Effect of Soil Type and Operational Speed on Performance of Some Selected Agricultural Field Machinery in South East Nigeria

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Abstract: The effect of soil type and operational speed on the performance of some selected agricultural field machineries in South-East Nigeria were examined. Results revealed that the disc plough had maximum field efficiency of 88.11% at a working speed of 6 km h^{-1} in clay-loam soil, while in sandy-clay soil; it recorded maximum field efficiency of 87.98% under the same operational speed (6 km h^{-1}) and in loamy-sandy soil it obtained maximum field efficiency of 87.55% at the speed of 5 km h^{-1}. The harrow had maximum field efficiency of 98.54% at operational speed of 9 km h^{-1} in sandy-clay soil; in clay-loam soil at a working speed of 8 km h^{-1}, it recorded maximum field efficiencies of 87.98%, and 87.19% respectively. Results further indicated that the ridger had maximum field efficiencies of 89.09%, 87.96% and 87.95% respectively, in sandy-clay, clay-loam and loamy-sandy soil under operational speed of 9 km h^{-1}. At this same working speed, the rotovator obtained maximum field efficiencies of 89.81%, 89.40% and 87.11% in clay-loam, sandy-clay and loamy-sandy soil respectively. On the other hand, the planter recorded its maximum field efficiency of 89.69% in sandy-clay soil at speed of 5 km h^{-1}, while in clay-loam soil, it had maximum efficiency of 89.30% at speed of 6 km h^{-1} and in loamy-sandy soil, and it achieved a field efficiency of 88.99% under working speed of 7 km h^{-1}. The harrow, ridger and rotovator attained maximum field efficiency at higher operational speeds (8 - 9 km h^{-1}) as compared to plough and planter that achieved their maximum field efficiencies at lower operational speeds (5 - 7 km h^{-1}). The lower operational speed of the plough was attributed to the higher tractive and draft force required in its operation, to initially break up and turn over the compacted soil which is associated with slow operational speed than other tillage implements; while that of the planter was attributed to the high precision required in its operation for proper metering, placement and covering of the seeds to avoid damages, which could only be achieved in a moderately slow working speed.

Keywords: field efficiency, implements, working speed, tillage operation, seed planting.

Citation: Oduma, O., C. S. Agu, B. O. Stephen, P. Ehiomogue, J. I. Eze, D. C. Nnadi, and K. N. Udensi. 2021. Effect of soil type and operational speed on performance of some selected agricultural field machinery in South East Nigeria. Agricultural Engineering International: CIGR Journal, 23(1): 17-27.

1 Introduction

Agricultural field machinery refers to those machines/implements basically used in the farm for field operations such as land clearing machines (eg. mowers, bulldozers, slashers, stumpers etc); tillage or seed bed preparation machines (eg. plough of different kinds, harrows of different kinds, power tillers, ridgers, rotovators,

Received date: 2020-01-21 **Accepted date:** 2020-05-06

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etc.), seed planting machines, fertilizer applicators, mechanical weeding machines; sprayers for weed and pest controls; harvesting machines and transporting machines (Hunt, 2013). These machines are powered by prime movers (tractor) and are used in the farm for agricultural field operations. Most of these machines are fully mounted/hitched implements, semi-mounted implements, self-propelled or trailed implements. Modern agricultural operation demands the application of these field machinery and implements in different farm operations from field clearing to harvesting operation (Onwualu et al, 2006). There are many land areas available in different agricultural areas of the world, but not all the lands are suitable for crop production. However, in order to make them economically feasible for agricultural production, different tillage operations have to be conducted. The most important operations required include: adequate seed bed preparation for seed planting, germination, proper growth of the crop, mechanical weed control or application of herbicides/pesticides, fertilizer application, harvesting and conveying the farm product to the final/designed destination (Ojha and Michael, 2012).

