Effects of Tillage Depth and Tractor Speed on Implement Speed for Three Tillage Implements on a Clay Loam Soil

ABSTRACT

The utilization of agricultural machinery represents the main aspect contributing to the total energy input in the agricultural system. The trials were achieved using five tractor speeds(3.6, 5.4, 7.2, 9.0 and 10.8 km/hr) and five tillage depths(10, 15, 20, 25 and 30 cm) to determine implement speed at different tillage depths for 3-bottom disc plough, spring tine cultivator and offset disc harrow on a clay loam soil. The design of the experiment used were two factors, five levels factorial of Central Composite Rotatable Design of Response Surface Method. The implement speed for 3-bottom disc plough, spring tine cultivator and offset disc harrow ranged from 0.78 to 1.95, 0.67 to 2.19 and 0.70 to 2.11 m/s, respectively. The effects of tillage depths and tractor speeds on implement speed for the three tillage implements were assessed. The results indicated that increasing the tillage depth decreased the implement speed for all the tested implements but increasing the tractor speed increased the implement speed. The tractor speed had more pronounced effect on the implement speed than the tillage depth. This study therefore recommends that the availability of time and implement width should be used in determining the speed required to finish the work on time.

Keywords: Implement speed, tractor, tillage depth, clay loam soil

1. INTRODUCTION

Agricultural mechanization is geared towards reducing human drudgery, improve timeliness and efficiency of various farm operations, bring more land under cultivation, preserve the quality of agricultural produce and provide better rural living condition [1]. Tillage operations for seedbed preparations are often classified as primary or secondary [2]. Primary tillage constitutes the initial major soil working operation. It is normally designed in such a way, so as to reduce the soil strength, cover crop residues and rearranges. It refers to the operation performed to open up any cultivable land which is to prepare a seedbed for growing crops. Secondary tillage refers to the tillage operations following primary tillage which are performed to create proper soil tilt for seeding and planting. Both primary and secondary tillage operations are generally recommended in the field in order to get a better pulverized and deeper seedbed [3].

Agricultural productivity is linked with the availability of farm power. The role of farm power in the development of agriculture is something very important. The total area under cultivation and the timeliness and efficiency of accomplishing crop husbandry tasks is strongly influenced by the amount of available farm power and its efficient use. The increased usage of farm power for cultivation creates further demand for related agricultural machinery for harvesting and storage and generates employment opportunities in the agricultural service and industry [4]. [5] stated that farm machinery field performance measures the rate and quality at which the operations are accomplished.

The objectives of this research work are to examine the effects of tractor speed and tillage depth on implement speed for three implements on a clay loam soil and carryout statistical analysis.

2. MATERIALS AND METHODS

2.1 Study Location

The study was conducted at the Department of Agricultural and Food Engineering demonstration farm in the University of Uyo located in Uyo local government area of Akwa Ibom state, Nigeria.

2.2 Experimental Design

The design of the experiment used were two factors, five levels, factorial central composite rotatable design (CCRD) of response surface methodology. Five levels of tillage depths (10, 15, 20, 25 and 30 cm) and tractor speeds (3.6, 5.4, 7.2, 9.0 and 10.8 km/hr) were chosen.

An experimental plot of 100 m long by 50 m wide was used for each implement. A plot of 50 m by 50 m was used as a practice area before the beginning of the experimental runs to enable the tractor and the implement to reach the selected tractor speed and tillage depth. Tillage depth was measured as a vertical distance from the top of the undisturbed soil surface to the implements deepest penetration using a steel measuring tape. The different tractor speeds (3.6 – 10.8 km/hr) were achieved by selecting appropriate gears and adjusting engine throttle at engine speeds of 1600 – 2000 rpm while the tillage depths of (10- 30 cm) were achieved by using tractor depth controller through its quadrant. Time taken for each implement to travel a distance of 100 m was taken and recorded.

2.3 Determination of Implement Speed

The implement speed of all the tillage implements was determined using the equation below.

$$S = \frac{D}{T} \quad \ldots (1)$$

Where;

S= Implement travel speed, m/s

D =Distance travelled, m

T=Time taken to travel the distance, sec

3. RESULTS AND DISCUSSION

3.1 Experimental test results

The average summary of the experimental results for the two factors, five levels factorial Central Composite Rotatable Design (CCRD) of the response surface methodology (RSM) for implement speed is presented in Table 1.

