) when the tractor was mounted with a 2-bottom and 3-bottom disc plough; determine wheel slippage of the tractor during harrowing operation on the soil(at the same moisture content) when mounted with a tandem disk harrow; determine the level of significance of the soil surface condition effect on the tractor wheel slippage during any of the three tillage operations in the soil. The wheel slippage were measured by counting the number of driving wheel revolutions when the tractor was moving without the implements in the soil over a measured distance and subtracting from the number of wheel revolutions counted when operated with the implements in the soil; the difference, expressed in percentage of the number of wheel revolutions counted when the tractor was operated with the implement in the soil was taken as the wheel slippage. It was concluded from the results that the wheel slippage of the tractor for first and second ploughing operations when mounted with a 2-bottom disc plough were 10.31 and 12.13 % respectively while they were 9.92 and 11.93 % respectively when mounted with a 3-bottom disc plough; When the tractor was mounted with a tandem disc harrow and used on areas ploughed with 2-bottom and 3-bottom disc plough, the wheel slippage was 15.07 and 14.83 % respectively; Use of 2-bottom disc plough resulted in higher wheel slippage for primary tillage and subsequent secondary tillage.*

Key words: *primary tillage, secondary tillage, wheel slippage, harrowing, Atabadzi soil series.*

INTRODUCTION

A tractor working at its highest level of efficiency does not only cut down fuel costbut, generally, also makes maximum use of time and money. The concept of Wheel slippage in tractorshas alwaysbeen one of the main efficiency factors affecting fuel consumption by tractors, for both on-field and off – field farm operations. Tractor performance is influenced by traction elements, soil conditions, implement type, and tractor configuration [5].

According to Olatunji and Davies,[11]the soil moisture content, bulk density, soil texture and shearstrength contribute to tillage energy requirement. Operations that involve machinery traffic and soil engaging tools, such as tillage and planting, on agricultural soil is considered tractable if it can develop adequate shear resistance to minimize tyre slip and soil damage and can as well produce soil tilth without the formation of clods[4] .

By decreasing soil moisture content, net traction of tractor decreased and resulted in reduced rolling resistance.

Fenyency et al., [7] found out that rolling resistance of wheel will increase by reduction of some key soil parameters.

According to Inchebron et al., [9] the mean value of wheel slip increased from 11.91 to 29.47% just by increasing ploughing depth from 10 to 20 cm. An increase in ploughing depth resulted in more engagement of the soil by the rear tires[10] . Furthermore, increasing the ploughing depth also increases the friction between the tire and soil interface which, changes the slicing forms of soil that, in turn, causes the percentage increase in rolling resistance[14] .

Primary tillage is the first mechanical disturbance of the soil after harvest. It is normally done when the soil is moist enough to allow ploughing and strong enough to give reasonable and efficient traction. Secondary tillage on the other hand is any working of the soil after primary tillage; it is usually less shallow and less aggressive than primary tillage.

According to Ahaneku et al.,[3] , agricultural tillage involves soil cutting, soil turning, and soil pulverization which thus, demands high energy, not just due to the large amount of soil mass that must be moved, but also due to inefficient methods of energy transfer to the soil.

It is known from related research efforts that the draft resistance of ploughs and energy requirement for ploughing depend on the plough body parameters and soil properties such as hardness, density, friction and adhesion[13;2] . Soltani and Loghavi,[12] reported that increasing the ploughing depth and traction power causes both the wheel slip and fuel consumption to increase.

Ijeoma,[8] reported that in every tillage operation, there are three main factors that should be considered for the achievement of desired results. These factors include personnel (i.e.operators), tillage tools and soils with the most important of them being the soils followed by the tillage tools.

Tractive efficiency is a measure of the ability of the tractor to transfer power from the axle to the drawbar through the tire and soil interface. This implies that tractive efficiency depends on wheel slip, soil and tire conditions as well as drive configurations.In the research work of Inchebron and Seyide,[9] , the measured and calculated parameters were rolling resistance, wheel slip and tractive efficiency. The inference taken from the work revealed that wheel slip might be considered higher for primary tillage than in secondary tillage operations due to the depth of the two different tillage implements (3-bottom disc plough and offset disc harrow) that were used to work on the soil.

