International Journal of Pure and Applied Researches http://ijopaar.com; 2021 Vol. 2(1); pp. 01-14, ISSN: 2455-474X

Development and Testing of Single Row Animal Drawn Groundnut Planter

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Abstract

This project was undertaken to develop and test the performance of a planter that capable of planting groundnut at predetermined spacing and depths. The planter, consisting of a frame, seed hopper, seed metering devices, seed tube/spout, adjustable furrow openers and covering device, and drive wheels. Physical properties of seeds involved in the study were investigated to optimize the design of planter's components. Field testing was conducted in two locations namely at Boko and Erer substations of different soil types. In this experiment, two types of sowing methods were used, the animal drawn planter and manual sowing. The animal drawn planter is simple in design and easily operated and can be maintained by farmers. Randomize complete plot with four replications were used with plot size of 20 x3m^2. The data was analyzed by two sample t-test statistical analysis of mean values, t- values and probability levels at 95% confidence interval. The parameters observed were sowing time, depth of sowing, speed of sowing, row spacing and plant spacing. The results showed that there were highly significant differences between the animal drawn groundnut planter and manual for a parameter such as time for sowing, depth of sowing and speed of sowing. The animal drawn planter saves sowing time and labor requirements when compared to manual sowing. It also gave better average seeding rate for planter 82 kg/ha than that of manual treatment (93 kg/ha). Effective field capacity and field efficiency of the planter was 0.08 ha/hr. and 73% respectively. Hence, it is recommended that this efficient planter will be upgrade the planting rows in future design in multi row planter for increasing planting capacity per unit time.

Keywords: Ground nut, Animal drawn, groundnut planter, single row planter.

1. Introduction

Planting is an art of placing seeds in the soil to have good germination. Planting began with the use of hands and later the use of stones, hand tools and mechanized form of planting (Yasir*et al*., 2012). Manual methods of planting resulted in low seed placement, low spacing efficiency, and health issues for the farmer considering the size of the farm land (Kumar *et al.*, 2015; Soyoye*et al.*, 2016). Seed planting machine is a device which helps in the sowing of seeds in a desired position, thereby assisting the farmers in saving time and reducing cost.

The basic objective of sowing operation is to bear the seed, put the seed in rows at desired depth and seed to seed spacing, cover the seeds with soil and provide proper compaction over the seed (Soyoye*et al.*, 2016). However, in fabricating the form of this mechanized planting equipment, some properties of the plant which is to be planted must be determined in order to accurately specify the design considerations (Jouki and Khazaei, 2012). The physical properties such as size, shape, axial dimensions, roundness and sphericity helps to determine the maximum size of the cup in the seed plate, the weight help in the material selection for the frame of the planter, the bulk density and moisture content helps to know the interaction between the seed and the material used for the hopper of the planter at maximum heat level (Jayan and Kumar, 2004).

Throughout the developing world and many developed countries, animals' traction is an inseparable part of agricultural practice, particularly in sub-Saharan Africa, the use of animal power for agriculture and rural transport is increasing every year (FAO, 2000).

In Ethiopia, development and adoption of improved agricultural technologies including farm implements and machinery has been a long term concern of agricultural experts, policy makers, and agricultural researchers and many others linked to the sector. However, evidence indicates that adoption rate of modern agricultural technologies in the country is very low (Kebede et al.1990).

The adoption of agricultural innovation in developing countries attracts considerable attention because it can provide the basis for increasing production and income. Small scale farmers' decisions to adopt or reject agricultural technologies depend on their objectives and constraints as well as cost and benefit accruing to it (Million and Belay, 2004). Therefore, farmers will adopt only technologies that suit their needs. In Ethiopia, about 69% of smallholder farmers own farmlands less than or equal to one hectare in size and average grain yield for various crop is less than one metric ton per hectare (CSA, 2013). It is very difficult for these farmers to own and operate costly agricultural machinery and equipment's that can establish the optimum plant population. Hence, in most part of the country, manual broadcasting method of sowing is still in use. This method of crop establishment adversely affects the seed requirement and production per unit area.