One of the basic considerations in selecting tillage machinery is its size. The operational speed, width of cut, soil type/condition is usually sufficient information to match the size of implements to the farming enterprise (Harrison and Reed, 1968). The selection of tillage machinery for seedbed preparation and weed control depends on soil type/condition, crop type, previous soil treatments, crop residues and type of weed (Upadhyaya et al, 1984). The performances of farm machinery are conversely influenced by different factors. These factors include the power units, machine/implements condition, operational speed, nature of field, crop type, weather condition, soil type/condition and system management. Olatunji (2011) studied the relationship between the depth of cut and the increase in the weight of disc plough and draft; the model derived from the field work showed that the draft for disc plough increase with speed of operation and soil moisture content and depth of cut. Bukhari and Baloch (1982) observed that operation speed, implement effective working width and cutting depth, soil type/conditions and operator’s skill of operation influence fuel (energy) consumption rate. It therefore, means that size of implement and speed of operation should be matched to machine size to improve the field capacitive performance of the machine (Collins et al., 1998).

Field capacity of a machine/implement depends upon the working speed. Thus, there may be a drop in the field efficiency if the machine/implement working speed is increased. An increase in travel speeds will decrease the productive working time needed; However when the time losses remain effectively the same, there will be drop in the field efficiency of the machine. Such a result according to Hunt (2013) suggests that as much as there is a speed consideration, it is not good management to attempt to reduce field efficiency; therefore, it is not good operation to use slow speeds to achieve high field efficiency. Since high field capacity and/or material capacity can possibly be achieved with fast working speeds, an experienced operator should assess the soil or crop conditions and thus operate with high speed while maintaining the best quality of operation. Infield operation speeds may be influenced by such factors as: machine overloading, poor steering operation, careful operation to avoid loss of functional and structural damage to the machine owing to rough ground surface and being prudent in handling materials.

Values of machine capacities are applied in scheduling field operations, its power units and labour; as well as to determine machine operating costs. According to Yohanna and Ifem (2001), different machines have different field efficiencies, though depending upon the system of operations, soil type/ conditions and the system of management. If crop or soil conditions are inefficient for machine operations, forward speed of operation must be reduced. This condition improves field efficiency but it is not, of course, a desirable operating condition (Grisso et al., 2002).

Machine/implement performance are the rate and quality at which the operations are accomplished (Hunt, 2013).Tillage operations are soil-related operation; soil type and condition are essential indices impacting the field performance of the tractor through their effect on the traction effect of the tractor and implement being powered (Belel and Dahab, 1997). Smith (1993) noted that the performance of plough differs extensively based on the soil type, moisture content, weed growth, crop residues and shape or pattern of the field. John et al. (1987) observed that soil type/ condition is a major factor that affects the performance of field machineries. Belel and Dahab (1997) posited that the implements working in firm soil conditions had better efficiency than in loose ones. Bukhari and Baloch (1982) noticed that wheel slip increase more in clay loam soil than other soils when the operational speed of ploughing increased. According to Kepner et al. (1982) energy consumption depends mostly among other factors on soil type/condition, speed of operation and quality of tillage; they explained the effects of soil type as they reported that clay soil has a higher break up energy requirement than sandy soils. Shebi et al (1988) maintained that for any given soil, energy requirements of farm machinery increase with bulk density of the soil.

Data are not available from operations under local conditions to be able to quantify the effect of soil type and operational speed on farm machinery performances in South-East Nigeria. It is therefore necessary to examine the effect of soil type and operational speeds on the performances of selected agricultural field machineries under field conditions. The aim of this study is to obtain data on the effect of soil type and speed of operation of some selected tractor hitched implements under field conditions in South-East agro-ecological region of Nigeria for suitable selection and matching of the field machineries.

2 MATERIALS AND METHOD

2.1 Description of the Study Area

The study area is South East agro - ecological zone of Nigeria comprising of Abia, Anambra, Ebonyi, Enugu and Imo state. South-East zone lies approximately latitudes 4° 47′ 35"N and 7° 7′ 44"N, and longitudes 7° 54′ 26"E and 8° 27′ 10"E (Anejionu et al., 2013), with a land area of approximately 28,873km^2. The vegetation of the area is a mixture of savanna and tropical rainforest with average annual rainfall of 2500mm (Ezemonye and Emeribe, 2012). The zone has an average annual temperature of above 27^{o}C with average relative humidity of about 75%. South-east zone has fertile and well drained soils; and the people are essentially farmers.

