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Design and Fabrication of a manually operating Mung bean Planter for Ethiopian Sugar cane fields intercropping uses

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Abstract: Planters have fully mechanized systems which enables to plant different crops by changing the metering device. They may power by manpower, animal power or attached on tractors. Even though there are such options, Ethiopian sugar estates/ projects used the traditional method to plant mung bean, soya bean and haricot bean between sugar cane plants. Now a research is carried out to use Mung bean planter and the design and fabrication of the planter has been completed. The planter has one seed and one fertilizer applicators from left side of its wheel and the same is too at the right side. Structurally it has four furrow openers at the front, two seed and two fertilizer applicators at the middle and four furrow closers at the back. The shaft is entering locked with the wheel by rectangular male and female mating systems, and two metering devices also fixed by keys on the same shaft. The housings are splitted in to two above and below the shaft centre. This is done for ease of assembly and disassembly. The upper part of the housings is joined with the hoppers and the bottom ones are with four applicators by welding. The hoppers have partitions for the seed and fertilizer at both sides. These partitions are extended to the housings to prevent mixing of seed and fertilizer. The planter is designed and manufactured to drive by human power pushing like a wheel barrow and made to lay the seed and fertilizer at a distance of 10 cm apart. After manufacturing, when tested in the field it had a promising effect.

Keywords: Planter, mechanized system, mung bean, metering device, fertilizer, applicator, furrow opener, furrow closer, housing

I. INTRODUCTION

Plants usually begin from either seeds or seedling transplants. Important factors affecting seed germination and emergence include seed viability, soil temperature, availability of moisture and air to the seeds, and soil strength and resistance to seedling emergence [1]. The planter can exert a strong influence on the rate of germination and emergence of seeds through control of planting depth and firming of soil around the seeds or roots of seedlings. In addition, the planter must meter seeds at the proper rate and, in some cases, must control the horizontal down-the-row placement of seeds in a desired pattern [2]. Most Research indicates that growers could improve their yields by just improving on the planter’s performance [3].

The Ethiopian sugar corporation sugar cane plantations also plants different crops to increase the soil fertility through intercropping with sugar cane. Mung bean, soya bean and haricot bean seeds are among the selected one for the intercropping at Wonji/Shoa and Metehara sugar estates. As evaluated by Sugar Cane Production Directorate, mung bean is an appropriate seed for the

intercropping at Wonji/Shoa. Normally, Seed planting process has to be made by machine or manually using labor, but heavy machine like tractor, which damages the cane, is difficult to use inside the planted field. Therefore, the plantation practice is carried out by traditional methods, i.e manually drop the seed between the canes with human labor. The practice of plantation is so tedious and takes longer time to cover even a hectare of cane planted land.
In response of the above problems the researchers proposed to utilize manually operating planter. The main objective of this journal is to Design and Fabricate an affordable manually operating double rows Mung bean planter and double rows Fertilizer applicator. This will be specifically applicable in Ethiopian Sugar Cane plantation fields to produce the crop with sugarcane as intercropping system. The design is thought to improve on seed spacing and depth uniformity in the seed planting process.
The function of a well-designed seed planter is to meter seeds of different sizes and shapes, place the seed in the acceptable pattern of distribution in the field, place the seed accurately and uniformly at the desired depth in the soil and cover the seed and compact the soil around it to enhance germination and emergence [4]. The recommended row to row spacing, seed rate, seed to seed spacing and depth of seed placement vary from crop to crop and for different agro-climatic conditions to achieve optimum yields.
The impact of seeds on the internal components of the planter is influenced by the coefficient of restitution of seeds on various impinging surfaces [5].
The benefits of this particular design are: Increased agricultural output; Reduced production cost, which makes the planter affordable; Makes crop cultivation less laborious; Makes farming more attractive state; Ensures capacity utilization of available farm land; Saves tremendous amount of time during farming.

II. METHODS AND MATERIALS

2.1. Experimental Approach

At the beginning of this research work the existing practices of the sugar estate has been studied in detail, problems and drawbacks of the current practices were listed and a solution is suggested to design and fabricate manually operating Mung bean planter. As per the suggestion, a design of the planter is made using Auto CAD, Nx5, and Catia software. The planter design was thought to plough and sow the seed and fertilizer on both sides of a hill made by two adjacent furrows in one pass. After completing the 3D and 2D drawings on the design stage, comments were given by different professionals and finally the design is fabricated in Wonji/ Shoa sugar factory work shop from different cross-section and size of structural steels.