Animal drawn planting technology is particularly important to the traditional rain-fed farming in Ethiopia and to neighboring countries as many experts count. The technology constitute one of the major solutions to low productivity and the expansion of the production area associated with traditional hand tools used by the rural farmers (Mekki and Mohamed 2011), so as to solve the food security problem of the rural farmers. According to Philip *et.al* (1988), the use of animal drawn planting technology for agricultural practices is potentially useful and is also an appropriate means of improving the efficiency of the traditional farming system. Animal traction would increase crop yield through better and timely cultivation and planting. It would reduce labor requirement per unit area and allow an increase in the area under cultivation. Therefore the project was conducted with the objectives of developing and testing of animal drawn groundnut planter and evaluating its performance in the field.

2. **Materials and Methods**

2.1**Description of experimental site**

Development and performance evaluation of the planter were done at FARC and tested at fades district on station and Babile district on Erer substation. Fadis station is located at the distance of 24 km away from Harar city in the south direction and it is located at the latitude of 9^0 07' 00'' N and longitude of 42^0 04' 00'' east, in middle and lowlands areas and at average altitude of 1702 meter above sea level with a prevalence of low lands. Babile was located at 9^0 10' 41.5'' north of latitude, $42^{'0}$ 15' 27.3'' east longitude and elevation 1274 meter above sea level

2.2 Materials

Groundnut seeds were used to evaluate performance of the planter that developed at FARC metal work shop. Hence, the planting machine was designed to plant groundnut seeds.

2.3 Methods

2.4 Experimental treatments

The experimental land was well prepared for assessment of animal drawn planter, two treatments were used which are described below.

Animal drawn planter:(required two human labor, one for guiding the animal and other to control the movement in the row)

Manual:Required four human labors, two for making the rows by hoe, one sowing the seed and one for covering seeds by soil.

2.5 Experimental site

The experiments were designed and conducted in the sandy loam and sandy clay loam soils. The experimental land size was 12×20 m^2 and divided in to four equal plots and accordingly for manual. Randomize complete plot with four replications were used with plot size of 20 x3 m^2. Local seed was selected and examined using the recommended cultural practices in the area.

2.6 Seeding rate and plant population

The optimum plant population per hectare can be calculated from recommended plant spacing (row spacing and distance between plants) for a given crop, as follows: -

$$Pp. = \frac{10{,}000m^2}{{p_s}^2} \quad (1)$$

Where: P_p= plant population per haP_s= area per plant (m^2)

2.7Determination of physical properties of seed

The mean sizes of the seed, used in the study, were determined by randomly selecting 100 seeds from the representative samples and measuring their three principal diameters using digital caliper. The larger, intermediate and minor diameters of the seeds were designated as length, width and thickness, respectively. The mean sizes of the seeds were determined as geometric mean diameters. The volume and sphericity of individual seed was calculated using the measured length, width and thickness of the seeds and equations given below (Davies, 2009).

$$D_g = \sqrt[3]{L * W * T} \quad (2)$$

$$V = \frac{\pi}{6}(L \times W \times T) \quad (3)$$

$$S_m = \frac{\sqrt[3]{L \times W \times T}}{L} \quad (4)$$

Where: D_g =Mean geometric diameter (mm), L= Mean length (mm); W= Mean width (mm); T = Mean thickness (mm); V = Mean volume (mm^3): S_m = Mean seed sphericity

2.8 Design and material selection of the planter components

The planter consists of frame, seed hoppers, metering mechanisms, furrow openers, seed covering devices, handles, drive wheels and rear wheel that used to press the soil. To achieve the best performance of planter, proper design and material selection of different components are important factor which optimize and suit planting mechanism at appropriate place as well as minimize seed damage.