2.2 Soil type classification of the study area

The soil classification of South east is as shown in the soil map (Figure 1).

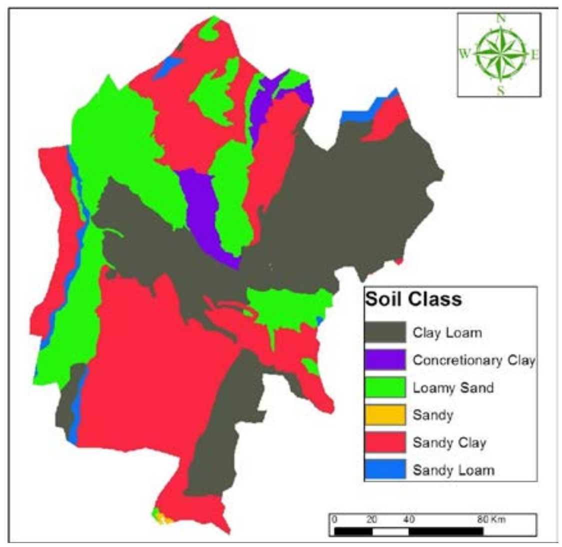

Figure 1 Soil map of south east zone (source: Anejionu et al., 2013)

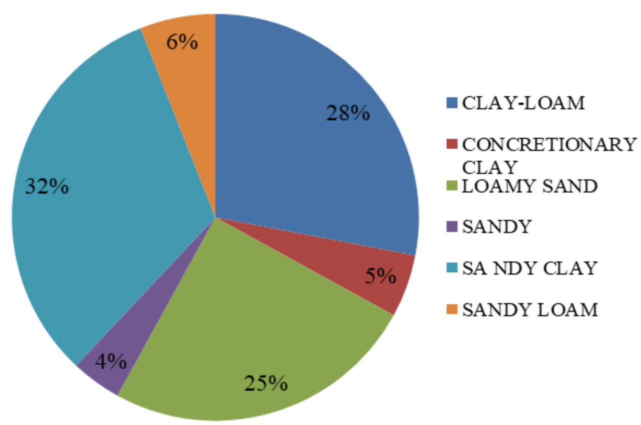

Figure 2 Percentage of soil type in South East Nigeria (source: Oduma et al., 2019)

According to the map different soils such as clay-loam, concretionary clay, loamy-sandy, sandy, sandy- clay and sandy-loam exist in the area; but the three dominant soils in the area are clay-loam, loamy-sandy and sandy-clay soils. This study was based/conducted on these three dominant soils of the area. The percentages of the soil type in the study area are represented on Figure 2.

2.3 Description of Experimental Site

The experiments were conducted at different locations, where the dominant soils in the study area were located. The experimental sites have an average land area of 8100 m^2 each. The land area was divided into four units of 45 × 45m^2 each for random observations. Each unit was separated by a distance of 2.5 m from the other to avoid interaction between the plot borders and to be equally used as head lands for turning and commencement of the experimental operations. A random distribution of treatments within the plots was carried out and the experiments were arranged in a randomized complete block design (RCBD) (Oduma et al., 2018).

2.4 Description of Machine Used for the Test

A Massey Ferguson tractor of model MF430E and capacity 55.2 kW, with 3- point hitch systems and age of 5months from date of first hand purchase was used for the test. This tractor was selected for the study because it recorded the highest pulverizing efficiency with the tillage implements as compared to tractors that are mostly used in south- east Nigeria for field operations (Oduma and Oluka, 2017). The hitched implements studied include disc plough, harrows, rotovators, ridgers, and planters. The same operator was used to operate the machine throughout the test with three replications of each operation to ensure minimal variation in the operation skill and style throughout the study (Oduma et al., 2018).

2.5 Determination of soil physical properties

Prior to the determination of the various performance indicators, some soil physical characteristics such as moisture contents, bulk density, soil structure, texture, porosity, that influence machinery performances, were determined using the method adopted by Oduma et al. (2019).

