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DEVELOPMENT AND EVALUATION OF ANIMAL DRAWN COMMON BEAN ROW PLANTER

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ABSTRACT

This project was undertaken to develop and evaluate the performance of a planter that capable of planting common bean 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 three replications were used with plot size of 20x5.33m^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 common bean 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 73.4kg/ha than that of manual treatment (100 kg/ha). Effective field capacity and field efficiency of the planter was 0.026ha/hr. and 83.8% respectively. Hence, it is recommended that this efficient planter will be upgraded the planting machine in future design in multi row planter for increasing planting capacity per unit time.

Keywords: Common bean, Field capacity, Field efficiency, Planter

INTRODUCTION

Haricot beans are the leading grain legume crop taking up 30% of the total pulse production and grown on more than 14 million hectares worldwide(9).Of the five domesticated species of *Phaseolus*, the common bean (*P.vulgaris*) is the most widely grown, occupying more than 85% of production area sown to all *Phaseolus* species in the worl(9). It is produced primarily in tropical low-income countries, which account for over three quarters of the annual world production. Economic significance of common bean in Ethiopia is quite considerable since it represents one of the major food and cash crops. It is often grown as cash crop by small-scale farmers and used as a major food legume in many parts of the country where it is consumed in different types of traditional dishes (3). Estimated production area and yield of common bean in Ethiopia in 2012/2013 cropping season were 366,876.94 hectares and 4,630,084.90 quintals, with respective increment of 2.99 % and 2% in area and production, respectively according to (1)

The term planting can be defined as a proses of depositing seeds at a specified rate in rows spaced to permit inter row cultivation. Common bean is cultivated manually ether by broad casting or by hand drilling until now a days, which is time consuming, labor intensive and costly. As labor cost accounts for over 70% of the total cost of production in most farming operations in rural setting. Searching for an alternative source of farm power which is cheap and affordable to the farmers became necessary. Due to the above problems a low cost animal drawn Common bean planter was, developed and tested on FARC Station and substation.

The planter was consists of two runner wheels, a seed hopper, an vertical plate type seed metering device, a seed tube, a pair of seed covering and handle. Power was transmitted from the runner wheel to the metering device through shaft mechanism. This project work was focused on the development and Evaluation of row common bean planter that is cheap, easily affordable by the rural farmers of the study area. This planter was easy to maintain and less laborious to use. So that this activity was initiated with the objectives of development and evaluation of animal drawn common bean planter that can place seeds in furrow under the different soil types in the study area.

MATERIALS AND METHODS

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^{o} 07″N and longitude of 42^{o} 04″ east, in middle and lowlands areas and at average altitude of 1702 meters above sea level, with a prevalence of low lands. Babile was located at 9° 10″ 41.5′ north of latitude, 42° 15″ 27.3 east longitudes’ and elevation 1274 meter above sea level

Materials

Materials used for testing and evaluation purpose were planter, metering tape, stopwatch, soil moister-tester, digital caliper etc.

Methods

Experimental site

The experiments were designed and conducted in the sandy loam and sandy clay loam soils. The experimental land size was 16×20 m^2 and divided in to three equal plots and accordingly for manual. Randomize complete plot with three replications were used with plot size of 20 x5.33 m^2. Awash1 seed variety was selected and examined using the recommended agronomic practices in the area.

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: -

$$Pp = \frac{10000m^2}{ps} \qquad (1)$$

Where: P_p= plant population per ha

P_s= area per plant (m^2)

Physical properties determination of the seed

The mean sizes of the seed, used in the study, were determined by randomly selecting 50 seeds from the representative samples and measuring their three principal diameters using digital caliper. The larger, intermediate and minor diameters of the seeds were denote 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 (2)

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

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

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

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

Design and material selection of the planter components

The planter consists of frame, seed hoppers, metering mechanisms, furrow openers, seed covering devices, handle and ground wheels. 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 rectangular pipe of 30 mm x 40 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 (from figure1 below)