Main frame design: The frame (Figure 1), which is the skeleton of the planter, supports all other component parts of the machine. The two design factors considered in the determination of the material required for the frame were weight and strength. In this design, mild steel angle iron of 30 mm x 30 mm and 3 mm was used to give the required strength and rigidity, so that it can with stand all types of load during operation. The frame was provided with holes on both ends for shaft bearings and support of drive/ground wheels that power to operate the metering devices during laboratory and field performance evaluations.

Connections between the frame and other component parts of the planter were made using appropriate sizes of bolts and nut.

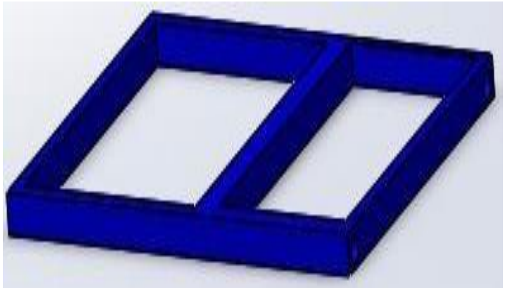

Figure 1. 3D of main frame design

2.8.1Hopper design

Hopper was designed to store and feed metering devices in vertical direction. The material used for the construction was sheet metal with thickness of 1.5 mm, which is readily available in the market and relatively affordable. The hopper has a shape of inverted frustum of rectangular pyramid truncated with rectangle bottom (5 cm x 20 cm) having a height of 22 cm) and rectangle top (20 cm x 30 cm). The bulk density of groundnut seed was 479.28 kg m^{-3}, and angle of repose 28^0 according to (Davies, 2009). The average seeding rate of groundnut is 84.5 kg ha^{-1}. Hence based on these seeding rates, the volume of the hopper was estimated using equation given by Olaoye and Bolufawi, (2001);

$$V=\frac{Sr}{nBD} \quad (5)$$

Where: - S_r = seeding rate (kg ha^{-1}); n = number of refilling per hectare BD = bulk density of the seeds (kg m^{-3})

$$\text{Volume of seed} = \frac{84.5}{20 \times 479.28} = 8.8 \times 10^{-3}\ m^3$$

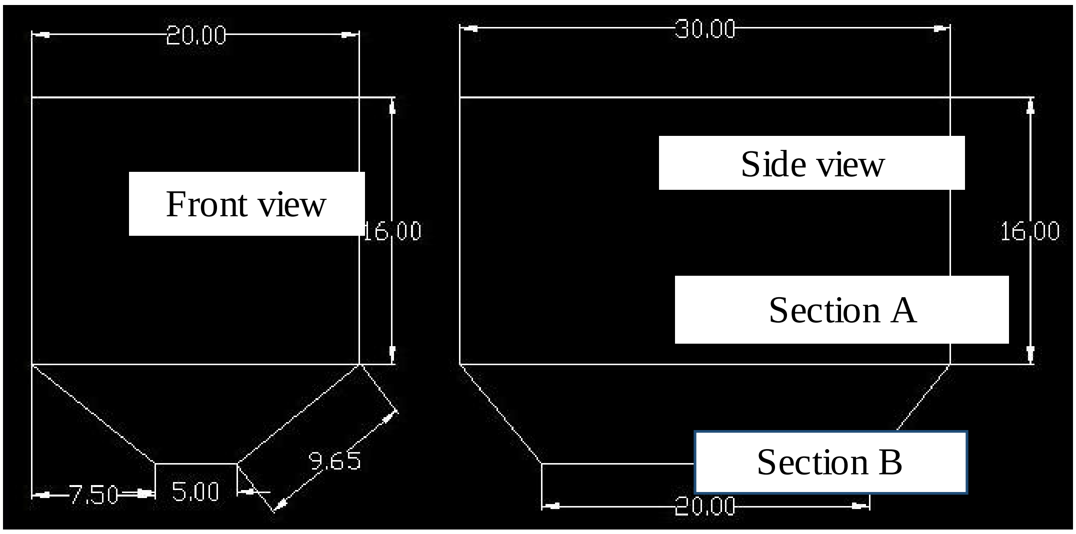

Figure 2: Cross-sectional view of hopper

Section A: H_1 =Height of the box, L = Length of the box, W= Width of the box

Section B: a= Bottom width; H_2=Height; t=Distance and ϴ= angle of repose of the crop degree 28^0