2.6 Field Operation Test

The field operation tests were conducted using the methods adopted by Oduma et al. (2019) in which the ploughing, harrowing, ridging, pulverization and sowing operations were generally performed longitudinally with the implement full width at selected forward speeds and cutting depth, the distance travelled and the corresponding time taken to complete the working distance were noted; and the performance indicators such as field efficiency, effective field capacity, theoretical field capacity and material capacity of the various implements were determined as stated below.

2.7 Determination field efficiency

The field efficiency was determined from the expression suggested by Kepner et al. (1982) as

adopted by Oduma et al. (2018)

$$\mathcal{E} = \frac{100 \times Te}{Tt} \tag{1}$$

Where, ε is the field efficiency (%);

T_e is the actual working (productive) time (h);

T_t is the total working time (h), $T_t = T_e + T_d$; and

T_d is the delay or idle time (h).

2.8 Determination of the Effective Field Capacity

The effective field capacity was evaluated from Equation 2 as proposed by Kepner et al. (1982)

$$Ce = \frac{w \times S}{1000}\ \varepsilon \tag{2}$$

Where,

w is the effective working width of machine (cm);

S is the operation speed (km h^{-1}); and

Ce is the effective field capacity (ha h^{-1})

2.9 Determination of the Theoretical Field Capacity

The theoretical field capacity was determined from Equation 3 according to ASAE (1999)

$$TFC = W_t \times V_t \times K \tag{3}$$

Where

TFC is the theoretical field capacity (ha h^{-1})

W_t is the theoretical operation width (cm)

V_t is the theoretical operation speed (km h^{-1})

K is the constant = 0.1

2.10 Determination of material capacity

The material capacity of the implements were determined from Equation 4 according to Hunt (2013)

$$M = \frac{S \times w \times e \times y}{c} \tag{4}$$

Where,

M is the material capacity (kg h^{-1})

e is the field efficiency (%)

and y is the yield (kg m^{-2})

Figure 3 Pictorial Views of the Experiment/Measurement on the Various Sites under Study (source: Oduma and Oluka, 2017)

3 Results and discussion

3.1 Effect of soil type and operational speed on performance of disc plough

Table 1 shows the effect of soil type and operational speed on performance of tractor- hitched plough. Results of this table revealed that plough recorded the highest field efficiency of 88.11% at operational speed of 6 km h^{-1} in clay – loam soil at moisture content range from 15.3% – 17.2% (w.b), followed by sandy – clay soil where it had a maximum field efficiency of 87.98% at the same working speed (6 km h^{-1}) with moisture content range from 14.8% - 18.6% (w.b) and least was in loamy- sandy in which it recorded maximum field efficiency of 87.55% at speed of 7 km h^{-1} and at soil moisture content of 15.2% – 16.2% (w.b). The plough worked at selected cutting depth of 25cm with its full width of 180cm. The field efficiencies obtained in this study is slightly higher than that obtained by Yohanna (1998) for Plateau state; the variation in the field efficiencies may be as a result of variation in soil condition and/or characteristics of the different areas. This result confirms the findings of Smith (1993) and Belel and Dahab (1997) who stated that the performance of plough varies considerably according to the type of soil and that soil type and condition are specific indicators that affect the field performance of the tractor through their effect on the hitched implement and tractor traction.

Furthermore, results also showed that the higher the field efficiency, the lower the theoretical and effective field capacities of the plough. This is consistent with the observations of Hunt (2013). The theoretical and effective field capacities maintained very small values and did not vary much with the speeds of the plough operation (i.e. they maintained almost constant values with the speed of operation). The plough generally recorded material efficiency range from 35.67 kg h^{-1} – 46.91kg h^{-1} with sandy-clay recording the highest average material capacity of 43.98 kg h^{-1} and least was clay loam soil with material capacity of 39.57 kg h^{-1}.

