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Optimization Performance Evaluation of Developed Tractor Drawn Single Row Irish Potato Planter with Fertilizer Applicator under Different Tractor Speed and Moisture Content

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Abstract

The developed tractor drawn single row Irish potato planter with fertilizer applicator was evaluated. The planter performance was tested in 18 plot with an area of 400 m² in each plots (40 m × 10 m for each plot) with specific soil properties. The performances of tractor drawn single row Irish potato planter with fertilizer applicator was tested in the laboratory and

field at different tractor walking speed of 3 km/hr, 3.5 km/hr and 4 km/hr and three different moisture content of 13.41%, 14.27%, and 15.76%. At the tractor speed of 3 km/hr, 3.5 km/hr and 4 km/hr, when the moisture content was kept constant at 13.41%; the average depth of planting was uniform at 133.3 mm, the average intra row spacing of the planted potato seedling was 290.8 mm, 291.2 mm, 300.4 mm respectively, the average number of potato per drop of the planted potato seedling was 2, 1, 1 respectively, the average percentage of missing was 2.14%, 2.46%, 3.58% respectively, the average height of ridge was 286.3 mm, 285.7 mm, 278.9 mm respectively, the average depth of fertilizer dropping was uniform at 133.3 mm, the average fuel consumption was 9.8 l/ha, 10.3 l/ha and 10.7 l/ha respectively, the average field efficiency was 74.35%, 75.04% and 76.67%. At the moisture content of 13.41 %, 14.27%, and 15.76%, when the tractor speed was kept constant at 3.5 km/hr; the average depth of planting was 133.3 mm, 135.1 mm and 135.9 mm respectively, the average intra row spacing of the planted potato seedling was 291.2 mm, 291.4 mm and 291.8 mm respectively, the average number of potato per drop was uniform at 1, the average percentage of missing 2.46%, 2.97% and 3.35% respectively, the average height of ridge was 285.7 mm, 291.3 mm and 294.7 mm respectively, the average depth of fertilizer dropping was 133.3 mm, 135.1 mm and 135.9 mm respectively, the average fuel consumption was 10.3 l/ha, 11.2 l/ha and 11.98 l/ha

respectively, the average field efficiency was 75.04%, 71.88% and 69.31% respectively.

Introduction

Potato (Solanum tuberosum L.), the world's third most important crop and first most important non-cereal food crop, has been regarded as a key source to ensure food security for the world's fast-growing population (Gaiero et al., 2018; Monte et al., 2018). Potato belongs to the tuber crops which are of two main types namely; Irish potato (Solanum tuberosum L.) and sweet potato (Ipoema batata) which is raised through vines, whereas the former are raised through tubers (Ugonna et al., 2013). Developing countries are now the world's biggest producers and importers of potatoes and its products.

Irish potato (solamun tubersun L.) belongs to the solanaceae family. It is a native of Western Hemisphere and is believed to have originated somewhere between Mexico and Chile, possibly in Andes highlands of Bolivia and Peru. It later spread to other places like England and Ireland. The planting stock has been received from Ireland, hence the name Irish potato (Jwanya et al., 2014). It was first introduced to Nigeria in the later part of the 19th century and early 20th century by the Europeans notably the tin miners in the Jos Plateau (Okonkwo et al., 2009). It can be grown for food as well as a commercial crop. It is a major source of income among the rural farmers in many African communities.

The advent of mechanized farming has revolutionized agricultural practices, offering opportunities to streamline operations, increase yields, and optimize resource utilization. The development of tractor drawn single row Irish potato planter with fertilizer applicator has emerged as a key technological innovation, enabling farmers to achieve precision planting and fertilizer application with minimal manual intervention (Okunade and Ibrahim, 2011). However, existing potato planters lack the sophistication needed to optimize planting depth, spacing, and fertilizer distribution for maximum yield potential. Furthermore, the integration of fertilizer application functionality into potato planters presents additional advantage in terms of potato production (Iritani et al., 2002).

The existing Irish potato planter are imported. Many are either too expensive or not available for Nigeria Irish potato farmers. They lack the technology to adapt different topography of Nigeria farm. Most of the existing one are not integrated with the fertilizer applicator which requires separate operations, which increases time and cost. Additionally, current Irish potato planter metering mechanism are made of iron and mild steel material which always causes injury to the planted tuber resulting to low germination.

These problem lead to development of locally made tractor drawn single row Irish potato planter with fertilizer applicator which needed to be evaluate and optimize.

The aim of this research is to optimize the performance evaluation on the developed tractor drawn single row Irish potato planter with fertilizer applicator under two independent variables (tractor speed and moisture content).

MATERIALS AND METHODS

Machine Description

The designed tractor drawn single row potato planter with fertilizer applicator as shown in Figures 3.9 consists of main frame, tubers metering mechanism, fertilizer metering mechanism, tubers hopper, fertilizer hopper, tuber tube, ground wheels, furrow openers and furrow coverer. The single-row potato planter has a general specifications with overall dimension of (1100 mm×1015 mm×800 mm), space between plants 20 cm-30 cm, space between furrow tops 50 cm-80 cm, connecting of 3 point linkage of category one. The tubers metering device of the tractor drawn single row potato planter with fertilizer applicator is a spoon type vertical drive which, consists of 12 spoons and chain with equivalent spoon distance of 12 cm. Tuber packing is greatly affected by the relationship between the cell size and thickness of the tuber (Yogesh and Shambhu, 2022). So, the chain-feed of the potato planter was developed to plant tuber pieces by modified spoons size. These spoons diameters range were 25-45 mm to suit the cut tubers, according to the measured physical properties by (El-Ghobashy et al., 2014). The spoons with chain is passed from the hopper bottom to top and driven by ground wheels. The tubers hopper having a capacity of 140kg was designed to easily feed the cut tubers and conveys it from the hopper-through the metering device to the furrow opener by tuber tube. The dropping of tuber-stakes was as a result of gravitational force. The transmission system was designed to control the number of spoons per revolution using different chain-sprocket transmission to prevent slipping and also to transmit the motion from the planter wheel (D = 450 mm) to the feeding device. Furrow opener (shoe shape type) is fixed in the front beam to adjust and control the depth of the furrow. The furrow coverer consists of two disc units located at the back end.

Mode of operation of the designed planter

During operation, the developed planter as shown in plate 1 moves forward by the tractor, then the chain and spoon assembly start moving anchored from the bottom to the top through the cut tubers hopper. As the chain moves up, each spoon carries one piece of cut tubers and the chain moves further up and the spoon gets inverted inside a tuber tube which drops the tuber piece to the ground at desired spacing and depth. At the same time, the furrow opener opens up a furrow in which the cut tubers are planted. As the planter moves further, the furrow coverer attachment then covers the cut tubers and makes a ridge. The fertilizer mechanism convey the appropriate designed quantity of fertilizer to the fertilizer delivering chute, which then places the fertilizer at the desired spacing and depth.

Plate 1: Pictorial view of the developed tractor-drawn single row Irish potato planter with fertilizer applicator.

Performance evaluation

According to Sagni (2019) it was essential to assess tractor drawn single row Irish potato planter with fertilizer applicator performance in terms of seed rate, seed distribution, seed placement, power requirements, and field efficiency. The following tests were conducted in the field and in the laboratory in order to evaluate it for the aforementioned parameter.

Field Test

The tractor was hitched to the potato planter. Three distinct operating speeds were observed at various gear and throttle positions. The planter was used on a seed bed that had been properly prepared. In the field, the planter was operated using the side-to-centre method. Three replications were made at each speed. The effective field capacity, field efficiency, and power needed were determined, and the potato planter was calibrated.

Field Description

According to Sagni (2019) the field condition has an impact on the yield of tubers and seed germination. As a result, this field conditions affect the sowing process. Prior to seeding, the following parameters were established.

i. Soil type
ii. Soil moisture content (percent)
iii. Seed bed depth
iv. Plot size
v. Bulk density
vi. Technique for planting

The field calibration test was carried out in the same way as the laboratory test. The developed tractor-drawn potato planter's seed rate and seed damage are determined in the field using the same approach that was used for the calibration tests.

Experimental Design

The Gudene potato variety (P) was used in the field for the experiments. Three tractor forward speeds of 3.0 km/h, 3.5 km/h, and 4.0 km/h and three different moisture content of 13.41%, 14.27% and 15.76% were used to produce the three treatments. Using a Randomized Complete Block Design, each treatment was replicated three times as shown in Figure 1 and Figure 2.

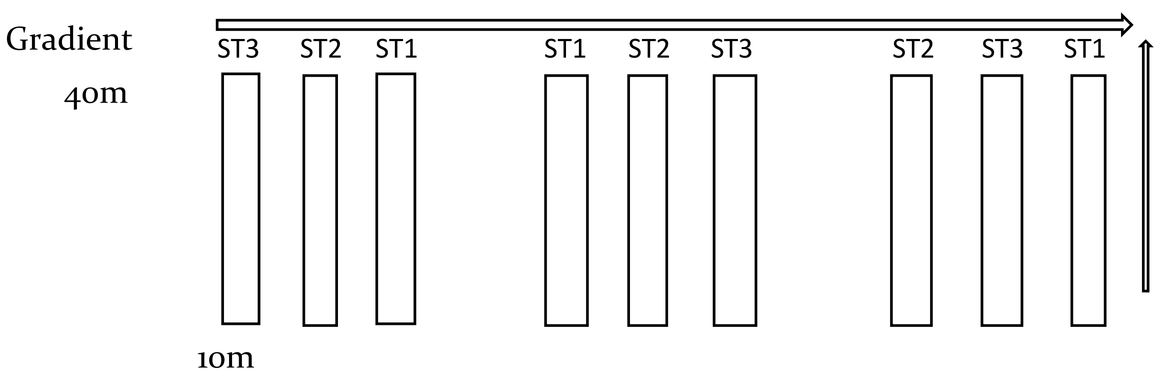

Figure 1: Tractor speed sample representation using RCBD plot size

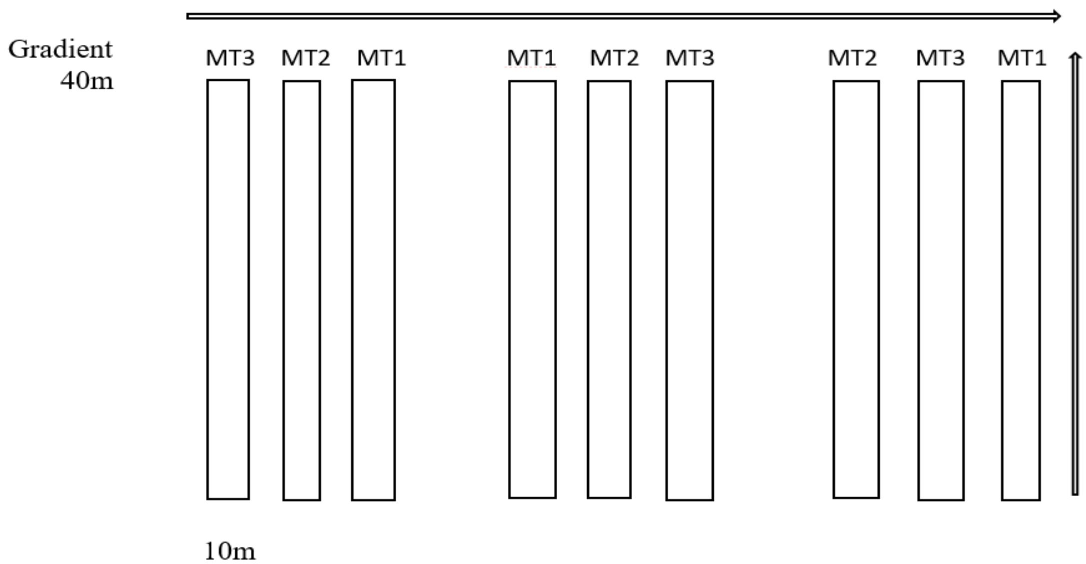

Figure 2: Tractor speed sample representation using RCBD plot size

Where: S- Tractor speed
M – Moisture content
T-Treatment with index number 1,

A carefully prepared experimental field was divided into 18 plot with an area of 400 m^2 in each plots (40 m × 10 m for each plot). Before testing, several machine adjustments were made to obtain the necessary plant-to-plant distance and seed depth. The potato planter was set up and adjusted for sowing after the field area was ready. By collecting performance assessment data, the tractor-drawn potato planter's throttle position was set to 3.0 km/h, 3.5 km/h, and 4.0 km/h. 9 plots was conditioned at three different moisture content of 13.41%, 14.27% and 15.76%. The sowing process was then completed for each randomly chosen plot sample.

Determination of theoretical field capacity, field capacity and field efficiency

According to Sagni (2019) theoretical field capacity, effective field capacity were computed using equation 3.29 and 3.30.