Table 1. Experimental results for implement speed using three implements on clay loam soil

S/N	Factor 1	Factor 2			
	D_T (cm)	S_T (km/hr)	IS(m/s)-3BDP	IS(m/s)-STC	IS(m/s)-ODH
1	10	7.2	1.95	1.75	1.86
2	15	5.4	1.27	1.43	1.38
3	15	9.0	1.87	2.19	2.11
4	20	3.6	0.78	0.67	0.70
5	20	7.2	1.57	1.32	1.38
6	20	7.2	1.50	1.30	1.36
7	20	7.2	1.54	1.33	1.49
8	20	7.2	1.56	1.31	1.35
9	20	7.2	1.51	1.30	1.37
10	20	10.8	1.83	1.57	1.64
11	25	5.4	1.03	1.25	1.41
12	25	9.0	1.65	1.75	1.78
13	30	7.2	1.43	1.24	1.25

D_T = Tillage Depth (cm); S_T = Tractor Speed (km/hr); IS = Implement speed (m/s); 3BDP = 3-Bottom Disc Plough; STC = Spring Tine Cultivator; ODH = Offset Disc Harrow

From this table, it could be observed that the implement speed for 3-bottom disc plough, spring tine cultivator and offset disc harrow ranged from 0.78 to 1.95, 0.67 to 2.19 and 0.70 to 2.11 m/s, respectively. This shows that the spring tine cultivator had the highest speed even though all the implements were pulled at the same tractor speed.

3.2 Effects of Tillage Depth and Tractor Speed on Implement Speed at the Study Location

The effects of tillage depth and tractor speed on implement speed for 3-bottom disc plough, spring tine cultivator and offset disc harrow at the study location are presented in Figures 1, 2 and 3 respectively. It could be seen from the figures that the implement speed increased with increases in tractor speed but decreased with increases in tillage depth. From the plots, it could also be observed that the plots of implement speed against the tillage depth is almost parallel to the axis of the tillage depth. But on the other hand, the plots of implement speed against the tractor speed is far from being parallel to the axis of the tractor speed. These results indicate that both factors have effect on the implement speed with the tractor speed having a more pronounced effect on the implement speed than the tillage depth.

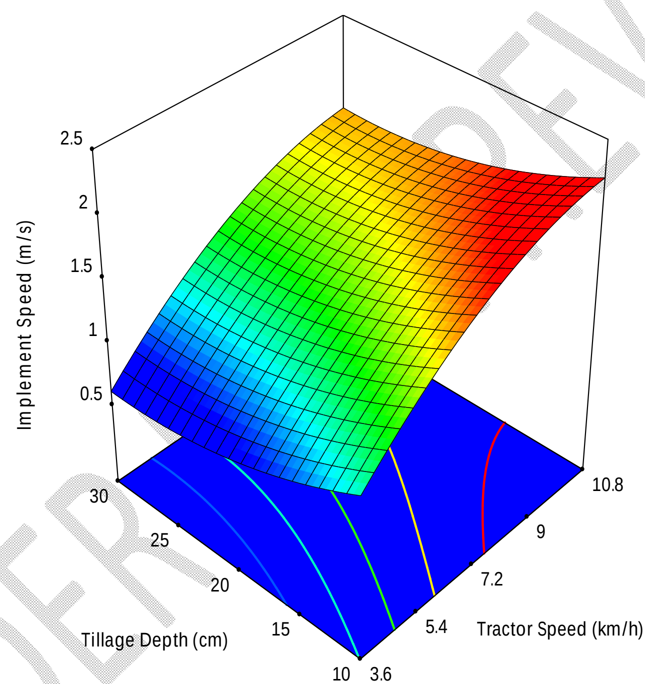

Fig. 1. Response surface plot of tillage depth and tractor speed against implement speed for 3-DBP at the study location