3.2 Effect of soil type and operational speed on performance of the harrow

Table 2 revealed that harrow had its highest field efficiency of 98.54% at an operational speed of 9 km h^{-1} in sandy –clay soil at moisture content range from 13.0% –

19.3% (w.b).This was followed by clay – loam soil where it recorded maximum field efficiency of 87.98% at speed of 8 km h^{-1} and at moisture content ranging from 14.8% – 16.2% (w.b) and the least was loamy- sandy soil in which it had its maximum field efficiency of 87.19% at the same working speed as in clay – loam soil and at moisture content varying from 13.3% – 15.4% (w.b). Harrow worked at selected cutting depth of 20 cm with its full working width of 225 cm. The sandy-clay soil has the highest performance efficiency as compared to clay – loam and loamy – sandy soil. This could be due to low aggregation stability, high moisture content and low decomposed organic matter found in sandy-clay than loamy-sandy and clay-loam soil types as observed by Alnahas (2003) which is consistent with the findings of Oduma et al. (2018).

Table 1 Effect of soil type and operational speed on performance of tractor-hitched disc plough.

Soil type	Plouging speed (km h^{-1})	Moisture content range (%, w.b)	Working width (cm)	Plowing depth (cm)	Field efficiency (%)	Effective field capacity (ha h^{-1})	Theoretical field capacity (ha h^{-1})	Material capacity (Kg h^{-1})
Clay-loam	5	15.3-17.2	180	25	87.08	1.931	1.384	43.46
	6		180	25	88.11	0.990	1.323	41.73
	7		180	25	87.05	0.978	1.324	41.82
	8		180	25	86.45	1.019	1.179	42.95
	9		180	25	85.74	0.846	1.187	35.67
	10		180	25	87.24	1.002	1.149	41.23
	Mean	16.25	180	25	86.93	1.389	1’267	39.57
Loamy-sandy	5	15.2-16.2	180	25	86.79	0.981	1.130	41.35
	6		180	25	87.55	0.991	1.119	41.77
	7		180	25	87.07	0.975	1.105	41.88
	8		180	25	87.13	0.932	1.102	41.30
	9		180	25	86.02	0.911	1.111	41.09
	10		180	25	85.31	0.885	1.103	39.32
	Mean	15.70	180	25	86.43	0.938	1.116	40.60
Sandy-clay	5	14.8-18.6	180	25	85.90	1.974	1.174	41.05
	6		180	25	86.23	1.162	1.275	44.76
	7		180	25	87.98	1.113	1.282	46.91
	8		180	25	87.23	1.143	1.296	46.18
	9		180	25	87.22	0.848	1.261	46.23
	10		180	25	87.78	0.985	1.162	41.52
	Mean	16.70	180	25	86.94	1.411	1.229	43.98

Table 2 Effect of soil type and operational speed on performance of tractor-hitched harrow.

Soil type	Operation speed (km h^{-1})	Moisture content range (%, w.b)	Working width (cm)	Harrowing depth (cm)	Field efficiency (%)	Effective field capacity (ha h^{-1})	Theoretical field capacity (ha h^{-1})	Material Capacity (Kg h^{-1})
Clay-laom	5	14.8-16.2	225	20	82.59	1.063	1.287	86.89
	6		225	20	83.42	1.126	1.35	92.04
	7		225	20	87.17	1.097	1.368	89.67
	8		225	20	87.98	1.289	1.365	95.36
	9		225	20	87.70	1.196	1.379	97.76
	10		225	20	87.56	1.239	1.399	101.28
	Mean	15.5	225	20	86.29	1.151	1.987	94.09
Loamy-sandy	5	13.3-15.4	225	20	86.58	1.192	1.526	97.43
	6		225	20	86.82	1.389	1.55	113.54
	7		225	20	87.08	1.436	1.649	117.38
	8		225	20	87.19	1.399	1.703	120.32
	9		225	20	85.22	1.386	1.711	121.18
	10		225	20	83.41	1.394	1.713	122.74
	Mean	14.4	225	20	85.40	1.314	1.620	110.09

Sandy-clay	5	13.0-19.3	225	20	87.55	1.095	1.351	89.51
	6		225	20	87.05	1.204	1.400	98.41
	7		225	20	87.95	1.281	1.473	104.71
	8		225	20	91.38	1.343	1.470	109.78
	9		225	20	98.54	1.311	1.480	107.16
	10		225	20	97.45	1.458	1.467	119.18
	Mean	74.65	225	20	92.80	1.274	1.416	104.35