Theoretical field capacity (ha/h) = $\frac{W\ x\ S}{10}$ 2.1

Where: W= Width of planter, (m)

S = Speedof operation, (km/h)

10 = factor calculated as = 10000/1000 = 10

Effective field capacity (ha/h) = $\frac{Area\ of\ plot\ (ha)}{Time\ taken\ (hr)}$ 2.2

According to Sagni (2019) field efficiency was the ratio of the effective field capacity to the theoretical field capacity and was calculated using equation 3.32

Ef = $\frac{FCe}{FCt} \times 100$ 2.3

Where: Ef = field efficiency, (%)

FCe = effective field capacity, (ha/h)

FCt = theoretical field capacity, (ha/h)

Statistical analysis of the result obtained from performance evaluation of the machine

The Statistical package for the social sciences (SPSS) and python 3.10 version was the Statistical tool adopted for analysis of the tractor drawn single row Irish potato planter with fertilizer applicator. The independent variable selected were tractor speed and moisture content of field. The tractor speed was 3.0 km/hr, 3.5 km/hr, and 4.0 km/hr while the moisture content of the land used for the experiment was 13.41%, 14.27%, 15.76% as shown in Table 1. The responses (dependent variables) selected for the experiment were Depth of planting (mm), Average intra row spacing of the planted potato seedling (mm), Number of potato per drop, Quantity of fertilizer per drop (kg), Percentage of missing (%), Percentage of double picking (%), Height of ridge (mm), Depth of fertilizer (mm), Fuel consumption (l/ha), Theoretical field capacity (ha/h), Effective field capacity (ha/h) and Efficiency of the planter (ha/h).

Result and Discussion

Table 1: Parameters and their values for the test

S/N	Factors	Levels
1	Tractor speed (km/h)	3.0
		3.5
		4.0
2	Moisture content of the field (%)	13.41
		14.27
		15.76

Laboratory Test Results

Laboratory performance of the potato planter

The newly developed Tractor Drawn Single Row Irish Potato Planter with Fertilizer Applicator (Busari et al., 2025) performance tests were conducted in a lab before taken the machine to the field. Depth of planting, Intra row spacing of seed, Number of potato per drop, Quantity of fertilizer per drop, Percentage of missing, Percentage of double picking, Height of ridge, Depth of fertilizer, Fuel consumption, Theoretical field capacity, Effective field capacity, etc. was examined at different tractor speed and moisture content. Fertilizer calibration was also completed prior to bringing the machine to the field as shown in plate 2.

Plate 2: Calibration of developed tractor drawn single row Irish potato planter with fertilizer applicator

Result of field performance evaluation of potato planter

The field calibration of the developed Tractor-Drawn Single Row Irish Potato Planter cum Fertilizer Applicator was carried out at the experimental field of national centre of agricultural mechanization (NCAM), Ilorin, Kwara State, Nigeria. The field was well prepared (ploughed and harrowed) with 20 cm depth of cut and 60 cm width of cut and free of surface trash and obstructions. The experimental field for the equipment testing was divided into eighteen experimental plots of 40 m × 10 m, respectively, making it 2 × 3 × 3 design factorial for each of the two independent variables (tractor speed and soil moisture content).

Results of the soil characterizations used for the planter evaluation is shown in Table 2. The following planter parameters were evaluated, namely; the depth of planting, capacity of the seed and fertilizer hopper, Intra row spacing of the planted potato seedling, number of potato seedling per drop, quantity of fertilizer per drop, percentage of missing plant, percentage of double picking, height of ridge, depth of fertilizer placement, planter efficiency at three different working tractor speed of 3.0 km/h, 3.5 km/h and 4.0 km/h as shown in Table 3 while Table 4 shows the performance of the developed tractor-drawn single row Irish Potato planter with fertilizer applicator using moisture content as dependent variable.

Table 2: The soil characterizations used for the field evaluation

S/No.	Parameters	Result
1	Type of soil	sandy loam
2	Soil moisture content	13.41%, 14.27%, 15.76%.
3	Soil bulk density	1.285 gm/cm3
4	Depth of seed bed	22cm
5	Method of sowing	centre to centre
6	Size of each plot	40 m × 10 m
7	Number of plot	18

Result of Statistical Analysis Using Statistical Package for the Social Sciences (SPSS) and Python 3.10

The statistical package for the social sciences (SPSS) and python 3.10 version was used to generate the descriptive analysis as shown in Table 5 and Table 6 and ANOVA analysis as shown in Table 7 and Table 8 respectively to show the impact level of the independent variables on the dependent variables of the tractor drawn single row Irish potato planter with fertilizer applicator by considering two independent variables (at three levels each for tractor speed (3.0 km/h, 3.5 km/h and 4.0 km/h) and moisture content of the field (13.41%, 14.27%, and 15.76%,).

Table 3: Performance evaluation of the developed planter using tractor speed as an independent variable

S/N	TESTING PARAMETERS	TRACTOR SPEEDS (MC = 13.41%)		
		3.0 km/h	3.5 km/h	4.0 km/h
1	Effective working width	765 mm	765 mm	765 mm
2	Depth of planting	133.3 mm	133.3 mm	133.3 mm
3	Average intra row spacing of the planted potato seedling	290.8 mm	291.2 mm	300.4 mm
4	Number of potato per drop	2	1	1
5	Quantity of fertilizer per drop	6.9 g	10.6 g	13.6 g
6	Percentage of missing	2.14%	2.46%	3.58%
7	Percentage of double picking	5.79%	4.12%	4.12%
8	Height of ridge	286.3 mm	285.7 mm	278.9 mm
9	Depth of fertilizer	133.3 mm	133.3 mm	133.3 mm
10	Fuel consumption	9.8 l/ha	10.3 l/ha	10.7 l/ha
11	Theoretical field capacity	0.23 ha/hr	0.26 ha/hr	0.3 ha/hr
12	Effective field capacity	0.171 ha/hr	0.1951 ha/hr	0.230 ha/hr
13	Total time	0.234 hr	0.21 hr	0.174 hr
14	Area of land	0.04 ha(400 m²)	0.04 ha(400 m²)	0.04 ha(400 m²)
15	Efficiency of the planter	74.35%	75.04%	76.67%

Table 4: Performance of developed planter using moisture content as an independent variable.

	TESTING PARAMETERS	MOISTURE CONTENT (3.5 km/h)		
		13.41%,	**14.27%,**	**15.76%.**
1	Effective working width	765 mm	765 mm	765 mm
2	Average depth of planting	133.3 mm	135.1 mm	135.9 mm
3	Average intra row spacing of the planted potato seedling	291.2 mm	291.4 mm	291.8 mm
4	Average number of potato per drop	1	1	1
5	Quantity of fertilizer per drop	10.6 g	10.2 g	9.84 g
6	Percentage of missing	2.46%	2.97%	3.35%
7	Percentage of double picking	4.12%	4.12%	4.12%
8	Height of ridge	285.7 mm	291.3 mm	294.7 mm
9	Depth of fertilizer dropping	133.3 mm	135.1 mm	135.9 mm
10	Fuel consumption	10.3 l/ha	11.2 l/ha	11.98 l/ha
11	Theoretical field capacity	0.26 ha/hr	0.26 ha/hr	0.26 ha/hr
12	Effective field capacity	0.1951 ha/hr	0.1869 ha/hr	0.1802 ha/hr
13	Total time	0.205 hr	0.214 hr	0.222 hr
14	Area of land	0.04 ha(400 m^2)	0.04 ha(400 m^2)	0.04 ha(400 m^2)
15	Efficiency of the planter	75.04%	71.88%	69.31%

Table 5: Descriptive statistics using statistical package for the social sciences (SPSS) using tractor speed as an independent variable

Variable	N	Minimum	Maximum	Mean	Mean	Standard. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Tractor speed (km/h)	3	3.0	4.0	3.500	.2887	.5000
Effective working width (mm)	3	765	765	765.00	.000	.000
Depth of planting (mm)	3	133.30	133.30	133.3000	.00000	.00000
Average intra row spacing of the planted potato seedling (mm)	3	290.80	300.40	294.1333	3.13546	5.43078
Number of potato per drop	3	1	2	1.33	.333	.577
Quantity of fertilizer per drop (g)	3	6.9	13.6	10.367	1.9376	3.3561
Percentage of missing (%)	3	2.14	3.58	2.7267	.43655	.75613
Percentage of double picking (%)	3	4.12	5.79	4.6767	.55667	.96417
Height of ridge (mm)	3	278.90	286.30	283.6333	2.37300	4.11015
Depth of fertilizer (mm)	3	133.30	133.30	133.3000	.00000	.00000
Fuel consumption (l/ha)	3	9.81	10.71	10.2767	.26034	.45092
Theoretical field capacity (ha/hr)	3	.23	.30	.2633	.02028	.03512
Effective field capacity (ha/hr)	3	.17	.23	.1987	.01713	.02966
Total time (hr)	3	.17	.23	.2047	.01867	.03233
Area of land (ha)	3	.04	.04	.0400	.00000	.00000
Efficiency of the planter (%)	3	74.35%	76.67%	75.3533%	0.68781%	1.19132%
Valid N (listwise)	3					

Table 6: Descriptive statistics using statistical package for the social sciences (SPSS) using moisture content as independent variable

Variable	N	Minimum	Maximum	Mean	Mean	Standard. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Moisture content (%)	3	13.41	15.76	14.4800	.68646	1.18899
Effective working width (mm)	3	765	765	765.00	.000	.000
Depth of planting (mm)	3	133.3000	133.3000	133.300000	0E-7	0E-7
Average intra row spacing of the planted potato seedling (mm)	3	291.2000	291.8000	291.466667	.1763834	.3055050
Number of potato per drop	3	1	1	1.00	.000	.000
Quantity of fertilizer per drop (g)	3	9.8000	10.6000	10.200000	.2309401	.4000000
Percentage of missing (%)	3	2.46	3.35	2.9267	.25783	.44658
Percentage of double picking (%)	3	4.12	4.12	4.1200	.00000	.00000
Height of ridge (mm)	3	285.7	294.7	290.567	2.6238	4.5446
Depth of fertilizer (mm)	3	133.3000	135.9000	134.766667	.7688375	1.3316656
Fuel consumption (l/ha)	3	10.31	11.98	11.1667	.48257	.83584
Theoretical field capacity (ha/hr)	3	.26	.26	.2600	.00000	.00000
Effective field capacity (ha/hr)	3	.1800	.1950	.187333	.0043333	.0075056
Total time (hr)	3	.2050	.2220	.213667	.0049103	.0085049
Area of land (ha)	3	.04	.04	.0400	.00000	.00000
Efficiency of the planter (%)	3	69.3100	75.0400	72.076667	1.6570288	2.8700581
Valid N (listwise)	3					

Table 7: ANOVA analysis using python 3.10 using tractor speed as independent variable

Variable	Sum of Squares	df	Mean Square	F-value	p-value	Decision
Effective working width (mm)	4.92E-26	1	4.92E-26	0.146364	0.767382	NS
Depth of planting (mm)	8.35E-28	1	8.35E-28	0.206753	0.728318	NS
Average intra row spacing of the planted potato seedling (mm)	46.08	1	46.08	3.570248	0.309883	NS
Number of potato per drop	0.5	1	0.5	3	0.333333	NS
Quantity of fertilizer per drop (g)	22.445	1	22.445	274.8367	0.038355*	S
Percentage of missing (%)	1.0368	1	1.0368	9.72	0.197596	NS
Percentage of double picking (%)	1.39445	1	1.39445	3	0.333333	NS
Height of ridge (mm)	27.38	1	27.38	4.273673	0.286825	NS
Depth of fertilizer (mm)	8.35E-28	1	8.35E-28	0.206753	0.728318	NS
Fuel consumption (l/ha)	0.405	1	0.405	243	0.040783*	S
Theoretical field capacity (ha/hr)	0.00245	1	0.00245	147	0.052389	NS
Effective field capacity (ha/hr)	0.001741	1	0.001741	89.53189	0.067032	NS
Total time (hr)	0.002048	1	0.002048	48	0.091258	NS
Area of land (ha)	1.04E-34	1	1.04E-34	1.0816	0.487519	NS
Efficiency of the planter (%)	2.6912	1	2.6912	18.27433	0.146292	NS
***. Correlation is significant at the 0.05 level (2-tailed)**						

Table 8: ANOVA analysis using python 3.10 using moisture content as independent variable

Variable	Sum of Squares	df	Mean Square	F-value	p-value	Decision
Effective working width (mm)	4.29E-28	1	4.29E-28	0.001954	0.971875	NS
Depth of planting (mm)	6.22E-29	1	6.22E-29	0.001352	0.976606	NS
Average intra row spacing of the planted potato seedling (mm)	0.186417	1	0.186417	747.2722	0.023278*	S
Quantity of fertilizer per drop (g)	0.312513	1	0.312513	41.74225	0.09776	NS
Percentage of missing (%)	0.376753	1	0.376753	17.03682	0.15132	NS
Percentage of double picking (%)	1.39E-31	1	1.39E-31	0.007989	0.943249	NS
Height of ridge (mm)	37.84337	1	37.84337	10.92697	0.187016	NS
Depth of fertilizer (mm)	3.077916	1	3.077916	6.566213	0.236869	NS
Fuel consumption (l/ha)	1.342945	1	1.342945	24.72197	0.126352	NS
Theoretical field capacity (ha/hr)	5.92E-35	1	5.92E-35	0.001601	0.97454	NS
Effective field capacity (ha/hr)	0.000109	1	0.000109	26.45364	0.122251	NS
Total time (hr)	0.00014	1	0.00014	27.77734	0.119372	NS
Area of land (ha)	1.91E-35	1	1.91E-35	0.00695	0.947048	NS
Efficiency of the planter (%)	15.73869	1	15.73869	21.39059	0.135561	NS
***. Correlation is significant at the 0.05 level (2-tailed)**						

Result Discussion

The result of the performance evaluation of the Tractor Drawn Single Row Irish Potato Planter with Fertilizer Applicator, particularly Depth of planting, Intra row spacing of seed, Number of potato per drop, Quantity of fertilizer per drop, Percentage of missing, Percentage of double picking, Height of ridge, Depth of fertilizer, Fuel consumption, Theoretical field capacity, Effective field capacity, is paramount to understanding its efficiency and effectiveness in agricultural operation.