2.2 Determining Physical Property of mung bean

Seed flow through a planter is dependent on size, shape, sphericity, true density and angle of repose of seed. Therefore, The range of shapes and sizes of mung bean crops and their physical properties like grain length, width and thickness were made used in designing grain cell sizes on the seed metering unit as shown on figure 1.. So, the size of seed metering cell was made based up on the physical property of mung bean. The physical property of the seed was analyzed as mentioned on [6], [7].

Figure 1. Mung bean seed.

2.3 Description, Design analysis, and Material selection

The mung bean planter (Figure 5) was tested and developed at the wonji-shoa sugar estate work shop. The mung bean planter consists of: the feed hoppers, metering discs and housing, drive (ground) wheels, discharge spouts (seed tube), furrow opening and covering devices, and the handles.

Feed hoppers:-There are two feed hoppers made of mild steel, which was divided into seed apartment (2 kg seed capacity) and fertilizer apartment (2 kg fertilizer capacity) made of light durable galvanized metal sheet, having a frustration cross-section of a pyramid. It was design based up on the repose angle of the mung bean seed.

Metering discs and housing:- The machine contain tow metering device which was counted the seed and fertilizer without mix. Seed metering mechanism was made out of roller Aluminum which was containing eight cells in each metering device. The seed holes on the template provide seed spacing of 5 cm to 10 cm [8]. The same was done for fertilizer metering unit ranging from complete drilling to spot dropping of fertilizer side by side with the seeds (2-3 cm apart from the seed) since they were both mounted on the same drive wheel shaft to reduce number of moving parts. The dimensions of the cells are 6 mm diameter, 10 mm length and 8 mm deep. These dimensions are such that three seeds can be accommodated if they are oriented on the major axis. Metering disc housing is made from mild steel which the metering dives are rotating on it.

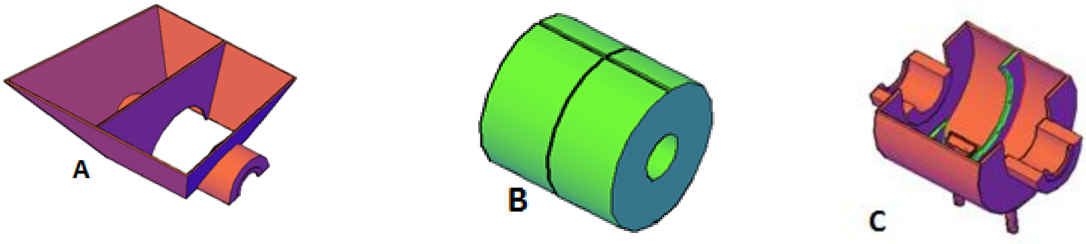

Figure 2. Component of the planter, A seed and fertilizer hopper, B seed and fertilizer metering dives and C seed and fertilizer metering dives housing.

Drive wheels:- The drive wheels are made of mild steel and are integral parts of the seed metering mechanism. The drive wheel is made of mild steel. The diameter of the wheels is 38 cm was coupled to the seed/fertilizer template drive shaft. The wheel has a horizontal plate that bears the key that slide the seed and fertilizer metering mechanism which was castellated in such a way that each castellated point pick up seeds and fertilizer at a time and introduces the seeds into the seed discharged tube while the fertilizers to fertilizer tub that deposits the seed in the soil. The circumference of the wheel is designed such that it is required seed spacing within row to enable the planter discharge eight times in one revolution of the wheels.

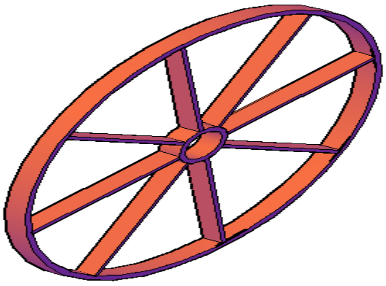

Figure 3. Derive wheel of the planter.

Furrow opening device: - The furrow opener is a 40 mm mild angle iron with a length of 120 mm. The angle iron is slightly beveled at the lower edge to facilitate an easy cut through the soil (from 3 - 4 cm) and provide V-shaped furrow to reduce seed rebounding when dropped to improve seed placement accuracy. To facilitate the attachment of the furrow- opening device to its support, a pipe of diameter 17 mm (3/4") and 25 mm long was drilled to accommodate an 8 mm diameter bolt with the nut welded on the periphery of the hole drilled.

Furrow covering device: To cover the seed and fertilizer V-shaped angle iron was attached behind the seed and fertilizer tube. The planter's handle was made of galvanized square pipes to make planting on the ridge. .