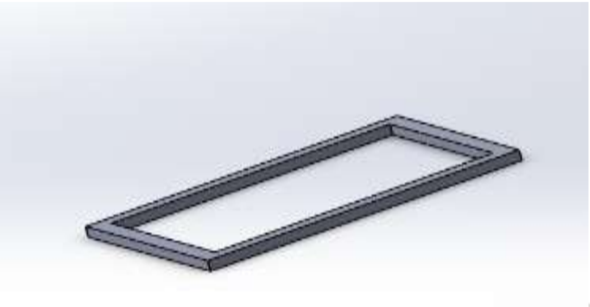

Figure1:3D of main frame design

Hopper design

The hopper was designed to feed the metering devices in vertical direction. The material used for the construction was sheet metal with thickness of 1.5mm, which was readily available in the market and relatively affordable. The hopper has a shape of inverted frustum of rectangular pyramid truncated with rectangle at bottom (6cm x20cm) having a height of 22 cm) and Rectangle at top (20 cm x 30cm) from the following Figure 2

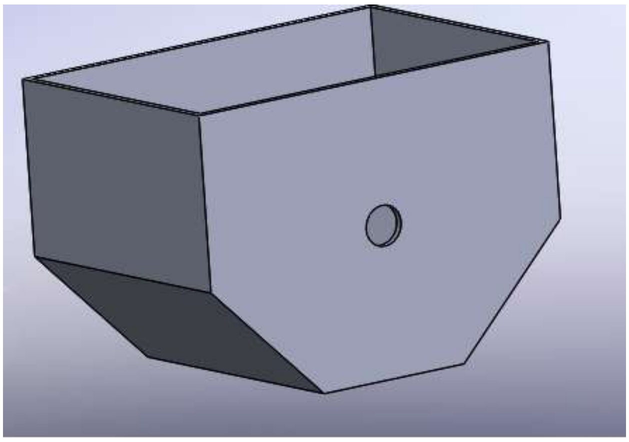

Figure 2: Hopper design

The bulk density of common bean seeds, was 709.27 kg/m^3, and angle of repose 35-40^o (A.A.S Palilo *et al.*,2018).The average seeding rate of common bean was 75kg/ha (10). Based on the above stated of rates of seeding, the volume of the hopper was estimated using the equation given by, (5), as follows:

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

Where: SR = seeding rate (kg/ha)

n = number of refilling per hectare

BD = bulk density of the seeds (kg/ m3)

$$\text{Volume of seed} = \frac{75kg/ha}{15\times709.27kg/m3} = 7.05\times10^{-3}\,m^3$$

The hopper has rectangular shape and the volume was calculated as:-

Volume at Vt = WxHxL=7800cm^3 and volume at point

Volume at point B was estimated by $V_b = \frac{(a+b)\times h\times lb}{2}$

Where v_b = volume of box with trapezoidal section

So volume of the hopper =Vt + Vb

a=bottom width

b=top width of the box

L_b= length of the box but b= a+2t

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

$\frac{(2a+2t)\times h\times lb}{2}$ tanϴ= t/h where ϴ is the angle of repose of the seed

The angle of repose for common bean was about 35-40^o (6).The angle of the seed box must be greater than the angle of repose for easily flowing of seed therefore α = 45^o that was the angle of hopper. Now putting the value in the above equation h=9cm but the total height of the hopper 22cm

Description of seed metering device

The metering devices were made from sheet metal of 3mm thickness and 19 cm diameter and twelve 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 was connected directly to the shaft on ground wheel by bolt and nuts, figure 3 below shows metering device