The results from a research work conducted by Aday et al, [2], shows that the maximum traction efficiency of 2WD and 4WD tractors are 0.72 and 0.79 which occurred at traction wheels slip of 12% and 7% respectively. The optimum traction efficiencies (the optimum tractor performance) are 0.78 and 0.85 and they occurred at wheels slip of 17% and 8% and at draft force of 22kN for 2WD and 4WD tractors respectively.The results indicate clearly that the field performance of 4WD tractor is superior to that of 2WD tractor and that was because it uses its total weight which enables the traction wheels to utilize the soil strength (soil friction) to greater extent. It wasconcluded in the study that the traction efficiency of 4WD tractor (0.79) is higher than that of 2WD (0.72) and that these two values were obtained at wheel of slip 7% and 13% respectively. This implies that thepower loss of the 4WD tractor due to wheels slip was lower than that of the 2WD tractor.

The objectives of this study were to: determine the wheel slippage of a 2-WD, tractor during primary tillage operations on the Atabadzi soil series (with 1.67% m.c., d.b.) when the tractor was mounted with a 2-bottom and 3-bottom disc plough; determine wheel slippage of the tractor during harrowing operation on the soil(at the same moisture content) when mounted with a tandem disk harrow; determine the level of significance of the soil surface condition effect on the tractor wheel slippage during any of the three tillage operations in the soil.

MATERIALS and METHOD

The experimental work in this study was performed on the Teaching and Research Farms of the School of Agriculture, University of Cape Coast located in the Coastal Savanah Zone of Ghana whose soil consists mainly of the Atabadzi soil series.

The soil which consists of yellowish red to red, well-drained clay loams and clays mixed with alluvial materials is classified as Uitisal and Aerisol according to soil taxonomy classification system (FAO/UNESCO, 2002).The soil consists of yellowish red to red, moderately well-drained clay loams, and clays developed in colluvial materials over gravely clay on middle slopes. They have medium internal drainage medium to rapid run-off and are moderately permeable. The top strata of the soil profile consists of sandy loam to clay loam free of gravel concretions(the gravel concretions are absent up to a depth a little over 150 cm) is about 20 m thick and dark to reddish brown in colour.The soil was developed from the parent material of decomposed Sekondinian sandstones[6].

A total land area of 4050 m^2(45 m x 90 m) was measured out and divided into three plots with equal area of 1350 m^2 (45m × 30m) per plot. Three different types of tillage implements viz: 2-bottom disc plough, 3-bottom disc plough and an off-set disc harrow were used in the study.

A 45 m x 15 m course was laid, with extra space at each end of the course for use as headland(for starting, turning and stopping of the tractor). A stake was set at the two headlands in the field for use in marking the beginning andthe end of the 45m long course.

To measure the wheel slip, a reference mark was made on the drive wheel tyre with white paint. Then someone was made to drive the tractor in a straight line while under full implement load at the normal speed and gear range to be used. Another individual was made to walk alongside the tractor, making sure sure he was clear of the implement. A starting reference point was marked on the ground with the use of a peg driven into the ground at the point and ten wheel revolutions were counted off. The point of the tenth revolution was marked on the ground, after which,the tractor was returned to its starting point. Next, the implement was detached or raised from the ground, and the tractor was driven between the two established reference points again. The number of wheel revolutions was counted again. The fractional last revolution was estimated as closely as possible.

This was repeated three times for first ploughing(ploughing on hard soil surface) using the 3-bottom disk plough in the first instance and then for the case when the tractor was mounted with the 2-bottom disk plough.

The entire process was repeated after two weeks for second ploughing(ploughing on previously ploughed soil).

Finally the experiment was carried out for secondary tillage operation using the tractor/offset-disk harrow aggregate.

The number of revolutions counted on the second trip was used to determine the percentage rear wheel slippage as shown equation (1):

$$S(\%) = \frac{A-B}{A}100 \qquad (1)$$

Where:

S = Wheel Slippage,%.

A = Number of wheel revolutions counted while the tractor was under full implement load.

B = Number of wheel revolutions counted while the implement was raised or detached from the ground.

A two-way analysis of variance was carried out on the data generated with the use of the General Linear Factorial Model in GENSAT Discovery Edit. 3 Software. The software was used in analysing the % wheel slippage values of the 2WD tractor during the different tillage operations on the the different soil surface conditions of the experimental plots. Thereafter, the Least Significant Differences (L.S.D) between the means of % wheel slippage were computed at 5 % level of significance and used to make paired comparisons between the treatment means.