Frame and Handle: The handle consists of two mild steel pipes of 17 mm internal diameter, each of length 1230 mm. These bushings have been previously drilled to accommodate 8 mm bolts. A crossbar, which is a pipe, 17 mm internal diameter and 900 mm long, was slotted through the upper sets of bushing of the pipes; the main shaft passes through the lower bushings.

Figure 4. A furrow opener A and B furrow covering.

Layout of the Implement

It is compact in construction and simple to operate, low investment and maintenance costs and more efficient in operation and can be made from locally available material anywhere.

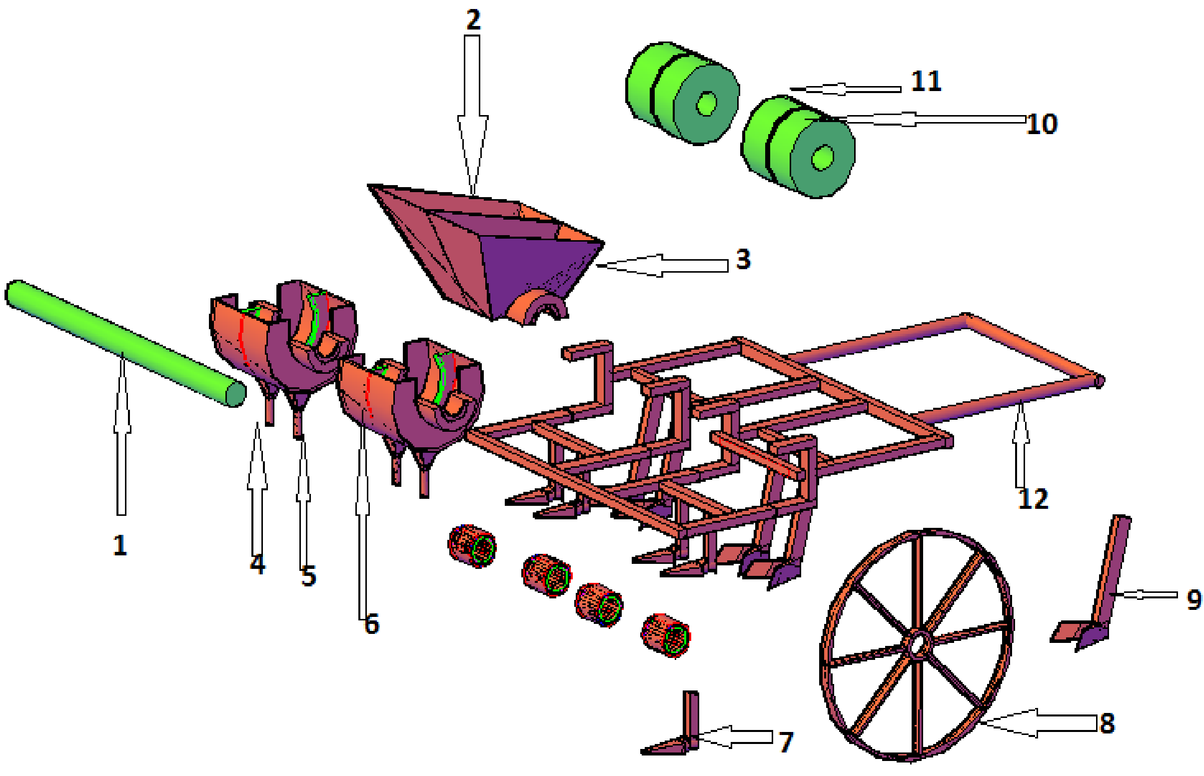

Figure 5. Parts of mung bean planter.

Key to Figure 5
1. Drive shaft
2. Hopper for fertilizer
3. Hopper for seed
4. Discharge spout fertilizer
5. Discharge spout seed
6. Seed and Fertilizer metering dives housing
7. Furrow opening device
8. Drive wheel
9. Furrow covering
10. Seed metering dives
11. Fertilizer metering dives
12. Handle and frame

2.4 Laboratory and Field Tests

To ascertain the design objective testes of seeding efficiency, seed spacing, labor requirement per hectare and external seed damage was conducted in the laboratory and in the field. The planter prototype parts after fabrication were coupled and taken to the laboratory and field for testing.

2.4.1 Laboratory Tests

The machine was calibrated in the laboratory to determine the rate of discharge, uniformity of seed spacing and seed damage during operation.