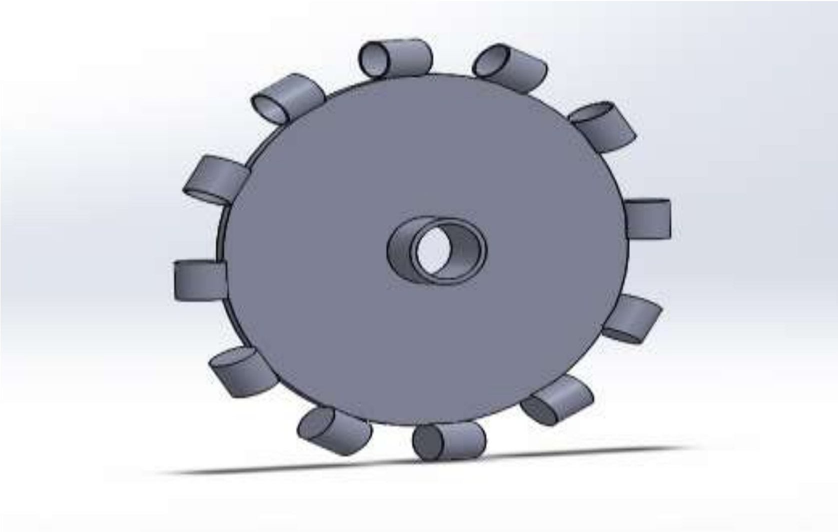

Figure 3 metering device design

The diameter of the ground wheels was 60cm.The size of the cups on the plate was determined on 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 (8)

$$m= \frac{\pi D2}{Irs} \tag{6}$$

$$t= \frac{\pi D1}{m} \tag{7}$$

Where:- D1 = Diameter of seed metering roller (19cm)

D2 = Diameter of ground wheel (60cm)

m = number of cups on a plate

Irs = Intra-row spacing of seeds

t = distance between consecutive cups

The number of cells on seed metering plate was 12 and consecutive distance between each cells on seed metering plate was 5cm

Hence since the seed metering device was connected to ground wheel by bolt and nut both ground wheel and seed metering device rotate in the same revolution that means as ground wheels rotates ones also seed metering device also rotates ones. The distance covered in one revolution of the ground wheels were calculated so that seed metering device was designed to place the seeds at 15cm plant to plant spacing

Ground wheel of the planter

The planter's ground wheel, with external diameter of 60cm, 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 thickness 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 was used to calculate the shear strength (τ) of the ground wheel.

$$\tau = \frac{T}{2\times A_m \times t_w} \tag{8}$$

Where: - T = the torque produced by the wheel (12.50 Nm)

A_m = the area of the wheel calculated based on the median diameter of the wheel

t_w = thickness of the wheel wall (0.006m).

r_m = the median radius of the wheel

r = the outer radius of the wheel (0.3m)

$$A_m = \pi r2 = \pi(r-0.5t_m)^2 = 0.277m^2$$

Therefore, the shear stress on the wheel

$$\tau = \frac{12.5\text{Nm}}{2\times0.006\times0.277} = 3760.5\text{N/m}^2 = 3760.5\text{pa}$$

Thus the calculated shear stress was much less than the maximum allowable shear stress of the mild steel that used in the construction of the ground wheel, 80.8MPa, hence the wheel is safe for operation. Figure 4 shows the 3D drawing of the wheel.

Figure 4 3D of ground wheel design

The Planter Field Testing and data collection

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 man power, one for guiding the animal and other to control the movement in the row)

Manual: Required four man power, two for making the rows by hoe, one sowing the seed and one for covering seeds by soil. Figure 5 shows the assembly drawing of the developed planter and during performance evaluation of the machine under taken in the field. .