The hopper has two kinds of shapes that were rectangular shape at point A and trapezoidal shape at point B

Volume at section A $V_a = W x H_1 x L = 9600 \ cm^3$ and Volume at section B was determined by

$$V_b = \frac{(a+b) \times h \times lb}{2} \quad (2)$$

Where: v_b = volume of box with trapezoidal section

Therefore, volume of the hopper $= V_a + V_b$ a=bottom width, b=top width of the box, L_b= length of the box but

b= a+2t

$$\text{So} \quad V_b = \frac{(a+a+2t) \times h \times lb}{2} = \frac{(2a+2t) \times h \times lb}{2}$$

$$\tan\Theta = t/h \quad (3)$$

The angle of repose for groundnut was about 28° (Davies, 2009).

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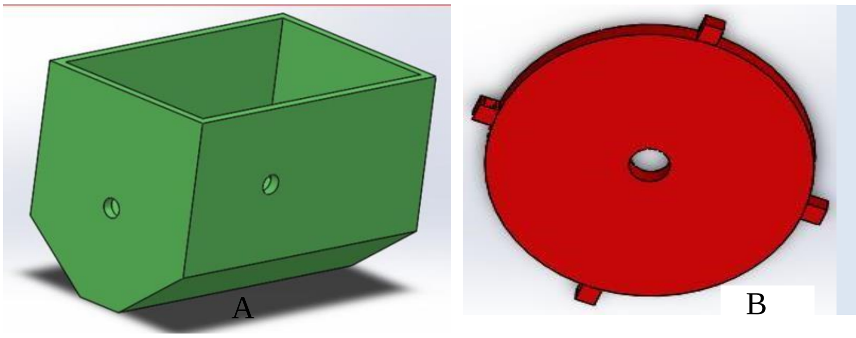

Figure 3: Hoper (A) *(B) Seed metering disk*

The angle of the seed box must be greater than the angle of repose for easily seed flow. Therefore, α = 49^0 was selected for designing of seed hopper.

2.8.2 Design of seed metering part

The metering devices were made from sheet metal of 3 mm thickness and 18cm diameter and four cups were made about its circumference at equal distance from each another. The size and number of cups on the plate depended on the size and shape of seeds. Seed metering device receive power from ground wheel through chain and sprocket mechanism. Hence the gear ratio of the bigger gear to the smaller is 2:1 that means as the ground wheel rotate once the seed metering device rotate twice of the ground wheel so that the distance covered in one revolution of the ground wheels were calculated so that seed metering device was designed to place the seeds at 20 cm plant to spacing.

The diameter and numbers of cells were determined on the basis of mean size of individual seeds, recommended intra-row spacing of seeds and economical and efficient size (diameter) of driving wheel. The plate had the size 3 mm x18 cm (thickness x diameter). The diameter of the ground wheels was 51 cm. The size of the cells on the plate was decided on basis size of the biggest seeds of a given crop. The number of cells and distance between consecutive cells on the seed metering plate were obtained using the following expressions;

$$M = \frac{\pi D2}{Irs} \quad (4)$$

$$t = \frac{\pi D1}{m} \quad (5)$$

Where: - D_1 = Diameter of seed metering roller (18 cm): D_2 = Diameter of ground wheel (51cm) ,m = Number of cells on a roller (minimum value): I_{rs} = Intra-row spacing of seeds and t = Distance between consecutive cells

The numbers of cups on seed metering plate were 4 and consecutive distance between each cups on seed metering plate was 14.13 cm. Hence the gear ratio of the bigger gear to the smaller is 2:1 that means as the ground wheel rotate once the seed metering device rotate twice of the ground wheel.