Like the ploughing operation, the higher the field efficiency, the lower the theoretical and effective field capacities of the harrow. The material efficiency of the harrow was higher than its field efficiencies for all the soils studied, and could be attributed to higher soil-implement interaction observed in harrow operation than ploughing and other field operations studied; and as evidence, the harrow recorded the best soil performance indicators as compared to other implements studied. It can be deduced from the results that for South-East agro-ecological soils, the maximum field efficiency range from 87.19% - 98.54% could be achieved at operational speed of 8 – 9 km h-1.

3.3 Effect of soil type and operational speed on performance of the ridger

The ridger (Table 3) had the highest field efficiency of 89.09% in sandy – clay soil at moisture content range from 13.0% – 17.1% (w.b); followed by clay-loam soil which recorded maximum field efficiency of 87.96% at moisture content range from 13.2% – 14.5% (w.b) and least was in loamy-sandy soil where it had maximum field efficiency of 87.95% at moisture content range from 14.0% – 14.4% (wb). For all the soils the ridger achieved its maximum efficiency at operational speed of 9 km h^{-1}. The disparity in the field efficiencies obtained in ridging operation were very small, this might be as a result of reduction in the bulk density and moisture content of the soil after being loosened during ploughing and harrowing operation which might have enhanced the field performances of the ridging implements by reducing the resistance to the penetration of the implements and also improved the soil workability making it to achieve its maximum efficiency at highest operational and steady speed (9 km h^{-1}) in all the soils studied. It worked at a selected cutting depth of 15 cm with its full working width of 210 cm. Results indicated that higher the field efficiency, the lower the theoretical and effective field capacities of the plough. The ridger generally maintained material capacity range from 52.38 kg h^{-1} – 79.19 kg h^{-1} with sandy-clay recording the highest average material capacity of 71.26 kg h^{-1} followed by clay-loam with average material capacity of 65.80 kg h^{-1} and least was clay- loam soil which recorded average material capacity of 61.99 kg h^{-1}.

The variation in the material capacity obtained in the various soils in which the clay loam recorded the least capacity and sandy-clay recording the highest was in agreement with the findings of Oduma et al. (2019); a confirmation of the observations of Kepner et al. (1982) that clay soil has a higher break up energy requirement than sandy loam soil and that was why the sandy clay soil recorded the highest material capacity as compared to other soils.

Table 3 Effect of soil type and operational speed on performance of tractor – hitched ridger

Soil type	Operation speed, (km h^{-1})	Moisture content range (%, w.b)	Working width (cm)	Ridging depth, (cm)	Field efficiency (%)	Effective field capacity (ha h^{-1})	Theoretical field capacity (ha h^{-1})	Material capacity (Kg h^{-1})
Clay-loam	5	14.0-14.4	210	15	83.65	0.065	1.273	59.85
	6		210	15	85.68	0.932	1.088	52.38
	7		210	15	86.90	1.057	1.260	59.40
	8		210	15	87.00	1.152	1.340	64.74
	9		210	15	87.96	1.945	1.373	53.11
	10		210	15	87.92	1.909	1.603	79.19

	Mean	14.2	210	15	85.81	1.177	1.346	65.80
Loamy-sandy	5	13.2-14.5	210	15	85.54	1.107	1.150	56.59
	6		210	15	86.45	1.165	1.344	66.04
	7		210	15	87.54	1.176	1.332	67.53
	8		210	15	87.54	1.170	1.370	67.18
	9		210	15	87.95	1.175	1.318	67.39
	10		210	15	87.32	1.169	1.301	64.52
	Mean	13.85	210	15	86.75	1.142	1.260	61.99
Sandy-clay	5	13.0-17.1	210	15	87.07	1.370	1.344	65.75
	6		210	15	86.60	1.382	1.365	66.43
	7		210	15	86.26	1.365	1.366	65.47
	8		210	15	87.19	1.376	1.37	67.78
	9		210	15	89.09	1.302	1.374	68.91
	10		210	15	81.82	1.218	1.371	77.05
	Mean	15.05	210	15	85.46	1.30	1.359	71.26