Comprehensive performance evaluation of the Tractor Drawn Single Row Irish Potato Planter with Fertilizer Applicator was carried out based on the data collected in table 3 and 4 and the following matrices discussed in a logical and structured manner to provide a clear understanding of the Tractor Drawn Single Row Irish Potato Planter with Fertilizer Applicator functionality and effectiveness.

Depth of planting

Moisture content has significant effect on the depth of planting while tractor speed does not have effect on the average depth of planting as shown in Figure 3 and Figure 4.

At the tractor speed of 3 km/hr, 3.5 km/hr and 4 km/hr, it was found that the depth of planting was 133.3 mm, 133.3 mm, 133.3 mm respectively when the moisture content was kept constant at 13.41%. This show that as tractor speed increases, the depth of planting remain uniform. Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia (CASCAPE) (2015) and Sagni, (2019) reported that the depth at which the seed must be planted to enable to get contact with a sufficient moist layer in order to ensure germination is generally 100 mm to 150 mm. the depth of planting gotten at the different tractor speed used for the experiment is within the required range. This shows that the planter can be operated at any of the tractor speed used for testing.

At the moisture content of 13.41%, 14.27%, and 15.76%, it was found that the depth of planting was 133.3 mm, 135.1 mm and 135.9 mm respectively when the tractor speed was kept constant at 3.5 km/hr. This show that as moisture content increases, the depth of planting increases. At higher moisture content the furrow opener go deeper the soil to create a furrow for the sowing of the potato seed. The result was as result of slippage gotten during the forward movement of the tractor with the planter which invariable increases the depth of planting

Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia (CASCAPE) (2015) and Sagni, (2019) reported that the depth at which the seed must be planted to enable to get contact with a sufficient moist layer in order to ensure germination is generally 100mm to 150mm. the depth of planting gotten at the different tractor speed used for the experiment is within the required range of Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia (CASCAPE) (2015) and Sagni, (2019) which reported that the depth at which the seed must be planted to enable to get contact with a sufficient moist layer in order to ensure germination is generally 100mm to 150mm. This shows that the planter can be operated at any of the moisture content used for testing. Anything higher than that can give undesired depth of planting.

Figure 3: Bar chart showing the result of tractor speed against depth of planting (mm)

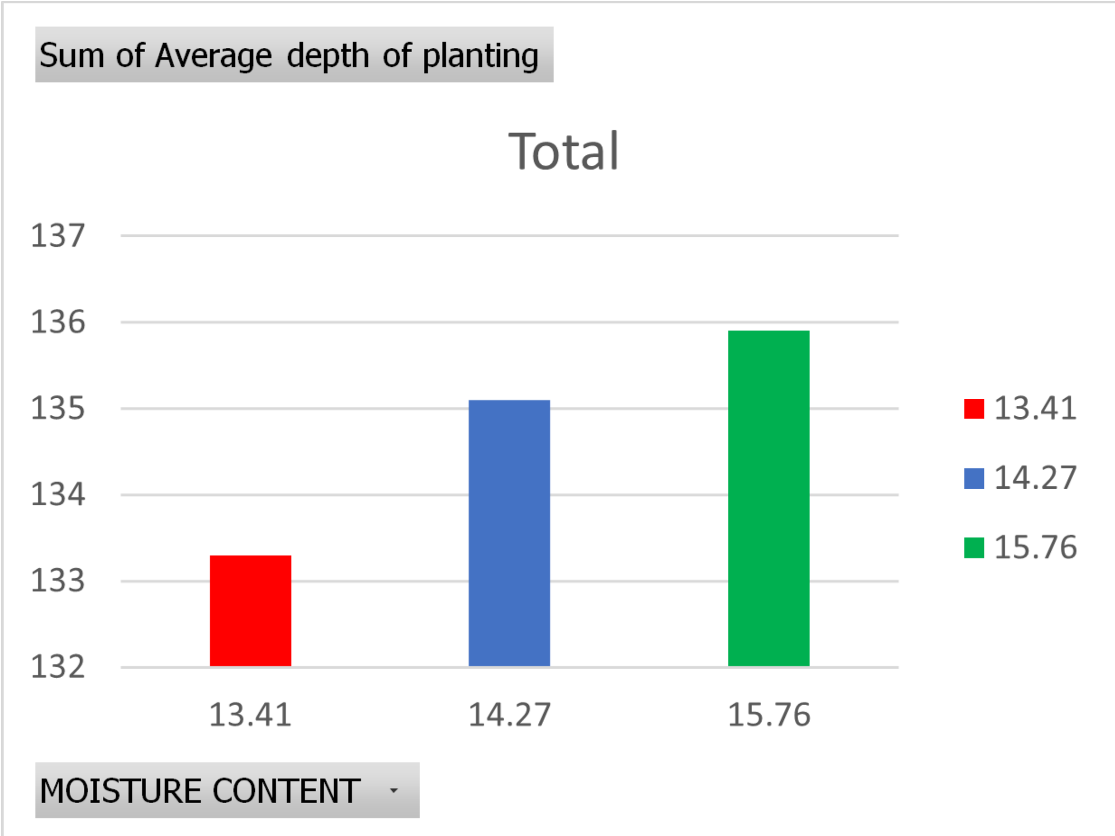

Figure 4: Bar chart showing the result of moisture content against depth of planting

Average intra row spacing of the planted potato seedling

The average intra row spacing of the planted potato seedling of the planter as shown in Figure 5 and Figure 6 indicated that moisture content and tractor speed has significant effect on the Average intra row spacing of the planted potato seedling

At the tractor speed of 3 km/hr, 3.5 km/hr and 4 km/hr. it was found that the Average intra row spacing of the planted potato seedling was 290.8 mm, 291.2 mm, 300.4 mm respectively when the moisture content was kept constant at 13.41%. This show that as tractor speed increases, Average intra row spacing of the planted potato seedling increases. According to Yogesh and Shambhu (2022) the recommended plant to plant distance for potato tuber is 200 mm – 300 mm. The Average intra row spacing of the planted potato seedling gotten at the different tractor speed used for the experiment is within the required range except at 4 km/hr which is above 300 mm. This shows that the planter can be operated at any of the tractor speed not up to 4 km/hr.

At the moisture content of 13.41%, 14.27%, and 15.76%, it was found that the average intra row spacing of the planted potato seedling was 291.2 mm, 291.4 mm and 291.8 mm respectively when the tractor speed was kept constant at 3.5 km/hr. This show that as moisture content increases, intra row spacing of the planted potato seedling increases. The increase in intra row spacing of the planted potato seedling is insignificant. The result was as result of slippage and resistance gotten during the forward movement of the tractor with the planter.

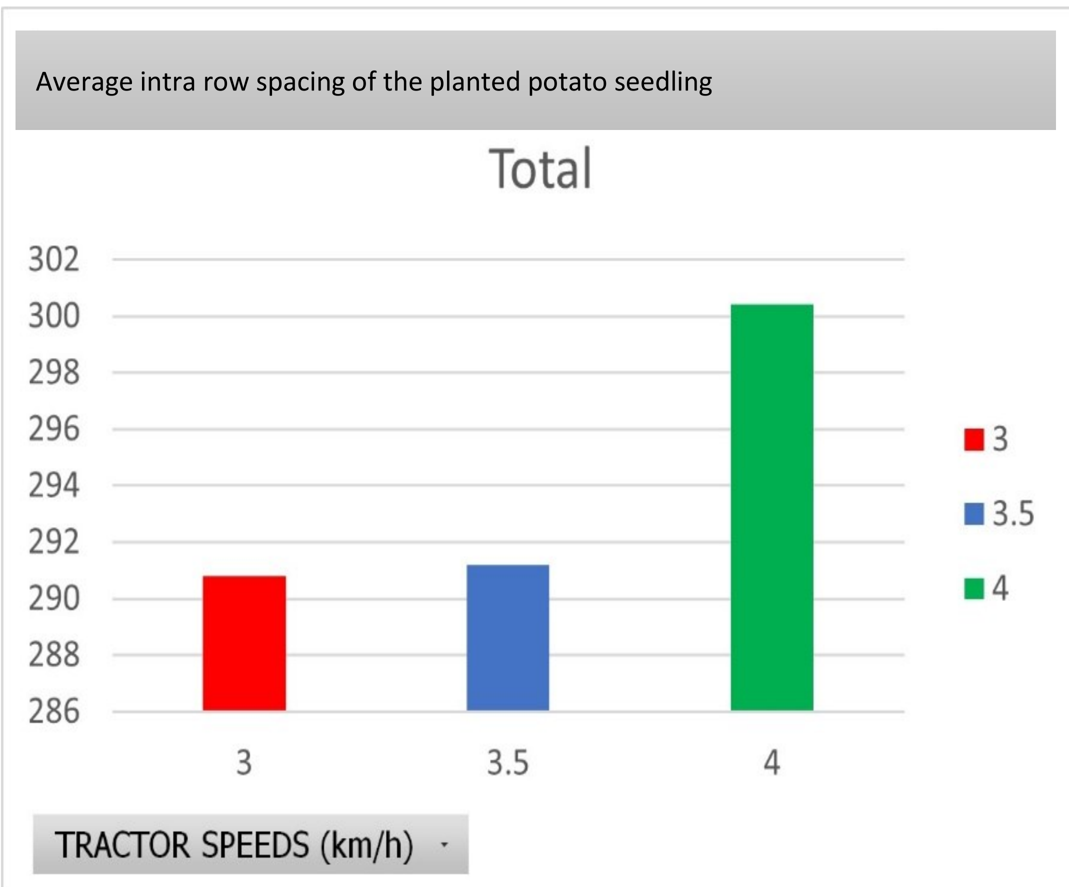

Figure 5: Bar chart showing the result of tractor speed against average intra row spacing of the planted potato seedling

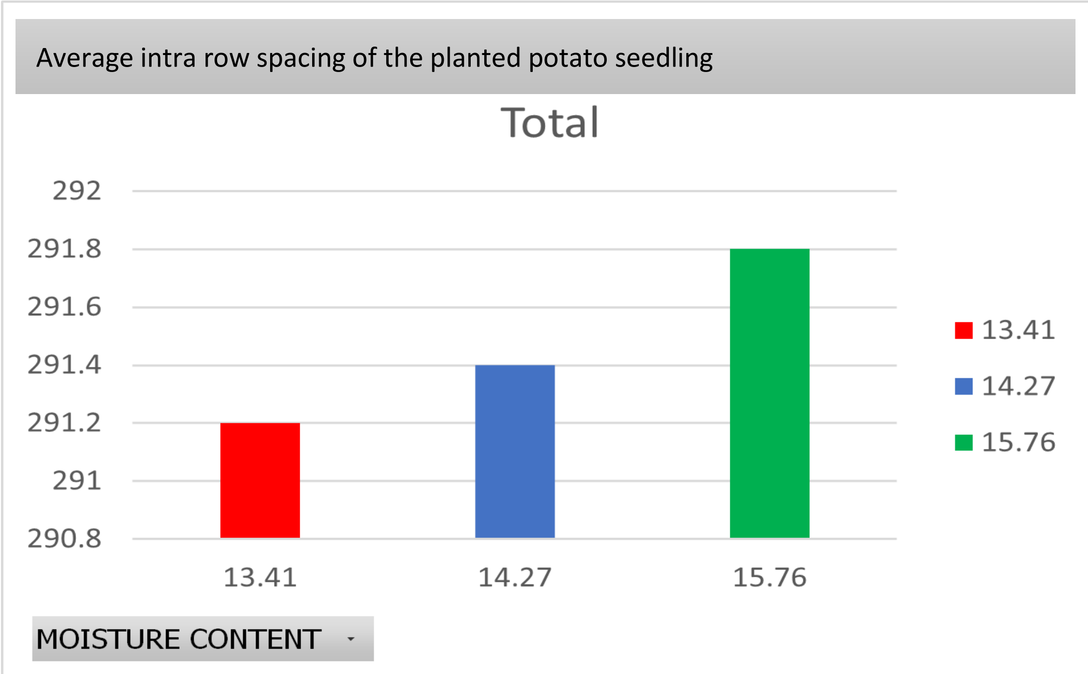

Figure 6: Bar chart showing the result of moisture content against average intra row spacing of the planted potato seedling

Average number of potato per drop

Figure 7 and Figure 8 showed that only tractor speed has significant effect on the average number of potato per drop of the planted potato seedling. The moisture content does not have effect on the average number of potato per drop.