Gear ratio = $\frac{N1}{N2}$:- where N_1 number of teeth on the driving gear and N_2 the number of teeth on the driven gear. So N_1=36 and N_2=18 The distance covered in one revolution of the ground wheels were calculated so that seed metering device was designed to place the seeds at 20 cm plant to plant spacing.

2.8.3 Design of ground wheel for the planter

The planter's ground wheel, with external diameter of 51 cm, was designed as an integral part of the seed metering mechanism connected to the seed metering device directly. The rim of wheel was made from mild steel flat iron 6 mm thick and 60 mm wide. Each wheel had eight spokes made from mild steel rods with diameter of 8 mm, and were welded to the rim and hub at the center of the wheel that served as bushing or shaft bearing, at equal interval Equation below (Thomas and Brown, 2005) was used to analyze the shear strength

(τ) of the ground wheel considering the wheel as thin-walled vessels.

$$\tau = \frac{T}{2 \times A_m \times t_w} \quad (6)$$

Where: T=Torque produced by the wheel (12.50 Nm) A_m = Area of the wheel calculated based on the median diameter of the wheel; t_w = Thickness of the wheel wall (0.006 m) and r_m = the median radius of the wheel r = the outer radius of the wheel (0.25m)

Therefore, the shear stress on the wheel

$$T = \frac{12.5}{2\times0.006\times0.019} = 54824 \text{N m}^{-2} = 54.8 \text{ KN}$$

Thus the calculated shear stress was much less than the maximum allowable shear stress of the mild steel flat iron used in the construction of the ground wheel, 80.8MPa, hence the wheel is safe for operation.

2.8.4 Furrow opener

The design of furrow openers of seed planters varies to suit the soil conditions of particular region. Most seed planters are provided with pointed tool to form a narrow slit in the soil for seed deposition. The adjustable furrow opener permits planting at each variety's ideal ground depth. The type used for this work is the V -shaped type. These types of furrow openers are used for forming slightly narrow under sandy soils for placement of seeds at medium depths. The Furrow opener is thin mild steel. The mild steel flat iron was fabricated to shoe type like structure to facilitate an easy cut through the soil. Nut and both were used to fasten the device to the frame through a hole drilled on the frame for adjusting sowing depth according to crop.