3.4 Effect of soil type and operational speed on performance of the rotorvator

Tractor - hitched rotovator recorded its maximum field efficiencies at operational speed of 9 km h^{-1} for all the soils (Table 4). At this speed, the rotovator recorded the highest field efficiency of 89.81% in clay-loam soil at moisture content varying from 13.0% – 14.2%(w.b); followed by sandy – clay soil where the rotovator had maximum field efficiency of 89.40% at moisture content range of 13.3% – 16.3% (w.b) and the least was in the loamy – sandy soil in which it recorded maximum field efficiency of 87.11% at soil moisture content range from 13.1% – 13.6% (w.b). The rotovator, harrow and the ridger achieved maximum field efficiencies under higher operational speed (8 – 9 km h^{-1}) as compared to disc plough implement. This might be attributed to the lower tractive and draft force required in their operation than the plough. Also the initial action of the plough on the soils have loosen and broken up the initial compacted soil enabling the speedy and easy working condition of the implements. Furthermore, the speed of operation of tillage implements among other factors depends on the depth of cut of the implements as noted by Al-Suhaibani and Ghaly (2010); the rotovator worked at lesser cutting depth (15 cm) as compared to ploughing operation making it to operate at a higher speed in pulverizing the soil.

Table 4 Effect of soil type and operational speed on performance of tractor- hitched rotorvator.

Soil type	Operation speed (km h^{-1})	Moisture content range (%, w.b)	Working width (cm)	Pulverizing Depth (cm)	Field efficiency (%)	Effective field capacity (ha h^{-1})	Theoretical field capacity (ha h^{-1})	Material capacity (kg h^{-1})
Clay-loam	5	13.0-14.2	145	15	85.81	0.775	0.903	20.93
	6		145	15	87.38	0.759	0.869	20.49
	7		145	15	88.20	0.962	1.091	25.97
	8		145	15	88.24	0.669	0.758	18.06
	9		145	15	89.81	0.811	0.903	21.90
	10		145	15	86.63	0.795	0.918	21.47
	Mean	13.60	145	15	87.81	0.861	0.925	22.02
Loamy-sandy	5	13.1-13.6	145	15	81.10	0.804	0.913	21.71
	6		145	15	86.79	0.803	0.925	21.68
	7		145	15	86.83	0.812	0.935	27.94
	8		145	15	84.92	0.800	0.911	22.69
	9		145	15	87.11	0.811	1.002	26.81
	10		145	15	85.81	0.804	0.916	24.41
	Mean	13.35	145	15	84.11	0.806	0.958	24.81

Sandy-clay	5	13.3-16.3	145	15	87.05	0.800	0.919	21.60
	6		145	15	88.36	0.778	0.933	21.01
	7		145	15	86.88	0.685	0.788	18.50
	8		145	15	87.51	0.902	1.031	24.35
	9		145	15	89.40	0.812	0.919	21.92
	10		145	15	87.13	0.828	0.950	22.36
	Mean	14.8	145	15	88.01	0.794	0.910	21.43

3.5 Effect of soil type and operational speed on performance of the planter

Table 5 presents the results of the effect of soil type and operational speed on the performance of tractor hitched planter. Results of this table showed that the highest field efficiency of 89.69% was recorded in sandy-clay soil at moisture content ranging from 13.2% – 16.3% (w.b) when the planter was operated at a working speed of 5 km h^{-1}. This was followed by clay – loam soil where it had maximum field efficiency of 89.30% at a working speed of 6km h^{-1} under moisture content range from 13.0% -13.8% (w.b). The least was in the loamy – sandy soil where it recorded maximum field efficiency of 88.99% under operational speed of 7 km h^{-1} at moisture content varying from 14.0% – 14.5% (w.b). The variation in the speeds under which the planter obtained its maximum field efficiency was achieved at 5 km h^{-1}, followed by speed of 6 km h^{-1} and lastly 7 km h^{-1}. It was evident that under low working speed, the field efficiency of machine/implements increases as noted by Hunt (2013). The low speed of planting operation as observed in this research work was attributed to high precision required for its operation in opening the soil, metering the seeds, proper deposition of the seeds in the opened furrow and coverage; which must be done to avoid damage of the seeds; and can only be achieved under moderately low working speed as observed by Oduma et al. (2015) and under low working speed, the productive time increases thereby increasing the field efficiency of the implement (Hunt, 2013).The planter worked at average sowing depth of 2.6 cm with full working width of 240 cm. It also recorded average material capacity of 62.33 kg h^{-1}.