Calibration Test: The hopper of the planter was loaded with 500gm of mung bean seeds. The planter was jacked up (held in the vice) to allow for free rotation of the drive wheels. A mark was made on the wheels to indicate the reference points to count the number of revolutions when turned, and a sac (polythene bag) was placed on the seed discharge tube to collect the seeds discharged. The drive wheels were rotated for 20 times at low speed as would be obtained on the field. A stop watch was used to measure the time taken to complete the revolutions. The seeds collected in the sac were weighed on a balance and the procedure was repeated five times.

Test for Uniformity of Seed Spacing: To determine the uniformity of seed spacing, 500gm of seeds were loaded into the hopper. 15m was marked out on the plain ground and the machine run within the length at walking speed, and the time of travel was recorded. A measuring tape was used to measure the distance between successive drop of seeds. This process was repeated five consecutive times and measurement of distance between successive drop of seeds were recorded.
Test for Seed Damage: The planter was jacked up as described in the calibration test; 500gm of seeds were loaded in the hopper. The wheels were rotated 20 times in turns and the time taken to complete the revolution was recorded with the aid of stop watch. The seeds discharged from the seed tube were observed for damage and recorded. The seeds discharged from each spout were observed for any external damage. The laboratory test is shown in figuer 6 and 7 below

Figure 6.Laboratory test for seed Calibration and seed damage.

Figure 7. Laboratory test for seed spacing.

2.4.2 Field Test

A field of 32 m x 5 furrow was used for the performance test of the planter. This land was properly ploughed and already the cane placed in the furrow, the test was on the ridge. The field efficiency and field capacity were determined.

Determination of Field Efficiency: To determine the field efficiency, the planting operation was performed longitudinally with a constant forward speed as determined by noting the distance of travel using measuring tape and corresponding time to complete the distance with the aid of a stop watch while planting the area of the prepared field. The effective operating time and the time spent to fill the seed hopper, remove stumps and other obstructions were recorded. The field efficiency was calculated from equation (1) suggested by [9].

$$\varepsilon = {}^{100T_e}/_{T_t} \qquad \text{-------------------} \quad 1$$

$where\ \varepsilon = Field\ efficiency$ (%) $T_e = effective\ operating\ time\ (min)$ $T_t = Total\ time$ (min)

Effective field capacity: The effective field capacity was determined by measuring the effective width of the machine using a measuring tape and the forward constant speed of planting operation; the effective field capacity was therefore evaluated from equation (2) propounded by [9]

$$C_e = \frac{ws}{100}\varepsilon$$

$where\ Ce = effective\ field\ capacity,\ (ha/hr)\ w = implement\ effective\ width, m$
$S = forward\ speed, km/hr\ \varepsilon = fielde\ efficiency$ (%)

 

Figure 8. Filed test of the planter.

III. RESULTS AND DISCUSSIONS

Table 1 reveals the results obtained from the calibration of the mung bean planter. It is observable from the table that the total average weight discharged by the two hoppers is 46.68gm and total mean is around 23.43 gm. Average discharge of the planter is 27.8gm.

Table 1. Laboratory Calibration of Mung bean Planter.

Trial for right side	Weight of seeds discharged (gm) per 20 revolution	Time for 20 rev (min)	Speed (rpm)	Trial for left side	Weight of seeds discharged (gm) per 20 revolution	Time for 20 rev (min)	Speed (rpm)
1	24.6	0.54	37.04	1	23.1	0.54	37.04
2	25.2	0.49	40.82	2	23.54	0.49	40.82
3	23.2	0.52	38.46	3	26.85	0.52	38.46
4	19.6	0.54	37.04	4	26.1	0.54	37.04
5	20.5	0.5	40	5	21.6	0.5	40
Average	22.62	0.52	38.67	Average	24.238	0.52	38.67

The planter was able to effectively meter out average of three to four seeds per discharge and has an average seed rate of 2.7 kg/hr. An adjustment can be affected using adjustable metering device to meter more seeds per discharge.
Table 2 presents the intra-row plant spacing measured in the laboratory determined. In the test conducted in the laboratory, the average intra-row seed spacing was 10.1 cm for the right side and 8.8cm for the left side. This has 9.45 cm space in average.

Table 2. Laboratory determination of uniformity of seed spacing in row.

Trial for right side	Time (s)	Speed (m/s)	Laboratory spacing (cm)	Trial for left side	Time (s)	Speed (m/s)	Laboratory spacing (cm)
1	30	0.5	10.5	1	30	0.5	10.2
2	30	0.5	9.5	2	30	0.5	12.2
3	30	0.5	9.8	3	30	0.5	6.8
4	30	0.5	13.25	4	30	0.5	8.6
5	30	0.5	10.1	5	30	0.5	6.2
		Average	10.63			Average	8.8

The result of plant spacing and equally gave close intra-row spacing from 5cm to 10cm as recommended by [8]. However, the slight discrepancies in the results may be due to seed clogging, same vibration of the implement during test in the laboratory, wind during test and other operational factors.