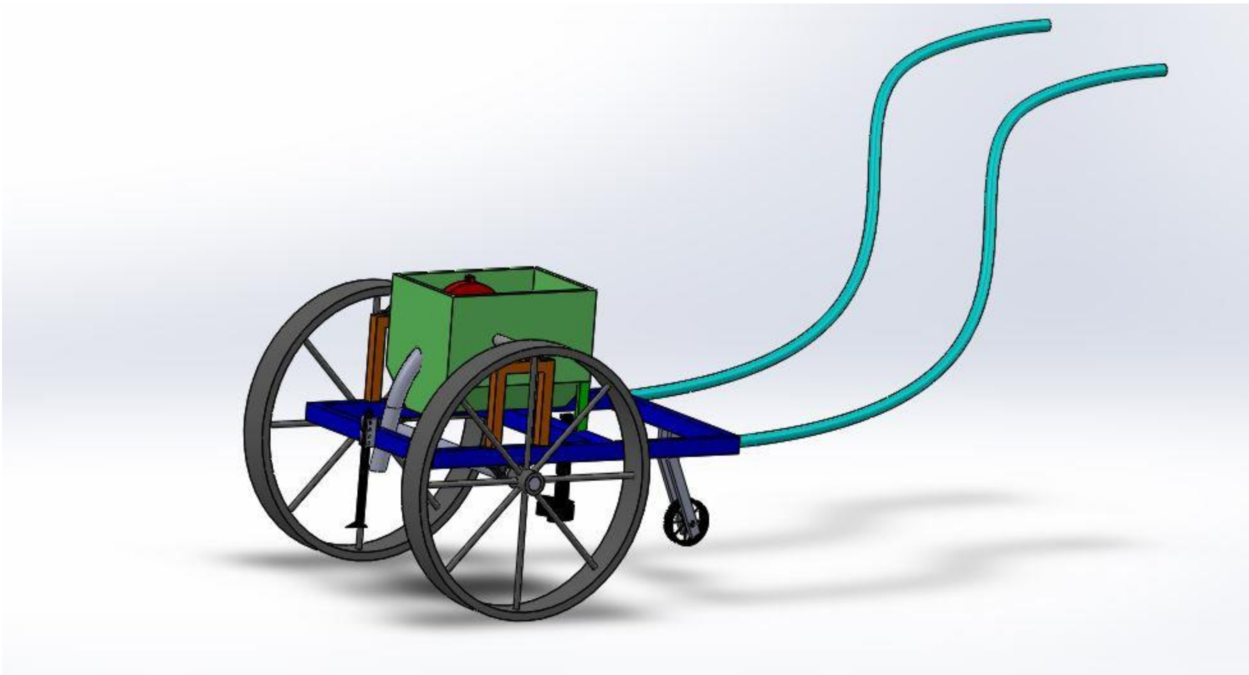

Figure 4planting machine

3. Data collection and statistical analysis

The data were collected from the parameters as described below:

Planting time: - The time taken for sowing by animal drawn planter and manual hr/ plot

Plant spacing: The distance between two consecutive plants

Row spacing: The distance between adjacent rows

Depth of planting: Depth at which furrow opener can open and was measured by ruler (cm)

Uniformity: The percentage of even distribution of plant per plot

Days to 50% seed emergency: The number of days from planting date to emergency.

Field test was conducted on a well prepared soil using tractor. The depth of planting was measured along the row the length of every 2 m at three randomly selected rows from each plot.

Field capacity and efficiency were determined in accordance to the recommendation made by Kepner (1978) and using relevant parameters that included effective operation time, turning time and time losses due to obstructions on the field. A plot of 12 m by 20 m requiring, on average, about 32 passes with inter-row spacing of 37.4 cm was used to assess field capacity and field efficiency. From the data gathered, working speed (km hr^{-1}), and effective field capacity (ha $hr.^{-1}$) and field efficiency (%) was estimated using the expressions below:

Actual field capacity was calculated:- $A_{FC} = \frac{A}{10{,}000T}$

Where: AFC=Actual field capacity (ha $hr.^{-1}$): A= Total area of the field (m^2) and T= Total time taken to finish the field (hr.)

Theoretical field capacity also calculated as:- T_{FC}=0.0036WS

Where: T_{fc}= theoretical field capacity (ha hr^{-1}.); W= width of planter (cm) and S = forward speed of the animal (m s^{-1})

Field efficiency is the ratio of actual field capacity to theoretical field capacity

$$FE = \frac{A_{FC}}{T_{FC}} \times 100$$

4. Result and Discussion

Using an experimental plot of 20 m by 12 m with the help of measuring instruments and devices performance data was collected. Data collected during field test include; speed of the animals, depth and width of furrow opener, spacing between rows and plant numbers of seed per drop, operational time and other as described in table 1 and 2

Table 1**: Experimental plot required and machine performance test**

Length of the Field (m)	Width of the Field (m)	Time taken to Finish field (min)	Time lost by turning and stopping (min)	Theoretical field capacity ha hr-1	Field capacity in ha hr^{-1}	Field efficiency %
20	12	15	3.2	0.11	0.08	73

The time taken to finish one hectare of land was 12:30 hr. that means by taking 8 hr. working time per day by farmer. Hence the time required to accomplished 1 hectare of land planter was 1 ½ day. But for manual planting the time taken to finish one hectare was 50 hr which was about 6.25 days this indicates significant different among them. This result agreed with on the other hand Table 2 result the proposed plant spacing was 20 cm and result obtained from the experiments was 22.78 cm so it is good in terms of plant spacing and plant spacing uniformity was about 86.7% which was acceptable