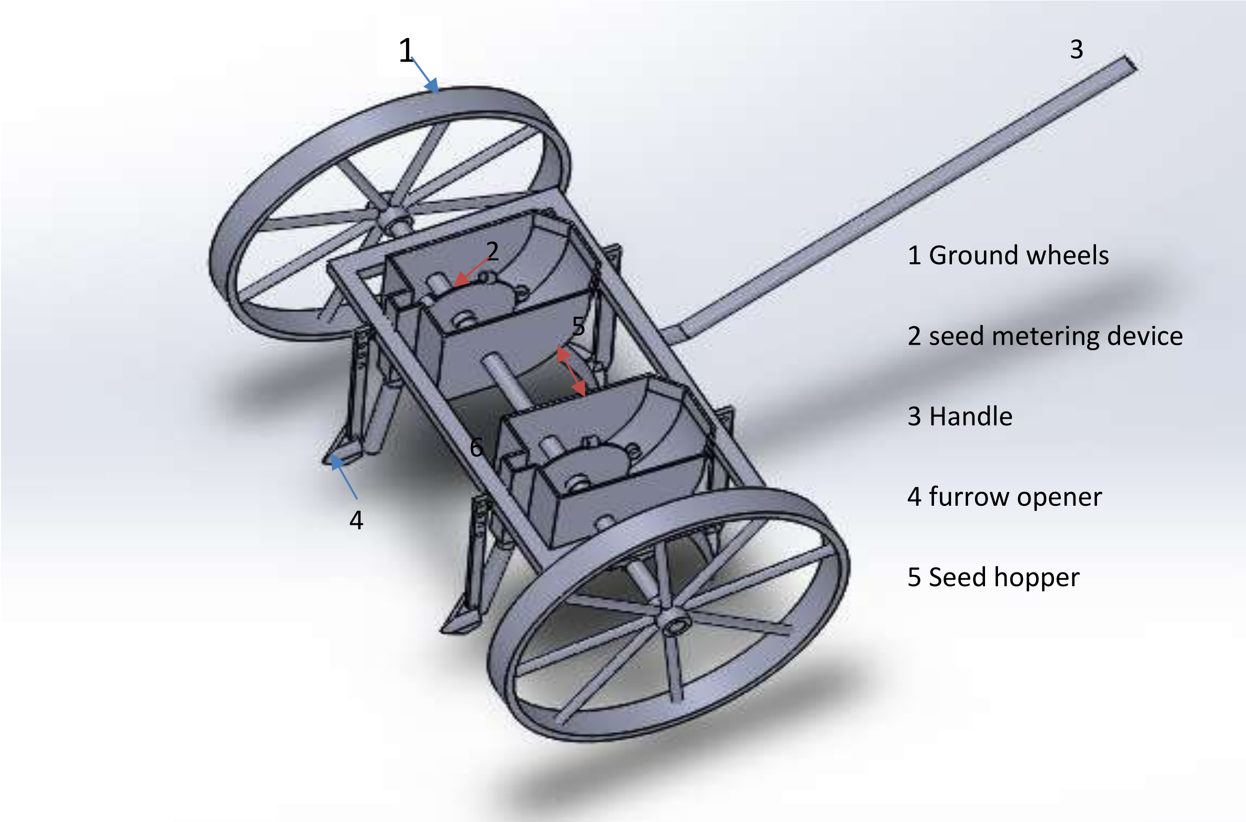

Figure 5 Photo taken during Planter testing

Figure.6. During manual planting at Fedis

Figure 7 The status of common bean that was planted by the planter

Theoretical field capacity

The Theoretical field capacity was determined by considering the width coverage of planter and its average operating speed.

It was calculated by following formula (Hossain, 2014)

$$T_{fc} = W*S/10 \qquad (9)$$

Where:

W = width of operation, m

S = average speed of operation, km/hr

Effective field capacity

Effective field capacity was determined by (Hossain, 2014)

$$E_{fc} = A/T \qquad (10)$$

Where,

A = Field coverage, ha

T = Actual time of operation, h

Field efficiency represents the ratio of effective field capacity to theoretical field capacity and was expressed as percentage.

$$\text{Field efficiency (\%)} = \boldsymbol{Fe} = \frac{E_{fc}}{T_{fc}}\ 100\% \qquad (11)$$

.Where, $\boldsymbol{E_{fc}}$= Effective field capacity

$\boldsymbol{T_{fc}}$= Theoretical field capacity**Experimental Design**

The software design used for analyzing the collected data was Gen-stat 18th Edition.

The data was analyzed by two sample t-test statistical analysis of mean values, t- values and probability levels at 95% confidence interval. The experiments were conducted in the clay sandy and clay sandy loam soil plots. The experimental land size used was 20m*16m = (320m^2) and then accordingly were blocked in to three equal with plot size of 20x5.3m^2 for each. For the designing of the seed cell the size of the seed was described by its length, width and thickness.