At the tractor speed of 3 km/hr, 3.5 km/hr and 4km/hr, it was found that average number of potato per drop was 2, 1, and 1 respectively when the moisture content was kept constant at 13.41%. This show that as tractor speed increases, average number of potato per drop decreases. The result was as result of vibration of the planter experienced during the forward movement of the tractor with the planter as the speed increases.

At the moisture content of 13.41%, 14.27%, and 15.76%, it was found that the average number of potato per drop was uniform at 1 respectively when the tractor speed was kept constant at 3.5 km/hr. This show that as moisture content has no effect on the average number of potato per drop.

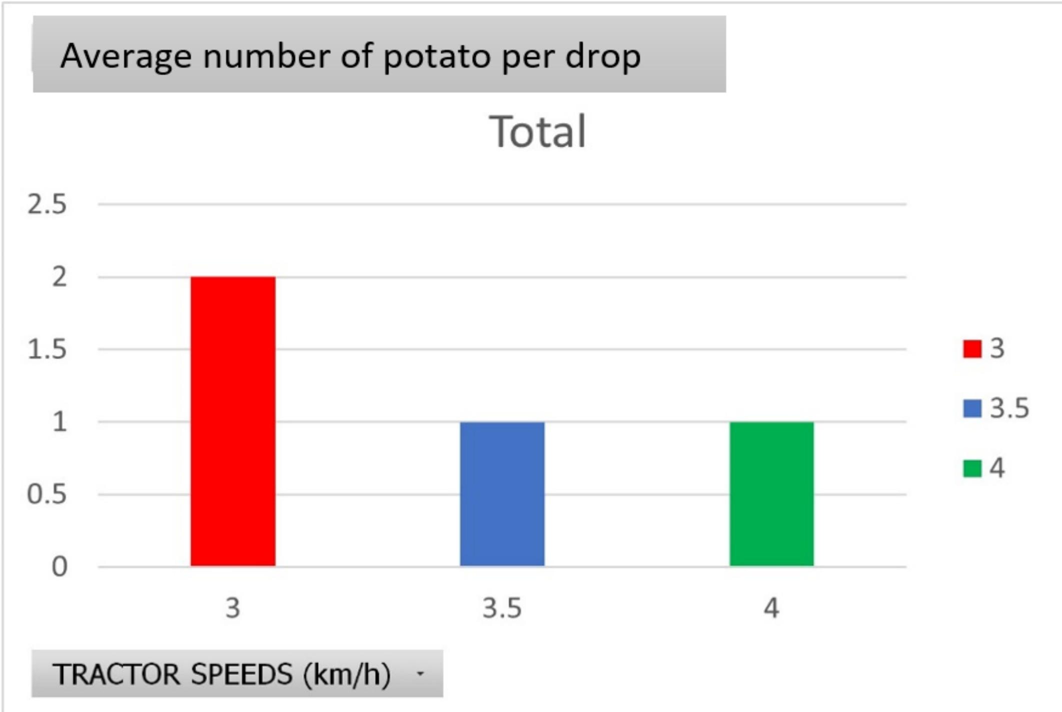

Figure 7: Bar chart showing the result of tractor speed against average number of potato per drop

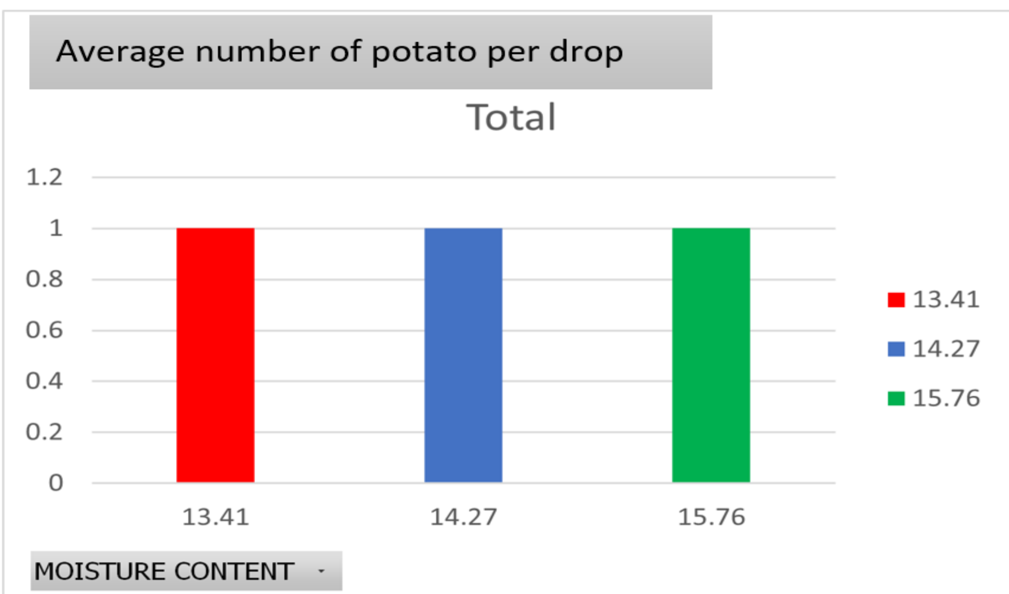

Figure 8: Bar chart showing the result of moisture content against average number of potato per drop

Average quantity of fertilizer per drop

Figure 9 and Figure 10 showed that moisture content and tractor speed has significant effect on the average quantity of fertilizer per drop

At the tractor speed of 3 km/hr, 3.5 km/hr and 4 km/hr, it was found that average quantity of fertilizer per drop was 6.9 g, 10.6 g, 13.6 g respectively when the moisture content was kept constant at 13.41%. This show that as tractor speed increases, the average quantity of fertilizer per drop increases. At the moisture content of 13.41%, 14.27%, and 15.76%, it was found that average quantity of fertilizer per drop was 10.6 g, 10.2 g and 9.84 g respectively when the tractor speed was kept constant at 3.5 km/hr. This show that as moisture content increases, average quantity of fertilizer per drop decreases. The result was as a result of slippage and resistance gotten during the forward movement of the tractor with the planter.

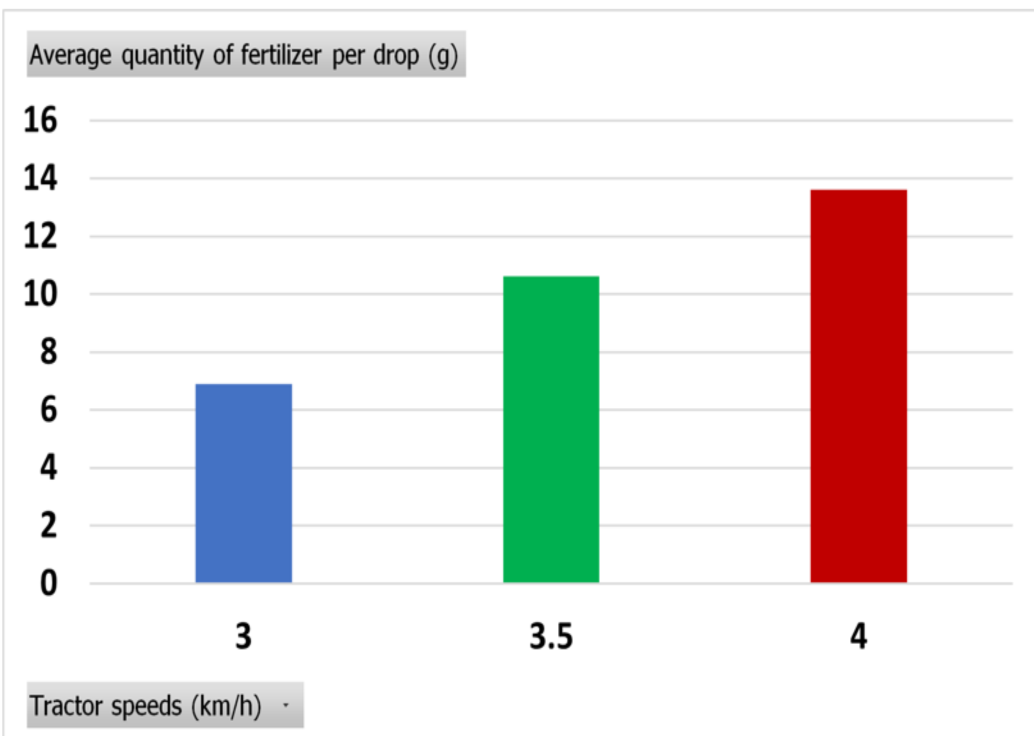

Figure 9: Bar chart showing the result of tractor speed against average quantity of fertilizer per drop

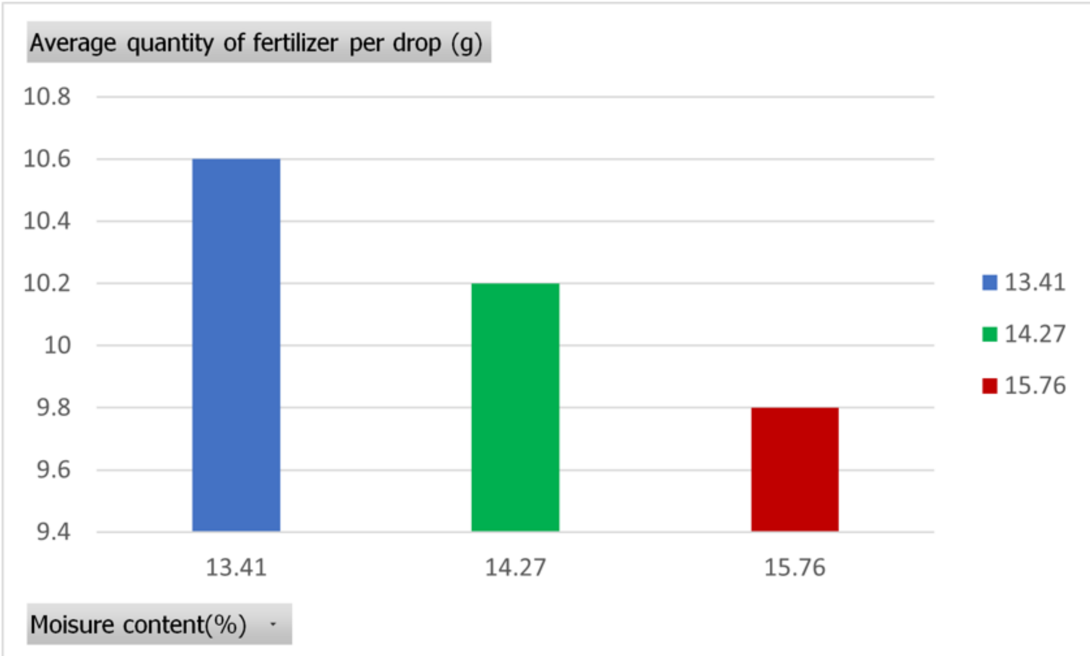

Figure 10: Bar chart showing the result of moisture content against average quantity of fertilizer per drop

Average percentage of missing

Figure 11 and 12 showed that moisture content and tractor speed has significant effect on the average percentage of missing

At the tractor speed of 3 km/hr, 3.5 km/hr and 4 km/hr. it was found that the average percentage of missing was 2.14%, 2.46%, 3.58% respectively when the moisture content was kept constant at 13.41%. This show that as tractor speed increases, the average percentage of missing increases. According to Sagni (2019), reported that seed missing percentage is dependent on the forward speed of the tractor. And it was found that this percentage missing is directly proportional.

At the moisture content of 13.41%, 14.27%, and 15.76%, it was found that the average percentage of missing was 2.46%, 2.97% and 3.35% respectively when the tractor speed was kept constant at 3.5 km/hr. This show that as moisture content increases, average percentage of missing increases. The result was as result of slippage and resistance gotten during the forward movement of the tractor with the planter.