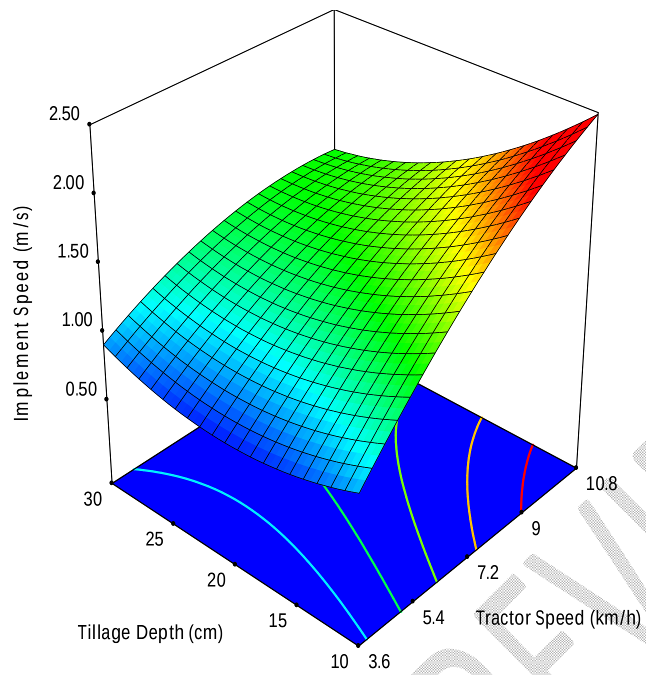

Fig. 2. Response surface plot of tillage depth and tractor speed against implement speed for STC at the study location

Fig. 3. Response surface plot of tillage depth and tractor speed against implement speed for ODH at the study location

3.3 Analysis of Variance for tillage depth and tractor speed on implement speed at the study location

Analysis of variance (ANOVA) for the effects of tillage depth and tractor speed on implement speed for 3-bottom disc plough, spring tine cultivator and offset dic harrow at the study location is presented in Tables 2, 3 and 4 respectively. From these tables, it was revealed that the effect of tractor speed on implement speed for these tillage implements at the study location are statistically significant at 0.05 level of significance, but the effects of tillage depth on implement speed for spring tine cultivator and offset disc harrow in this location is not statistically significant at 0.05 level of significance.

Table 2. Analysis of Variance of implement speed for 3-bottom disc plough at the study location

Source	Sum of Square	df	Mean Square	F-Value	P-Value
Tillage Depth (cm)	0.1875	1	0.1875	66.78	< 0.0001
Tractor Speed (km/hr)	0.9185	1	0.9185	327.12	< 0.0001
Error	0.0037	4	0.0009		
Total	1.28	12			

Table 3. Analysis of Variance of implement speed for spring tine cultivator at the study location

Source	Sum of Square	df	Mean Square	F-Value	P-Value
Tillage Depth (cm)	0.2241	1	0.2241	4.38	0.0628
Tractor Speed (km/hr)	0.7803	1	0.7803	15.26	0.0029
Error	0.0007	4	0.0002		
Total	1.52	12			

Table 4. Analysis of Variance of implement speed for offset disc harrow at the study location

Source	Sum of Square	df	Mean Square	F-Value	P-Value
Tillage Depth (cm)	0.1925	1	0.1925	4.26	0.0660
Tractor Speed (km/hr)	0.7400	1	0.7400	16.37	0.0023
Error	0.0130	4	0.0032		
Total	1.38	12			

The interaction plots shows the impact of tillage depth and tractor speed on implement speed for 3-bottom disc plough, spring tine cultivator and offset disc harrow on clay loam soil are shown in Figures 4, 5 and 6 respectively. Interaction means that the effect of one factor depends on the level of the other factors, each point in the interaction plot shows the mean implement speed at different combinations of factor levels. If the lines are not parallel, then the plot indicates that there is an interaction between the two factors while parallel lines indicate otherwise. From Figures 4 to 6, it could be seen that there is an interaction between the two factors for 3-bottom disc plough, spring tine cultivator and offset disc harrow. It could also be observed from these figures that the slope of the line for tractor speed is steeper than the slope of the line for tillage depth which confirms that the tractor speed has a more pronounced effect on implement speed than the tillage depth.