RESULTS and DISCUSSION

The mean percentage wheel slippage values in the three soil surface types for the three tillage operations tested are as tabulated in Table 1.The mean % wheel slippage of 10.12 for first plough is the mean of the paired operation with 3-bottom and 2-bottom disc ploughs replicated 3 times. Similarly, the mean % wheel slippage of 12.03 for second ploughing is that of paired operation with the two plough types in soil initially ploughed while the mean % wheel slippage of 14.95 is for pair mean of harrowingoperations in soil initially ploughed with 2-bottom and 3-bottom disk ploughs.

Table 1: Mean % wheel slippage values

Tillage operation	Soil surface condition		
	Hard soil	Ploughed soil	Tilled soil
First Ploughing	10.12	-	-
Second Ploughing	-	12.03	-
Harrowing	-	-	14.95

Furthermore, it is observed from the results in Table 1 that the mean %wheel slippage of the 2WD tractor increases as the tillage operation progresses from primary tillage to secondary tillage. This is even without exception to the fact the %wheel slippage also increases from10.23% for first ploughing to 12.03% for for second ploughing which are both primary tillage operations. This was so because ploughing depth tends to increase during second ploughing operation due to the fact that the soil was softer. These results corroborate the findings of Soltain and Loghavi,[12] that %wheel slippage and fuel consumption increase as ploughing depth increases.

Table 2: Mean % Wheel slippage for the two primary and one secondary tillage operations and implements used

Tillage operation	Implement used	Hard soil surface	Ploughed Soil surface	Tilled Soil surface
First	3-bdp	9.92	-	-
Ploughing	2-bdp	10.31	-	-
Second	3-bdp	-	11.93	-
Ploughing	2-bdp	-	12.31	-
Harrowing	3-bdp	-	-	14.83
	2-bdp	-	-	15.07

The results in Table 2 show the %wheel slippage of the 2WD during first ploughing and second ploughing using 2-bottom and 3-bottom disk ploughs. The first ploughing was on hard surface while the second ploughing was on soil surface initally ploughed and left for 2 weeks as it is usually done by the farmers in Ghana and most countries in the West African subregion. The harrowing was done with the use of offset disk harrow on soil surface initially given first and second ploughing with the two plough types under study.It could also be observed that the mean % wheel slippage of the 2WD tractor when mounted with

3 – bottom disc plough for the primary tillage operations was less than that obtained from the tractor when mounted with a 2 – bottom disc plough in both hard and ploughed soil surface. For first and second ploughing, the %wheel slippage for the tractor when mounted with 3-bottom disk plough were 10.31 and 9.92% respectively; when mounted with 2-bottom disk plough, they were 11.93 and 12.13% respectively for the two types of primary tillage operations. The results in Table 3 are the output of the two-way analysis of variance carried out on the generated data with the use of the General Linear Factorial Model in GENSAT Discovery Edit. 3 Software . The results show that there was no significant difference between the two categories of paired values.

Table 3: Analysis of Variance

Variance: %_wheel slippage

Source of variattion	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**$F_{pr.}$**
Reps stratum	2	0.9497	0.4748	1.00	
Reps.*Units* stratum					
Trt_1 2	71.0383	35.5192	74.47	<0.01	
Trt_2 1	0.3389	0.3389	0.71	0.419	
Trt_1.Trt_2	2	0.0309	0.0154	0.03	0.968
Residual	10	4.7693	0.4769		
Total 17	77.1272				

No significant difference was also observed in the mean % wheel slippage value of the rear wheel of the tractor during harrowing operation on soils ploughed with 3 – bottom and 2 – bottom disc plough. The implication of these results is that although there are differences in the rear wheel slippage of a 2-WD tractor when operating with either a 2- or 3- bottom disk plough on Atabadzi soil series of Ghana when the soil moisture content is 1.6%w.b., these differences are not significant(p>0.05).However, since these results may not be true for other types of tillage implements and soil types, there may be need for further investigations that entail the use of other of tillage implements, soil series and ,even, soil moisture content regimes.

CONCLUSIONS

In view of these findings, it was therefore concluded from the the study that:

- the wheel slippage of the tractor for first and second ploughing operations when mounted with a 2-bottom disc plough were 10.31 and 12.13 % respectively while it was 9.92 and 11.93 % respectively when mounted with a 3-bottom disc plough;
- When the tractor was mounted with anoffset disc harrow and used on areas ploughed with 2-bottom and 3-bottom disc plough, the wheel slippage were 15.07 and 14.83 % respectively;
- Although the use of 2-bottom disc plough mounted on 2-WD tractor resulted in higher wheel slippage for primary tillage and subsequent secondary tillage operations in the Atabadze soil series of Ghana than that obtained with the use of 3-bottom disk plough, the difference was not significant.

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