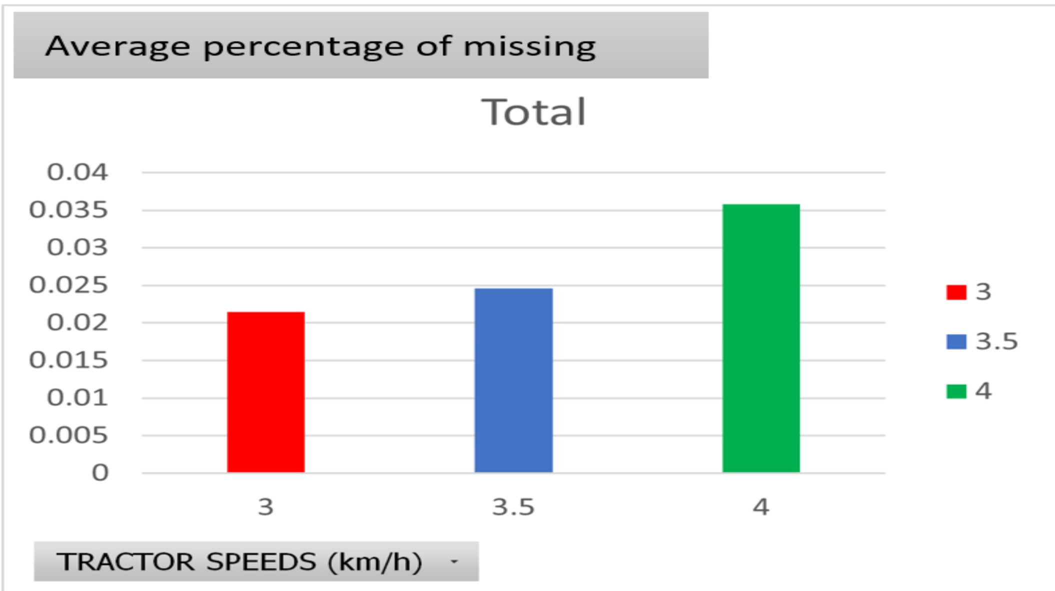

Figure 11: Bar chart showing the result of tractor speed against percentage of missing

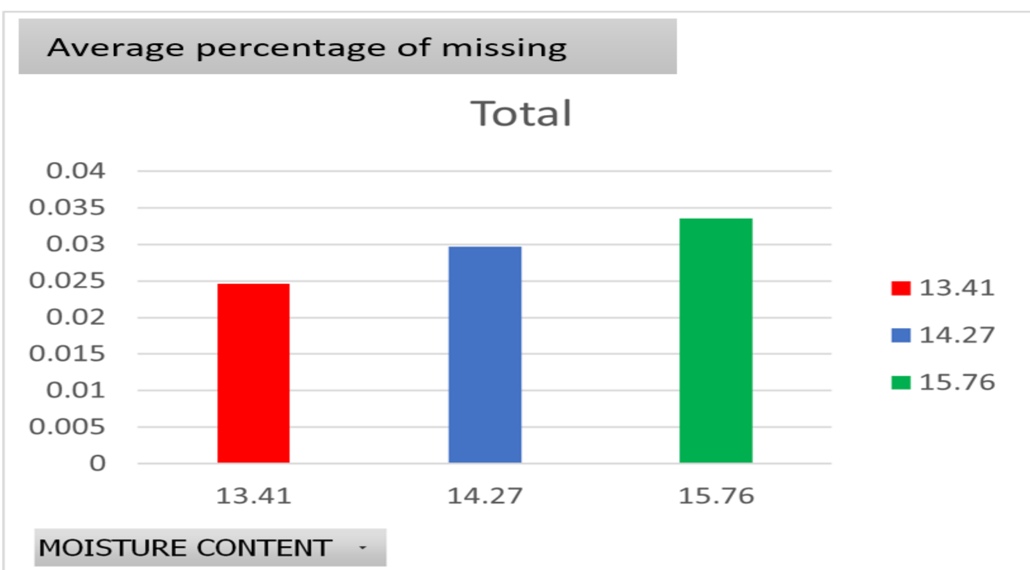

Figure 12: Bar chart showing the result of moisture content against percentage of missing

Percentage of double picking

Figure 13 and Figure 14 showed that only tractor speed has significant effect on the percentage of double picking. The moisture content does not have effect on the percentage of double picking

At the tractor speed of 3 km/hr, 3.5 km/hr and 4 km/hr, it was found that percentage of double picking was 5.79%, 4.12%, and 4.12%respectively when the moisture content was kept constant at 13.41%. This show that as tractor speed increases, percentage of double picking decreases. The result was as result of vibration of the planter experienced during the forward movement of the tractor with the planter as the speed increases.

At the moisture content of 13.41%, 14.27%, and 15.76%, it was found that the percentage of double picking decreases was 4.12%, 4.12% and 4.12% respectively when the tractor speed was kept constant at 3.5 km/hr. This show that moisture content has no effect on the, percentage of double picking.

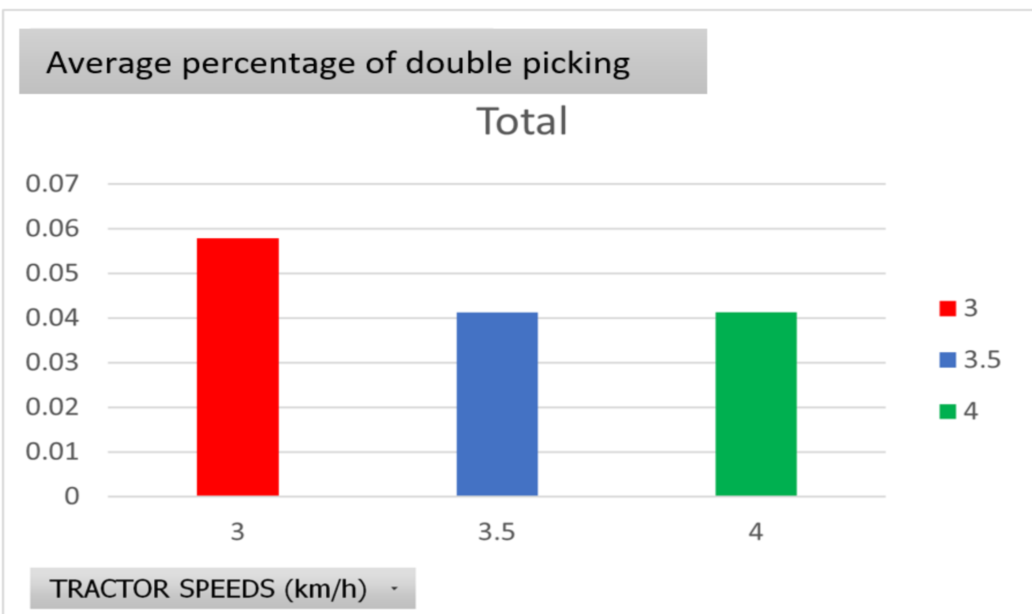

Figure 13: Bar chart showing the result of tractor speed against percentage of double picking

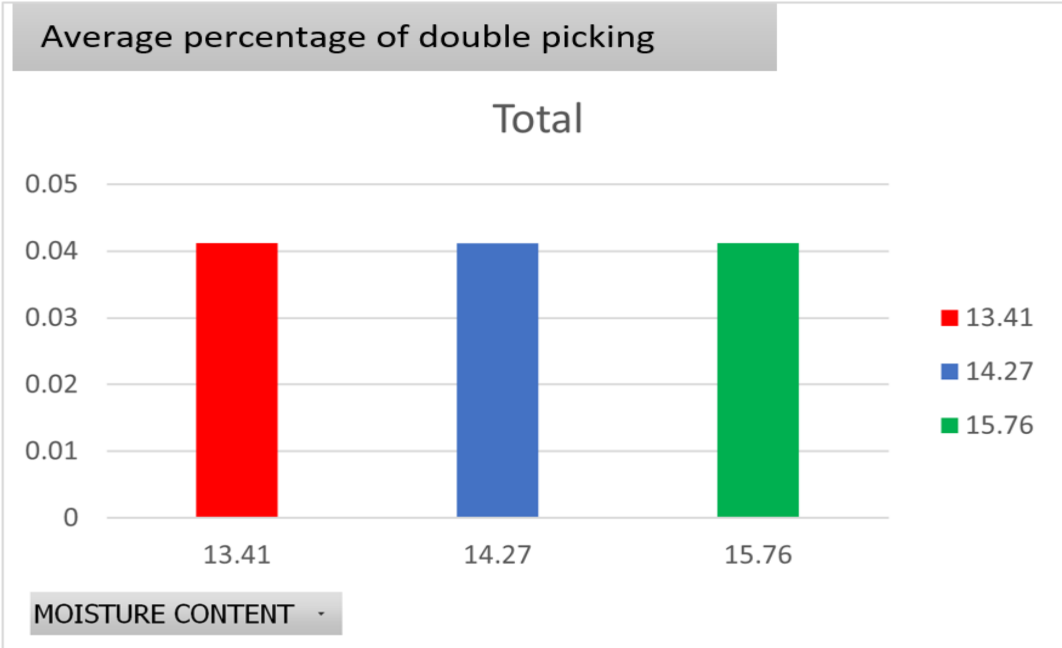

Figure 14: Bar chart showing the result of moisture Content against percentage of double picking

Height of ridge

The average height of ridge of the planter as shown in Figure 15 and Figure 16 showed that moisture content and tractor speed has significant effect on the depth of planting.

At the tractor speed of 3 km/hr, 3.5 km/hr and 4 km/hr, it was found that the height of ridge was 286.3 mm, 285.7 mm, 278.9 mm respectively when the moisture content was kept constant at 13.41%. This show that as tractor speed increases, the average height of ridge decreases. This as a result of heap collapsing when the tractor is on high speed.

At the moisture content of 13.41%, 14.27%, and 15.76%, it was found that the average height of ridge was 285.7 mm, 291.3 mm and 294.7 mm respectively when the tractor speed was kept constant at 3.5 km/hr. This show that as moisture content increases, the average height of ridge increases. At higher moisture content the furrow coverer go deeper the soil to cover the planted potato seedling. The result was as result of slippage gotten during the forward movement of the tractor with the planter which invariable increases the average height of ridge.

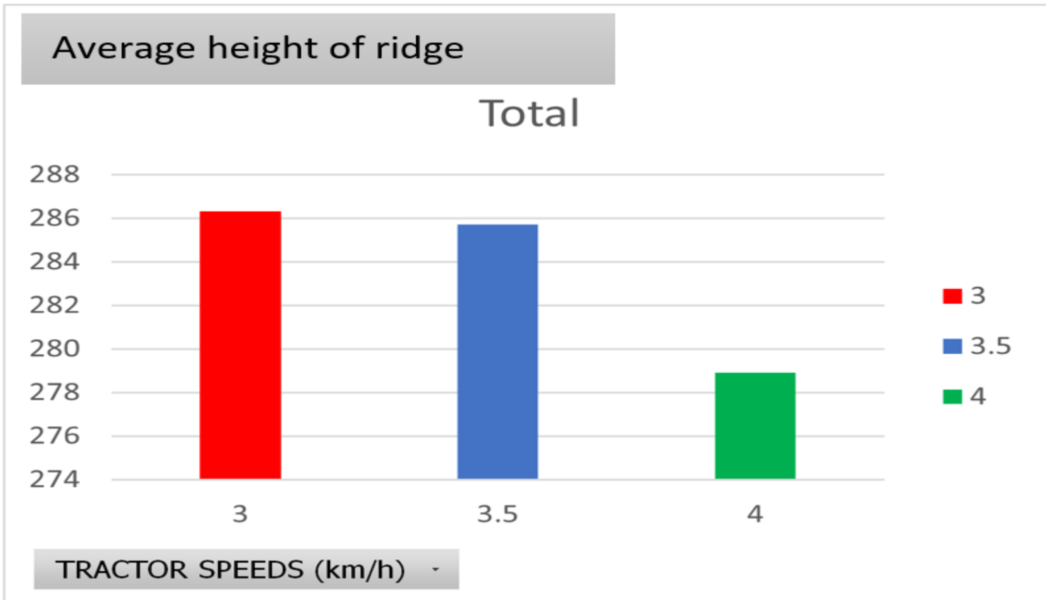

Figure 15: Bar chart showing the result of tractor speed against height of ridge

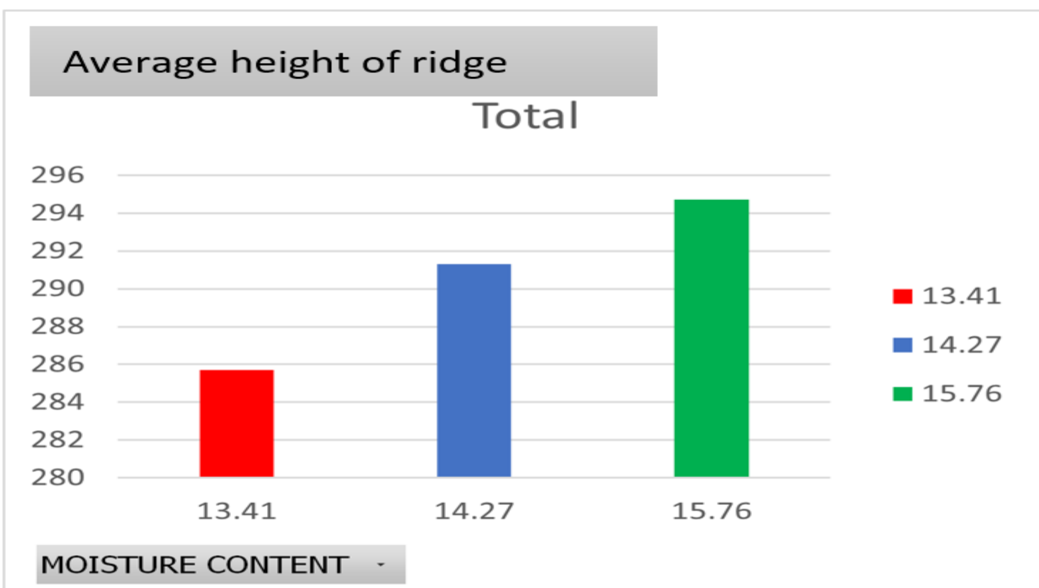

Figure 16: Bar chart showing the result of moisture content against height of ridge

Depth of fertilizer dropping

Figure 17 and Figure 18 showed that moisture content has significant effect on average depth of fertilizer dropping while tractor speed does not have effect on the average depth of fertilizer dropping.