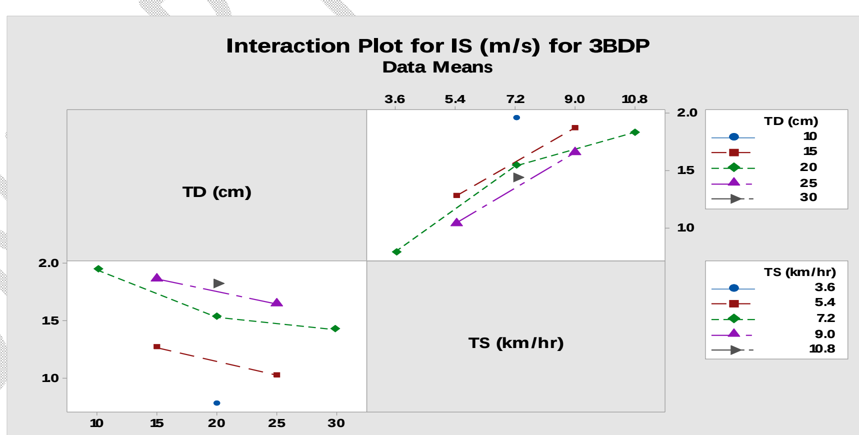

Fig. 4. Interaction plot of implement speed (m/s) for 3-bottom disk plough (3-BDP) at the study location

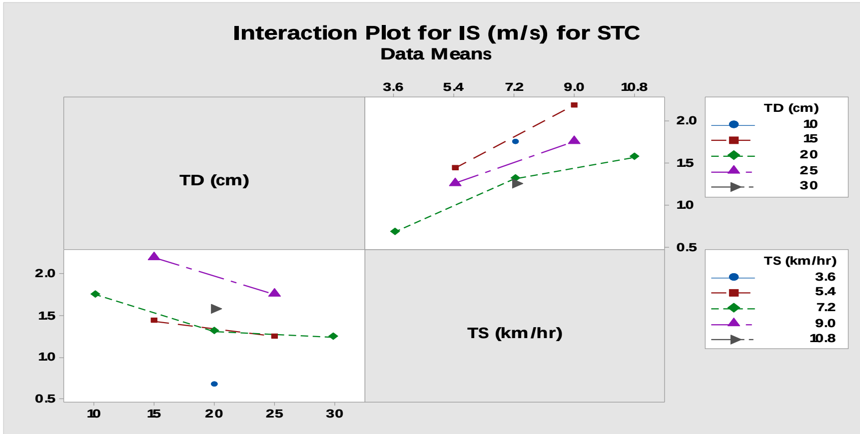

Fig. 5. Interaction plot of implement speed (m/s) for spring tine cultivator (STC) at the study location

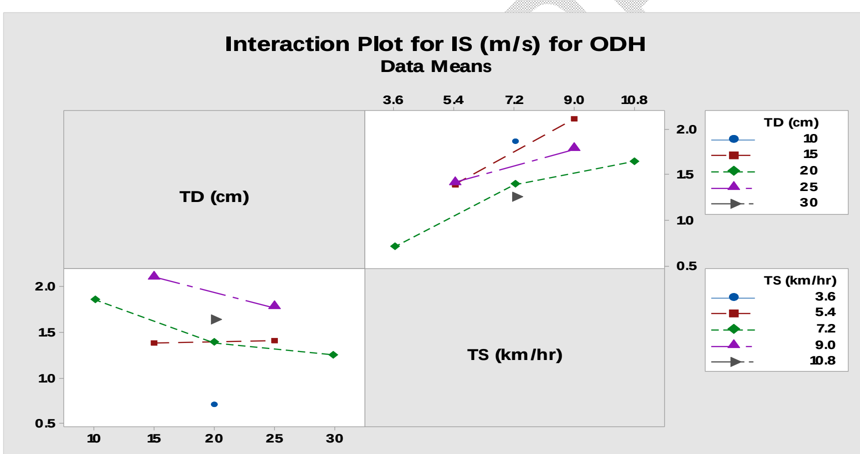

Fig. 6. Interaction plot of implement speed (m/s) for offset disk harrow (ODH) at the study location

4. CONCLUSION

The effects of tillage depths and tractor speeds on implement speed for 3-bottom disc plough, spring tine cultivator and offset disc harrow on a clay loam soil were evaluated. The results indicated that increasing tillage depth decreased the implement speed while increasing the tractor speed increased the implement speed. The spring tine cultivator had the highest speed even though all the implements were pulled at the same tractor speed.

The tractor speed had a more pronounced effect on the implement speed than the tillage depth. Analysis of Variance (ANOVA) showed that both tillage depth and tractor speed had significant effect ($p \leq 0.05$) on implement speed for 3-bottom disc plough. But tillage depth had no significant effect ($p \leq 0.05$) on implement speed for spring tine cultivator and offset disc harrow. This study therefore recommends that the availability of time and implement width should be used in determining the speed required to finish the work on time.

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