Table 3 shows the total average percentage of seed damage incurred during operation. It is observable from the table that the percentage total average damage for both hopper is 5.46%.

Table 3. Percentage seed damage (External damaged)

Trial for right side	Weight of seeds discharged (g	Time for 20 rev (s)	Speed (rev/ min)	Percentage Damage (%)	Trial for left side	Weight of seeds discharged (g	Time for 20 rev (s)	Speed (rev/ min)	Percentage Damage (%)
1	26.6	0.54	37.04	3.19	1	31.55	0.54	37.04	5.2
2	31.54	0.49	40.82	5.88	2	27.25	0.49	40.82	3.06
3	23.2	0.52	38.46	4.25	3	30.85	0.52	38.46	9.18
4	30.85	0.54	37.04	6.12	4	31.2	0.54	37.04	0
5	20.5	0.50	40.00	7.29	5	24.6	0.50	40.00	2.12
Average of seed damage				5.95	Average of seed damage				4.97

The damage is relatively high as compared to 3.51% obtained for Two-Row Okra planter (Bangboye and Motolasayo, (2006). So, the clearance of metering dives need small modification. From the two metering devise we gate different seed damage, the right side has high seed damage (5.95%) than the left side (4.97). Thus, the left hopper gave a better result than the right hopper, probably because of the minimal clearance between the metering device (flute) and its housing. But as a total this percentage of seed damage is not grate problem. Low damage of seeds and good spacing will be maintained if the machine is being operated at a uniformly low speed.

Table 4 reveals the field efficiency and field capacity of the planter obtained from the field test. From the result, average field efficiency of the machine is 71.63%. Which implies good performance and fall within the range of values 71.71% obtained by [9], [10]. [11] and [12]. More so, the result of the field capacity according to the table showed average value of 0.268 ha/hr.

Table 4. Actual field capacity and field efficiency the planter.

Number	Area of the plot			Total time taken to complete (hrs)	Time loss taken to complete (hrs)	Actual field capacity (ha/hr)	Field Efficiency (%)
	Furrow	Length (m)	Area (ha)				
1	5	32	0.023	0.088	0.027	0.261	69.3
2	5	32	0.023	0.083	0.022	0.277	73.5
3	5	32	0.023	0.086	0.024	0.267	72.09

Average field capacity (ha/hr and field efficiency of the planter from Table 4 is 0.268 ha/hr and 71.63% respectively.This value significantly fall within the range of 0.282 ha/hr for manually operated seeding attachment of animal drawn cultivator designed and constructed by [12] and average value of 0.260 ha/hr for development and performance evaluation of a manually operated Cowpea Precision Planter by [10].

IV. ECONOMIC IMPACT

This machine is an intermittent of technology that will be helped to change from fully manual to semi mechanized. When we will use this mung bean planter technology the benefit is control rate of seed per hectare, control requirement depth of planting, and seed and fertilizer will be applied without additional labor. In most estate four laborer sowing one hectare per day and other four laborers required to apply fertilizer hectare per day.

Using this planter one person can be planted:-

In one day = 0.268 ha/h × 8 h = <u>2.1 h/day.</u> Currently the cost of laborer is 26 birr which 104 birr per hectare for seed and 104 birr per hectare for fertilizer, total 208 birr per hectare. But this mung bean planter works both seed and fertilizer at the same moment and around 2 hectare is covered per day which saves <u>182 birr per hectare</u>.

Generally the planter save time, reduce cost of operation, maintain the depth of seed, control seed and fertilizer rate and control the space between seed to seed.

V. CONCLUSION AND RECOMMENDATION

The manually operated mung bean planter for intercropping was developed from locally available materials to match the need and relief the difficulties of the sowing of mung bean intercropping in sugar cane of the estates. It has a field efficiency of 71.63% and operates at a field capacity of 0.268 ha/hr with an average spacing of 10.1 cm for the right side and 8.8cm for the left side respectively. This has 9.45 cm space in average. The planter meters an average of three to four seeds per discharge with 5.46% damage of the seeds. The relative ease with which the machine is adjusted and maneuvered in the field suits the technical knowhow of the average peasant field workers.

With small modification in metering dives and metering dives house it can be transfer to end users because the field efficiency and field capacity tests in the field is in average of planter technology and it can be given good attention in the technology of intercropping mung bean.

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