At the tractor speed of 3 km/hr, 3.5 km/hr and 4 km/hr, it was found that the average depth of fertilizer dropping was uniform at 133.3 mm, 133.3 mm and 133.3 mm respectively when the moisture content was kept constant at 13.41%. This show that as tractor speed increases, the average depth of fertilizer dropping remain uniform.

At the moisture content of 13.41%, 14.27%, and 15.76%, it was found that the depth of fertilizer dropping was 133.3 mm, 135.1 mm and 135.9 mm respectively when the tractor speed was kept constant at 3.5 km/hr. This show that as moisture content increases, the depth of planting increases. The result was as result of slippage gotten during the forward movement of the tractor with the planter which invariable increases the depth of planting

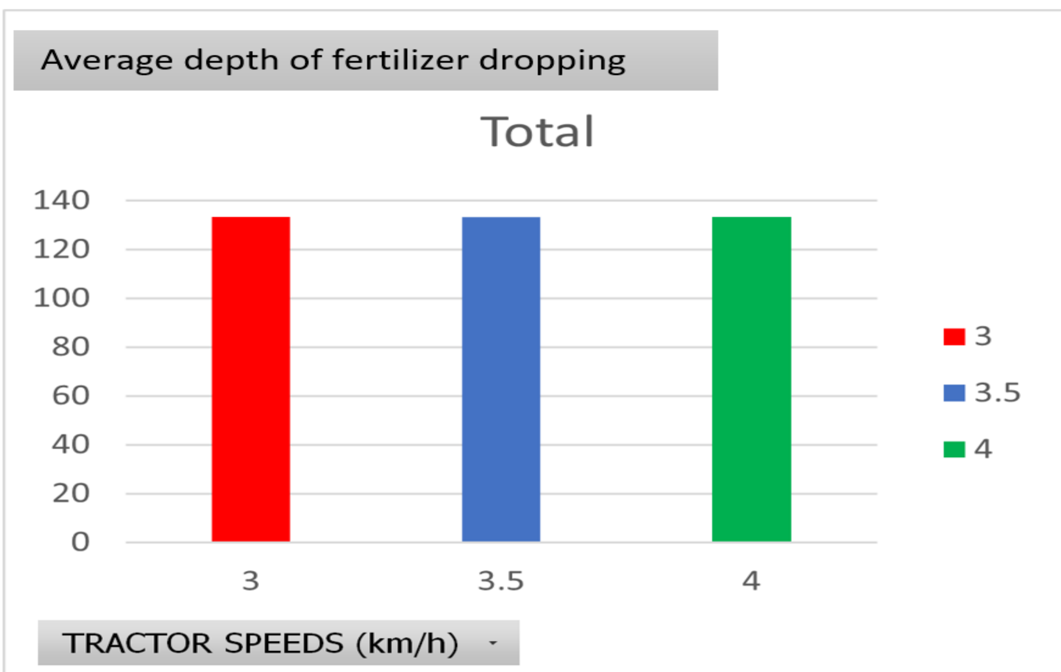

Figure 17: Bar chart showing the result of tractor speed against depth of fertilizer dropping

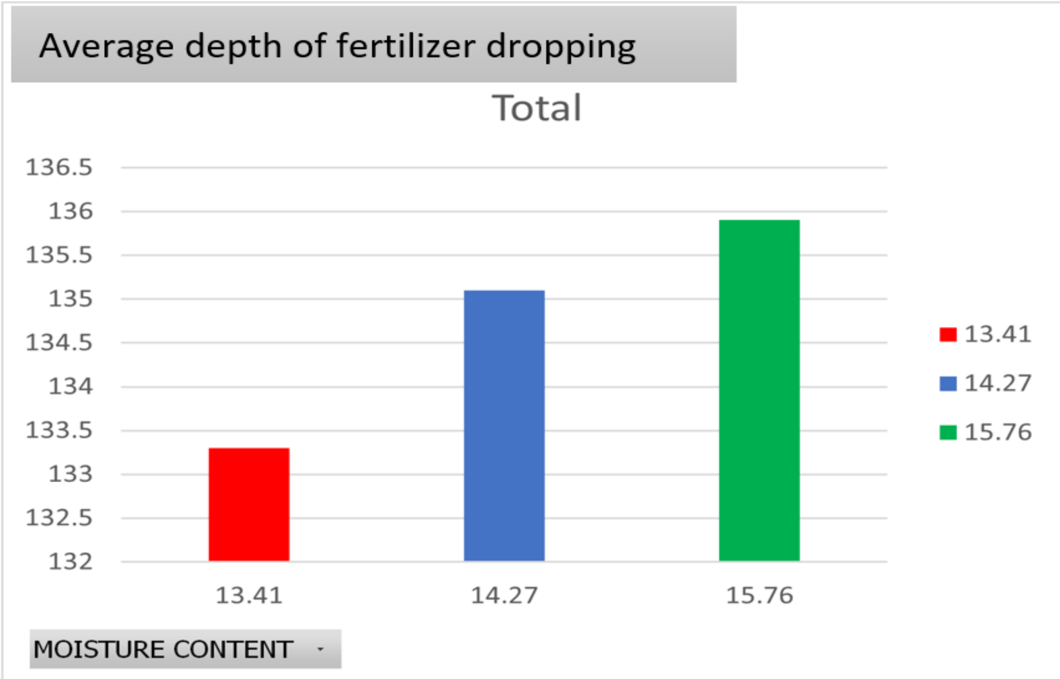

Figure 18: Bar chart showing the result of moisture content against depth of fertilizer dropping

Fuel consumption

The average Fuel consumption of the planter as shown in Figure 19 and Figure 20 showed that moisture content and tractor speed has significant effect on the Average Fuel consumption.

At the tractor speed of 3 km/hr, 3.5 km/hr and 4 km/hr. it was found that the Average Fuel consumption was 9.8 l/ha, 10.3 l/ha and 10.7 l/ha respectively when the moisture content was kept constant at 13.41%. This show that as tractor speed increases, average fuel consumption increases.

At the moisture content of 13.41%, 14.27%, and 15.76%, it was found that the average fuel consumption was 10.3 l/ha, 11.2 l/ha and 11.98 l/ha respectively when the tractor speed was kept constant at 3.5 km/hr. This show that as moisture content increases, average fuel consumption increases. The result was as result of slippage and resistance gotten during the forward movement of the tractor with the planter.

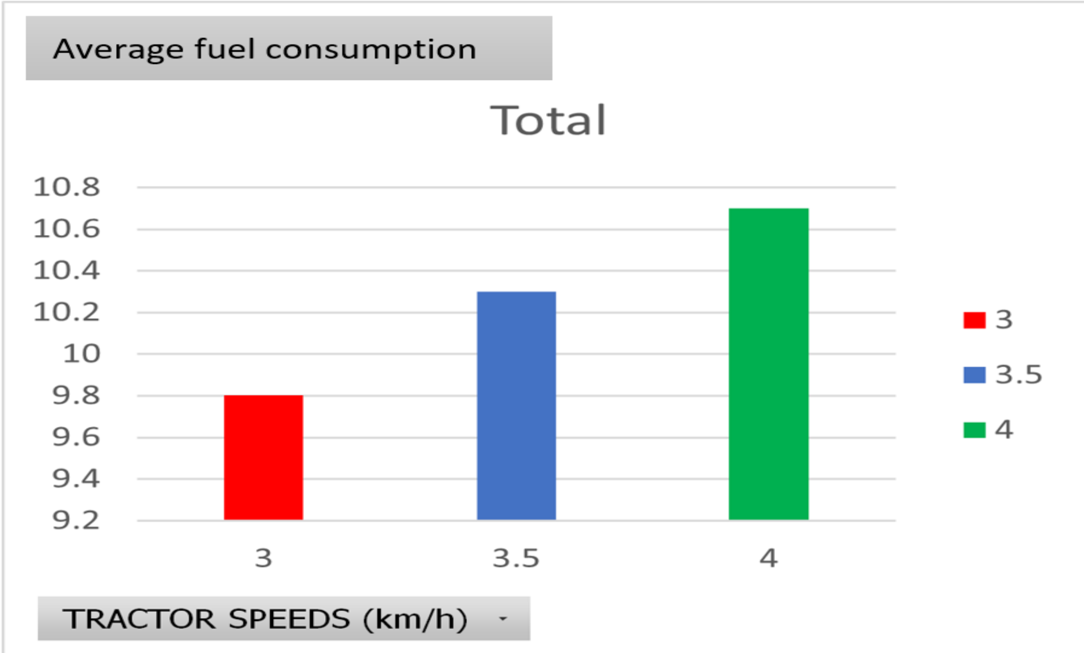

Figure 19: Bar chart showing the result of tractor speed against fuel consumption

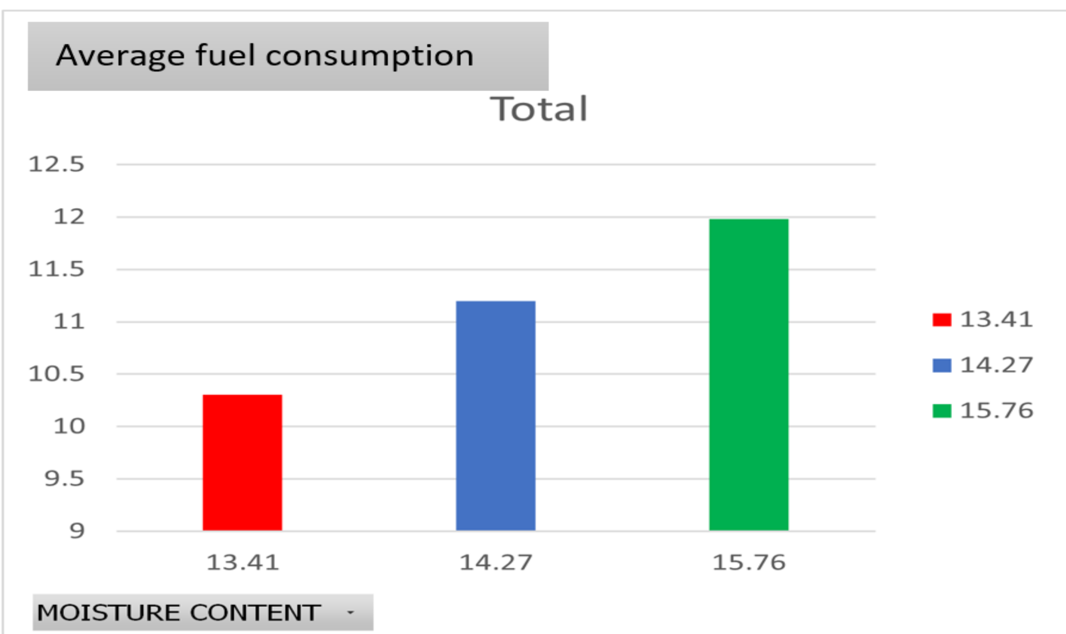

Figure 20: Bar chart showing the result of moisture content against fuel consumption

Theoretical field capacity

The theoretical field capacity (TFC) of the planter as shown in Figure 21 and Figure 22 showed that tractor speed has significant effect on the theoretical field capacity while moisture content does not have effect on the theoretical field capacity.