RESULTS

Planter performance evaluation data was collected. The data collected during field test include; speed of operation, depth and width of furrow opener, spacing between rows and operational time and other as described in table below.

Table.1 Experimental plot size and machine performance test results

Length of the plot (m)	Width of the plot (m)	Time taken to finish the plot (min)	Time lost by turning and stopping (min)	Effective field capacity ha hr^{-1}	Theoretical Field capacity in ha hr^{-1}	Field efficiency %
20	16	12.5	2.38	0.026	0.031	83.8

Hence, time required to accomplish a hectare of land with this planter was 7.75 hr. For manual planting the time taken to finish one hectare was 50hr. The proposed space between plants was 15 cm. In our case it was obtained 13.72 cm and 14.22cm for planter and manual planting respectively and its uniformity for row spacing was 90.5%

Table.2 Effect of planter on seeding rate at Erer

Treatment	**Area(m^2)**	**Weight of seed sown (kg)**	**Seeding rate kg/ha**
Planter	320	2.35	73.4
Manual	320	3.2	100

From the above table we can say that the planter was well performed because the seed rate of the crop was within the range. In addition to labor and time saving, the planter can save 26.6kg of the seed that plant about 0.36 hectare of land.

Table.3 Performance testing of planter according to FAO (1994) planter testing specification

Field Test	Unit	Symbol	Field value
Seed spacing* Seed spacing standard deviation Seed spacing evenness=(SS-SSD)/SS *100	Cm Cm -	SS SSD EU	13.72 1.302 90.5%
Seeding depth* Seeding depth standard deviation Seeding depth evenness =(d1 –d^{1}d)/d1 *100	Cm Cm -	d^1 d^1_d E_d	7.333 0.9014 98.7%
Row spacing* Row spacing standard deviation Row spacing evenness =(HS-HSD)/HS*100	Cm Cm -	HS HSD E_h	38.67 1.581 95.9%

The proposed depth of planting for planter was between 5-10 cm and the result obtained from our planter was 7 .333 cm which is acceptable depth and depth of planting uniformity was 98. 7%.

The proposed row spacing for haricot bean or was 40 cm and result obtained was 38.67 cm and its uniformity for row spacing was 95.9%

Table.5 Field performance of the planter at mean values for Erer and Fedis station

Variety	Time of planting(min)	Speed of planting(m/s)	Row Spacing (cm)	Planting spacing(cm	Depth of planting(cm)
Planter	0.7	0.6256	38.67	13.67	7.333
Manual	2.6	0.1277	38.53	14.22	6.778
SE±	1.619	0.0110	1.381	0.525	0.442
t-value	-70.57	45.46	0.10	0.53	1.26
Level of significant	**	**	ns	ns	ns

Note: ** and ns = significant at < 0.001 and not significant, for 95 confidence interval of difference in means respectively. Planting time and speed of planting had significant effects among the treatments while row spacing, plant spacing and depth of planting, had none significant effects with in the treatments

CONCLUSION AND RECOMMENDATION

The donkey drawn common bean planter developed at the FARC to meet the need of the state farmers was found to operate at a field capacity of 0.026 ha/h with the depth of seed placement of 7.33cm. The planter was effectively meter out the seeds with minimum seed damage of zero percent. During field and lab test, the calibration of seed planter showed similar seed rate of 87.5 kg/ha and 81.87 kg/ha for both variety of SER-125 and Awash-1 respectively. The machine adjustment and maneuverability observed to be ease to the operator.

From the above result we can conclude that the donkey drawn planter is more suitable than manual sowing of common bean 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 haricot bean planting when compared to manual sowing. Therefore the technology should be adapted and popularized to the farmers in order to change their life. The performance evaluations made indicated that the planter can be used successfully on small farm holders. From 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.

Recommendation

Since, tested planter is animal driven; it is essential to upgrade to engine driven to improve field capacity and efficiency of planter. Lack of trained animal during data collection was the problems that must be solved.

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