Table 2: **Performance testing of planter**

Field Test	Unit	Symbol	Field value
Seed spacing*	cm	SS SSD	22.78
Seed spacing standard deviation	cm	Eu	3.0
Seed spacing evenness=(SS-SSD)/SS			86.7%
Seeding depth*	cm	d1	8.91
Seeding depth standard deviation	cm	d1d	0.8
Seeding depth evenness $=(d^1 - d^1_d)/d^1$		E_d	90.9%
Row spacing*	cm	HS	37.4
Row spacing standard deviation	-	HSD	4.58
Row spacing evenness =(HS-HSD)/HS		E_h	87.7%
Number of seeds per row*	-	H hSD	7.4
Number of seed standard deviation	-	E_n	1.54
Seeds per row evenness	-		79%

The proposed depth of planting for planter was about 6-10 cm and the result obtained according to (Tarig *et al.*, 2013) was 6.1 cm for groundnut and the result from the planter was 8.91 cm which is acceptable depth in the dry land and the result obtained from the test was about 90.9% and depth of planting uniformity was 94% according to (Tarig *et al.* 2013) which was almost the same results when compared to the previous work. The proposed row spacing for groundnut planter was 40 cm and result obtained was 37.4 cm that is good results and its uniformity for row spacing was 87.7%.

Table 3: **Effect of planter and manual on seeding rate**

Location	Area(m^2)	Weight of seed sown (kg)	Seed rate (kg/ha)
Fedis planter	240	1.92	80.0
Erer planter	240	1.97	82.0
Erer manual	240	2.23	93.0

Manual planting slightly is higher than single row animal drawn planter Table 3. In the other word the result confirmed that performance of planter was falls within the standard range of seed rate of the crop. In terms of work drudgery i.e. labor and time saving, this planter have significant on the amount of seed sawing that is 11kg, which can saw or cover 0.13 ha of additional land.

Table 4. ***Statistical analysis: Gen-stat 18th Edition statistical package was utilized to analyze by two sample t- test method***

Treatment	Time of planting (min)	Speed of animal (m/s)	Spacing between row (cm)	Spacing between Plant (cm)	Planting depth (cm)
Planter	0.41	0.82	37.38	22.66	8.250
Manual	3.00	0.13	38.34	22.79	9.563
SE±	0.01	0.0166	2.358	1.553	0.220
T value	-2.98	41.40	-0.41	-0.08	-5.96
Level of significant	**	**	ns	ns	**

Note: ** and ns = significant at < 0.001 and not significant, for 95 confidence interval of difference in means values respectively. Planting time, speed of planting and depth of planting had significant effects among the treatments while plant spacing and row spacing had not significant effects within the treatments

5. Conclusion and Recommendation

From the above result we can conclude that the donkey drawn planter is more suitable then manual sowing of groundnut under rain-fed condition on Erer and Fadis at sandy loam and sand clay loam soil respectively. Also, it was significantly reduced the sowing time and labor requirement for groundnut planting when compared to manual sowing. Manual placement of seeds required four persons: two to make rows one for seed placing and one for seed covering. But, row planter required only two persons one to guide the animal and one to control the movements in rows. The time required to plant one hectare of land using traditional method, with four persons, was 50 hours while using the planter, with two persons required only 12:30 hours-ha-1 to do the same works. Hence, one can note that the time requirement per hectare is reduced by one-fourth and labor requirement was reduced by half when the planter was used. In addition to time and labor the farmers can save about 11kg seed when compared to manual sowing. Then the machine was portable and can be easily operated and maintained by the farmers.

6. Recommendation

The performance evaluations made indicated that the planter can be used successfully on small farm holders. Form the test results the planter was better than manual planting interims of performance indicators, time and labor saved indicated that the planter can be used successfully at farmer's level. The tested planter is single row; it is necessary to improve as large scale farmers by increasing number of rows of the planter to improve field capacity of planter.

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