The theoretical Field Capacity (TFC) which is solely influenced by the full operational width of the machine and the average travel speed within the field. This calculation signifies the utmost potential field capacity achievable when the machine operates at its full width. Equation 3.29 was applied to compute this value and the theoretical Field Capacity (TFC) was estimated to be 0.23 ha/hr, 0.26 ha/hr and 0.3 ha/hr at different tractor speed of 3 km/hr, 3.5 km/hr and 4 km/hr respectively. While at the moisture content of 13.41%, 14.27% and 15.76%, it was estimated to be 0.26 ha/hr, 0.26 ha/hr and 0.26 ha/hr respectively. The result shows as the tractor speed increases, the theoretical field capacity of the planter increases. While the moisture content does not affect the theoretical field capacity at a constant tractor speed.

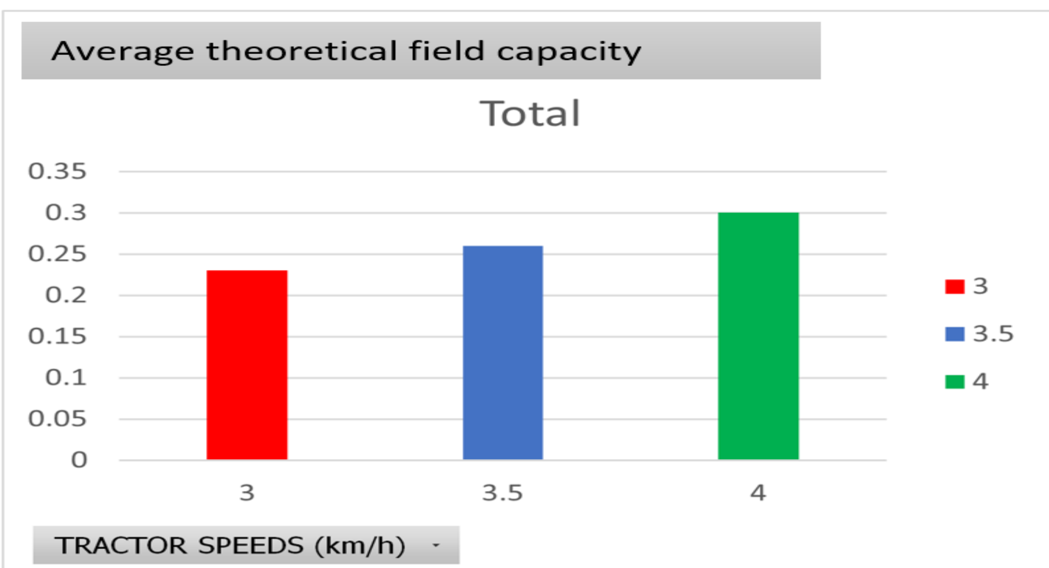

Figure 21: Bar chart showing the result of tractor speed against theoretical field capacity

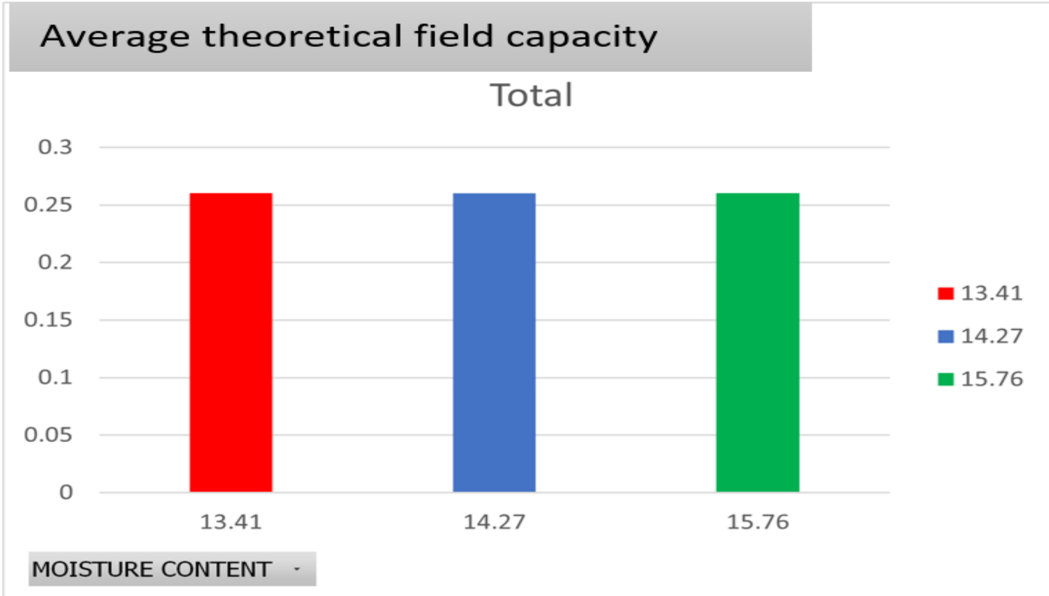

Figure 22: Bar chart showing the result of moisture content against theoretical field capacity

Effective field capacity

The effective field capacity (EFC) of the planter as shown in Figure 23 and Figure 24 showed that moisture content and tractor speed has significant effect on the effective field capacity (EFC)

The effective field capacity (EFC) which Contrasts with theoretical field capacity (TFC), accounted for real-world factors such as obstacles and turning time, offering a more realistic assessment of planter productivity was determined by dividing the total hectare completed by the actual time spent in the field to complete the work measured in hours. Equation 3.30 was applied to compute this value and the effective field capacity (EFC) was estimated to be 0.171 ha/hr, 0.1951 ha/hr and 0.230 ha/hr at different tractor speed of 3 km/hr, 3.5 km/hr and 4 km/hr respectively. While at the moisture content of 13.41%, 14.27% and 15.76%, it was estimated to be 0.1951 ha/hr, 0.1869 ha/hr and 0.1802 ha/hr respectively. The result shows as the tractor speed and moisture content increases, the effective field capacity (EFC) of the planter increases

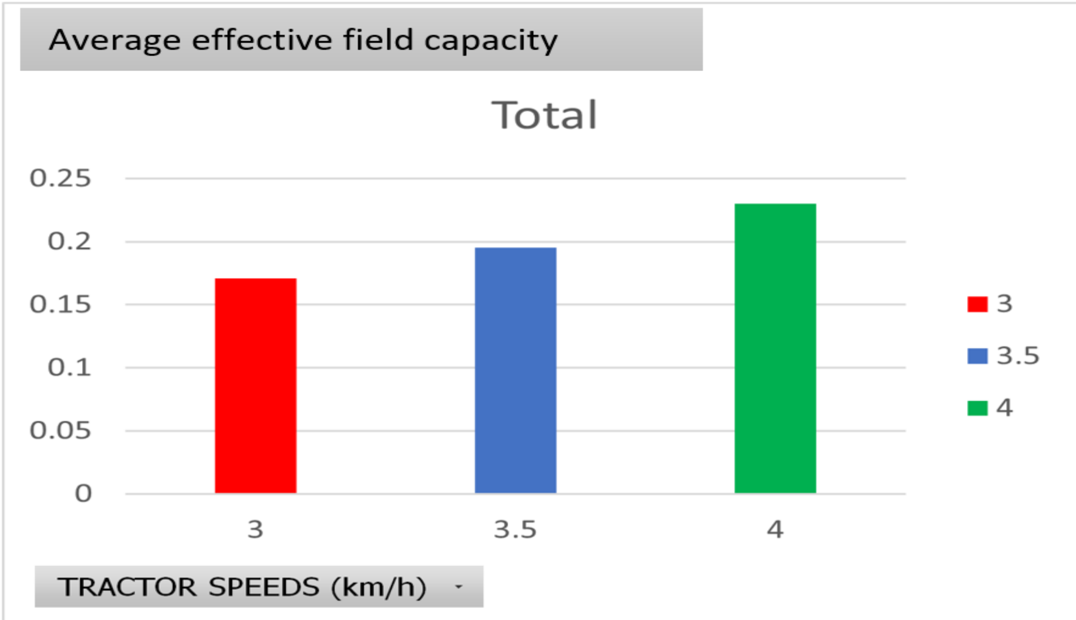

Figure 23: Bar chart showing the result of tractor speed against effective field capacity

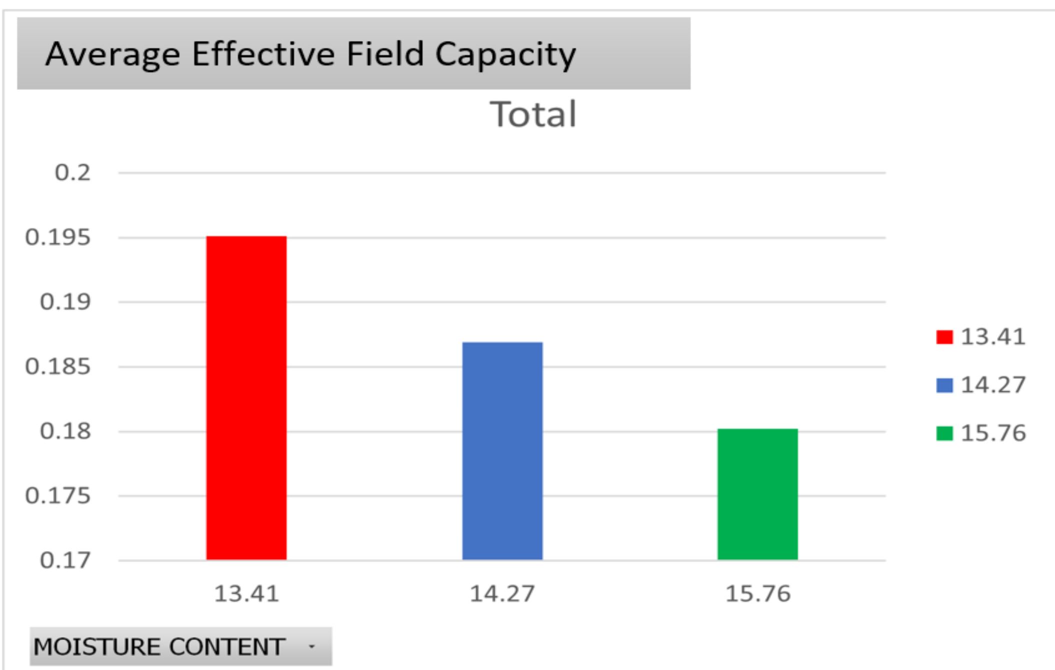

Figure 24: Bar chart showing the result of moisture content against effective field capacity

Efficiency of the planter

The Field Efficiency of the planter as shown in Figure 25 and Figure 26 was established by examining the relationship between the Effective Field Capacity (EFC) and the Theoretical Field Capacity (TFC), which was then expressed as a percentage using Equation 3.31. The Field Efficiency of the planter was estimated to be 74.35%, 75.04% and 76.67% at different tractor speed of 3 km/hr, 3.5 km/hr and 4 km/hr respectively. While at the moisture content of 13.41%, 14.27% and 15.76%, it was estimated to be 75.04%, 71.88% and 69.31% respectively. The result shows that as the tractor speed increases, the field Efficiency of the planter increases. While as the moisture content increases, the field efficiency decreases.

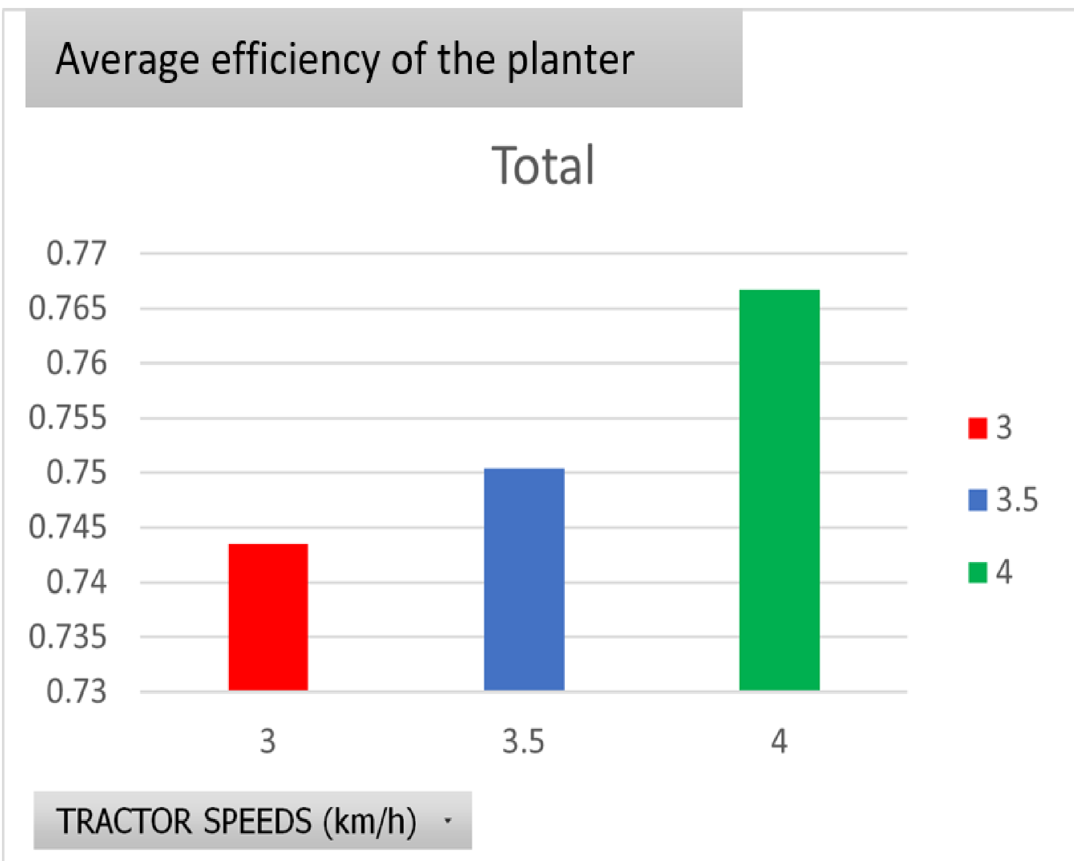

Figure 25: Bar chart showing the result of tractor speed against efficiency of the planter.