Table 5 Effect of soil type and operational speed on performance of tractor- hitched planter

Soil type	Operational speed (km h^{-1})	Moisture content range (%, w.b)	Working width (cm)	Planting depth (cm)	Field efficiency (%)	Effective field capacity (ha h^{-1})	Theoretical field capacity (ha h^{-1})	Material efficiency (kg h^{-1})
Clay-loam	5	13.0-13.8	240	2.4	82.71	1.012	1.224	50.60
	6		240	2.5	89.30	1.316	1.474	65.80
	7		240	2.7	86.53	1.319	1.524	65.95
	8		240	2.5	88.78	1.338	1.507	66.90
	9		240	2.6	87.54	1.137	1.299	56.85
	10		240	2.6	88.59	1.327	1.491	66.35
	Mean	13.4	240	2.6	86.01	1.175	1.374	58.75
Loamy-sandy	5	14.0-14.5	240	2.6	86.30	1.332	1.543	66.60
	6		240	2.6	80.63	1.386	1.719	69.30
	7		240	2.5	88.99	1.397	1.570	69.85
	8		240	2.6	86.69	1.346	1.552	66.25
	9		240	2.6	86.62	1.312	1.561	66.00
	10		240	2.5	85.66	1.310	1.516	67.12
	Mean	14.3	240	2.6	87.33	1.354	1.618	67.93
	5	13.2-16.3	240	2.4	89.69	1.346	1.553	67.30
Sandy-clay	6		240	2.7	86.06	1.334	1.550	66.70
	7		240	2.5	86.30	1.481	1.716	74.05
	8		240	2.6	86.37	1.392	1.558	69.60
	9		240	2.6	87.09	1.348	1.548	67.40
	10		240	2.6	87.30	1.368	1.532	68.40
	Mean	14.8	240	2.6	87.88	1.408	1.624	70.38

4 Conclusions

The study was carried out to obtain data on the effect of soil type and speed of operation of some selected tractor hitched implements under field conditions in South-East agro-ecological region of Nigeria for suitable selection, operation and matching of the field machineries. From the findings in the research work, the following conclusions can be made about the study:

Harrow, ridger and rotovator attained maximum field efficiency at higher operational speeds (8 – 9 km h^{-1}) as compared to plough and planter which achieved their maximum field efficiencies at lower operatonal speeds (5 – 7 km h^{-1}). The lower operational speed of the plougher was due to higher tractive and draft force required in its operation to initially break the compacted soil than other tillage implements while that of planter was due to high precision required in its operation for proper metering, planting and covering of the seeds to avoid damage.

The average field efficiency for all the implements was highest on sandy-clay soil with average field efficiency of 87.35%, followed by clay-loam that gave average field efficiency of 86.53% and least was 68.21% obtained on the loamy-sandy soil. This could be due to low aggregation stability, high moisture content and low decomposed organic matter in sandy- clay than other soils.

Tractor hitched-harrow had the best soil-machine performance indicators as compared to the other implements. The material efficiency of the harrow was higher than its field efficiency as compared to other field machinery studied; and could be attributed to higher soil-implement interaction observation in harrow operation than other field operations studied.

Results obtained in this study will aid in proper selection, management and operation of the farm machinery based on soil type/condition and operational speed for better performance. Finally, owing to differences in soil type/conditions among different agricultural areas; it is therefore recommended that studies of this kind should be carried out in every agricultural zone to provide data on machine/implement performances based on soil types for increased production.

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