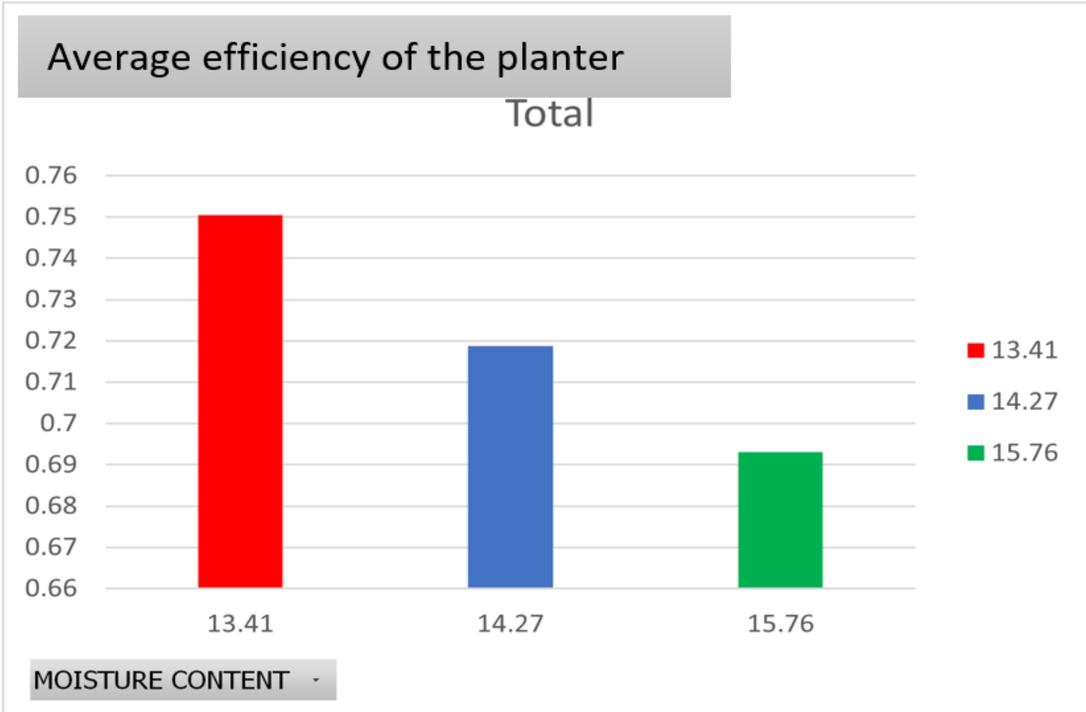

Figure 26: Bar chart showing the result of moisture content against efficiency of the planter.

Statistical analysis of developed tractor drawn single row Irish potato planter with fertilizer applicator result discussion

Table 7 shows the result of ANOVA of the variables with change in tractor speed and constant moisture content. For the depth of planting (mm), the F-value is 0.207 and a p-value is 0.728, showing that speed does not significantly influence the depth of planting. For the average intra-row spacing of the planted potato seedling (mm), the F-value is 3.57 and the p-value is 0.310, showing that speed does not significantly affect intra-row spacing. The number of potatoes per drop has an F-value of 3.0 and a p-value of 0.333, indicating no significant effect of speed. However, the quantity of fertilizer per drop (g) has a very high F-value of 274.84 and a p-value of 0.038, indicating a significant effect of speed on fertilizer quantity, suggesting that changes in speed are strongly associated with variations in fertilizer application.

For the percentage of missing plants, the F-value is 9.72 and the p-value is 0.198, indicating that speed does not significantly affect this variable. The percentage of double picking shows an F-value of 3.0 and a p-value of 0.333, again suggesting no significant effect of speed. The height of ridge (mm) has a modest F-value of 4.27 and a p-value of 0.287, showing no significant influence of speed. For the depth of fertilizer (mm), the F-value is 0.207 and the p-value is 0.728, similarly indicating no significant effect. The fuel consumption (l/ha) shows a very high F-value of 243.0 and a p-value of 0.041, meaning that speed significantly impacts fuel consumption, with speed explaining a significant portion of its variance.

The theoretical field capacity (ha/hr) has a high F-value of 147.0 and a p-value of 0.052, suggesting a near-significant effect of speed, though it does not reach the conventional significance level. The effective field capacity (ha/hr) shows an F-value of 89.53 and a p-value of 0.067, suggesting that while the F-statistic is large, speed does not have a statistically significant effect at the 5% level. The total time (hr) has an F-value of 48.0 and a p-value of 0.091, indicating no significant impact of speed. The area of land (ha) has a very low F-value of 1.08 and a p-value of 0.488, suggesting no significant effect of speed. Lastly, the efficiency of the planter (%) shows an F-value of 18.27 and a p-value of 0.146, meaning that while the F-statistic is relatively high, speed does not significantly impact planter efficiency.

Table 8 shows the result of ANOVA of the variables with change in moisture content of the field and constant speed. For the depth of planting (mm), the F-value is 0.001352 and the p-value is 0.976606, showing that moisture content has no significant effect on the depth of planting. In the case of the average intra-row spacing of the planted potato seedling (mm), the F-value is 747.27 and the p-value is 0.023278, indicating that moisture content has a statistically significant effect. For the quantity of fertilizer per drop (g), the F-value is 41.74 and the p-value is 0.09776, suggesting that while the F-statistic is high, moisture content does not significantly affect the quantity of fertilizer per drop.

For the percentage of missing plants, the F-value is 17.04 and the p-value is 0.15132, meaning moisture content is not statistically significant. The percentage of double picking shows an F-value of 0.007989 and a p-value of 0.943249, indicating no significant effect. The height of ridge (mm) has an F-value of 10.93 and a p-value of 0.187016, showing moisture content does not significantly impact the ridge height. For the depth of fertilizer (mm), the F-value is 6.57 and the p-value is 0.236869, also indicating no significant impact. The fuel consumption (l/ha) has an F-value of 24.72 and a p-value of 0.126352, showing that although the F-statistic is relatively high, moisture content does not significantly affect fuel consumption.

The theoretical field capacity (ha/hr) has an F-value of 0.001601 and a p-value of 0.97454, indicating no significant effect. For the effective field capacity (ha/hr), the F-value is 26.45 and the p-value is 0.122251, meaning moisture content does not significantly explain its variance. The total time (hr) has an F-value of 27.78 and a p-value of 0.119372, again showing no significant relationship with moisture content. The area of land (ha) shows an F-value of 0.00695 and a p-value of 0.947048, indicating no significant effect. Lastly, the efficiency of the planter (%) has an F-value of 21.39 and a p-value of 0.135561, suggesting that although the F-statistic is large, moisture content does not significantly explain the variation in planter efficiency.

Table 5 shows the result of descriptive statistics analysis of the variables with change in tractor speed and constant moisture content. The depth of planting was constant at 133.3 mm. The average intra-row spacing of planted potato seedlings varied between 290.8 and 300.4 mm, with a mean of 294.13 mm and a standard deviation of 5.43 mm. The number of potatoes per drop ranged from 1 to 2, averaging 1.33. The quantity of fertilizer per drop ranged from 6.9 to 13.6 g, with a mean of 10.37 g and a standard deviation of 3.36 g.

The percentage of missing plants ranged from 2.14% to 3.58%, averaging 2.73%, while the percentage of double picking varied from 4.12% to 5.79%, with a mean of 4.68%. The height of the ridge ranged from 278.9 mm to 286.3 mm, with a mean of 283.63 mm. The depth of fertilizer application remained constant at 133.3 mm. Fuel consumption ranged between 9.81 and 10.71 l/ha, with a mean of 10.28 l/ha and a standard deviation of 0.45 l/ha.

Theoretical field capacity ranged from 0.23 to 0.30 ha/hr, with a mean of 0.263 ha/hr, while effective field capacity ranged from 0.17 to 0.23 ha/hr, with a mean of 0.199 ha/hr. The total time ranged from 0.17 to 0.23 hours, with a mean of 0.2047 hours. The area of land remained constant at 0.04 ha. Lastly, the efficiency of the planter ranged from 74.35% to 76.67%, with a mean of 75.35% and a standard deviation of 1.19%.

Table 6 shows the result of descriptive statistics analysis of the variables with change in moisture content and constant tractor speed. The depth of planting was consistently 133.3 mm. The average intra-row spacing of planted potato seedlings varied slightly between 291.2 mm and 291.8 mm, with a mean of 291.47 mm and a standard deviation of 0.31 mm. The number of potatoes per drop remained constant at 1.00.

The quantity of fertilizer per drop ranged from 9.8 g to 10.6 g, with a mean of 10.20 g and a standard deviation of 0.40 g. The percentage of missing plants varied from 2.46% to 3.35%, with an average of 2.93%, while the percentage of double picking remained constant at 4.12%. The height of the ridge ranged from 285.7 mm to 294.7 mm, with a mean of 290.57 mm and a standard deviation of 4.54 mm. The depth of fertilizer application varied between 133.3 mm and 135.9 mm, averaging 134.77 mm.

Fuel consumption ranged from 10.31 l/ha to 11.98 l/ha, with a mean of 11.17 l/ha and a standard deviation of 0.84 l/ha. Theoretical field capacity remained constant at 0.26 ha/hr, while effective field capacity ranged from 0.18 to 0.195 ha/hr, with a mean of 0.187 ha/hr. The total time ranged from 0.205 to 0.222 hours, averaging 0.214 hours. The area of land was constant at 0.04 ha, and the efficiency of the planter ranged from 69.31% to 75.04%, with an average efficiency of 72.08% and a standard deviation of 2.87%.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The field test of the potato planter was operated with 3.0 km/h, 3.5 km/h and 4 km/h speed at a different moisture content of 13.41%, 14.27% and 15.76%.

The following conclusions were deduced from the evaluation of the machine:

1. The highest efficiency of the planter was obtained when the tractor speed is high at 4 km/h as 76.67% and low moiture content of 13.41% as 75.04%.
2. The study showed that independent variables (speed of tractor and moisture content of the field) have significant effect on most of the responses used for the test. However, the reposnses that are more influenced by the speed of the trctor include average intral row spacing of the planted potato seedling, average number of potato per drop, quantity of fertilizer per drop, percentage of missing, percentage of double picking, height of ridge, fuel consumption, efficiency of the planter while those responses that are more influenced by the moisture content of the field include average depth of planting, average intra row spacing of the planted potato seedling, quantity of fertilizer per drop, percentage of missing, height of ridge, depth of fertilizer dropping, fuel consumption, efficiency of the planter.
3. The ANOVA statistical analysis of the planter result showed that quantity of fertilizer per drop and fuel consumption have significant effect on the planter at different tractor speed of 3.0 km/h, 3.5 km/h and 4 km/h at a constant moisture content of 14.27% while only average intra row spacing of the planted potato seedling has significant effect on the planter at different moisture content of 13.41%, 14.27% and 15.76% at a constant tractor speed of 4.5 km/hr.
4. The test run and statistical analysis done on the implement indicated good performance and high reliability. This is because of its simplicity and ease of disassembly for repair or replacement of parts.

RECOMMENDATIONS

Based on the results obtained from the performance evaluation carried out on the planter, it is recommended that the furrow opener need to be redesigned to spring loaded type to suit different topography of the farm and work effectively when it encounter any obstruction, future designs could focus on expanding the planter to handle multiple rows, which would further increase efficiency which in return increase productivity and benefit larger-scale operations.

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