# Design and Development of AutomaticPotato Planter

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**Abstract** – Potato is one of the major staple food items in Ethiopia. Potato planting in Ethiopia has been accomplished by traditional methods to planting the potato tubers on the field, which is labor intensive, time consuming and low yields of potato per hectare. This is due to lack of suitable row planting machine. In order to solve above problem, this study aimed todesign and development of automatic potato planter which capable of plantings potato tubers in rows at desired depth and spacing. The developed tractor drawn potato planter machine consists of trapezoidal shape hopper, cup feed seed metering mechanism, shovel type furrow opener, ground wheel and furrow covering device. The physical properties of five varieties of potato were studied. The sphericity result was 79.27 % to 86.6 %. The angles of repose of all varieties were nearly equal to 35.5º.The performances of tractor drawn potato planter were evaluated in the laboratory and field. Row to row spacing can be 60 cm and average depth of seed placement was found 12.18 cm as per potato agronomic requirement. The seed rate was calibrated and observed that 2,027.4 kg/ha which is laying in the acceptable range of 18 to 22 quintal/ha. The preliminary test conducted at speed of 3.0, 3.5 and 4.0 km/h speed show good seed rate but 3.5 km/h speed gave better operation result than other operating speed. The theoretical field capacity, effective field capacity and field efficiency of the machine were 0.525 ha/hr, 0.351 ha/hr and 67.18 % respectively.The average germination of the metered seed was observed 88.54 % seeds. The cost of fabrication of the planter was estimated approximately 10,927.07 ETB Birr. The saving in Man-h/ha requirement and in terms of cost of planting were quite substantial and justified the use of planter.

**Keywords:** Potato Planter, Design, Speed, Seed rate,Fieldtest, Field efficiency, Performance

## 1. INTRODUCTION

### 1.1. Background and Justification

Potato plays an important role in improving food security and cash income of smallholder potato growers in Ethiopia. Potato production can be increased both by increasing in acreage and productivity. The country has a very high potential for potato production as 70 % of the 10 million hectares of arable land is located in the mid and high altitudes, which is suitable for potato production (FAO, 2008). However, national average yields are still far below attainable yields and ample opportunities exist to realize this crop's potential for increased food security and income generation (Berga and Gebermedhin, 1994). Currently, only 2 % of the potential area in Ethiopia is under potato production and the average productivity of potato is less than 10 tonnes per hectare. The low productivity is partly due to the use of manual method of potatoes planting by most potato growers (Mulatu et al., 2005).

In Ethiopia total production from Gudene potato varieties was 943,233 tons with an average productivity of 13.5 tonnes/ha. The area under potato was 70,132 ha cultivated by 1.4 million households in the main cropping season of 2015/16. During the same period, it ranks first in area coverage and third in both total production and productivity among the root crops grown in Ethiopia (CSA, 2016).

The great variation in engineering parameters of potato planter and other planting machines show how difficult is to mechanize potato crop. Moreover, tuber of potato is different considerably one from another in dimension and their surface is highly irregular (Ismail, 1991).

Culpin (1986) classified potato planters into two categories namely semiautomatic and automatic planters. He added that, generally, automatic potato planters are working at a higher speed level more than the other category (Semiautomatic). Therefore, the choice of automatic or semi-automatic potato planters depend on the farm size and the available labor of the system. He concluded that the design of cup-feed planter type is a slow-moving belt with a double row of cups for each row of potatoes.

Ismail (in Arabic Ref., 1991) offered another classification for the potato planters according to the metering mechanism type. His classification includes four categories. Those are picker

power wheels, chain-cup, belt cup, and belt-spoons. He added that any metering mechanism of the above mentioned categories could be occupied into any trailed, or semi-mounted, or even mounted planter types.

The potato sub-sector in Ethiopia is relatively undeveloped and low productivity with less than 10 tonnes/ha. There was potential for yields of 13.5 tonnes/ha, which are being attained by model farmers using quality potato seed of improved varieties coupled with improved management practices, under the same rain-fed conditions. Therefore, this study was aimed at and initiated with the objective of designing the best performing of automatic potato planter.

### 1.2. Statement of the Problem

The manual potato planting is requiring high amount of labor. The main constraint to enhance the productivity and quality of vegetable crops in Ethiopia is lack of mechanization. Basically, vegetable farming is labor intensive. Potato planting has been performed by human power, mechanical power or animal power. As our population continues to increase, it required more food, but this can only be achieved by increasing level of mechanization. Traditional method of potato planting, results improper spacing, depth and the farmer which limits the size of field that was planted. However, potato planter which was normally required to increase more yield is unaffordable to the farmers to purchase. As a result, these farmers still continue to planting manually, which may have resulted low productivity of the potato. Therefore, necessary to develop a low-cost tractor drawn row potato planter that is reduced drudgery and increasing productivity of potato.

### 1.3. Objective

- The main objective of this study was to design and developmentautomatic potato planter
- To find the physical properties of potato tuber related to multi-row potato planter.
- To design and fabricate automatic potato planter
- To conduct on station performance evaluation of the potato planter.

## 2. MATERIALS AND METHODS

### 2.1. Study Area Description

The study site was located near the town of Awash-Melkassa, Adama Woreda, East Shewa Zone, Oromia Regional State, 117 km east of Addis Ababa and 17 km southeast of Adama city at Melkassa Agricultural Research Center (MARC).It's found at an elevation of 1560 m above sea level with point locations of 8°24' N latitude and 39°21' E longitude. The average annual rainfall in the area is 768 mm, which is erratic and uneven in distribution. The agro- ecology is termed as Kolla (Warm, semi-arid lowlands). The dominant soil type in the area is sandy loam. Because of its agro-climatic condition, most varieties of potato grow well in the area. Fabrication of prototype and any adjustment or maintenance also conducted in AIRIC workshop, which was found in the center.

### 2.2. Materials Used for Experiments

The selection of materials was based on durability, cost and availability, strength and rigidity, weight and friction.

Table 2.1 Materials

| Number | Part name | Materials |
|---|---|---|
| 1 | Frame | MS square pipe |
| 2 | Seed hopper | MS sheet metal |
| 3 | Chain and sprocket | Steel |
| 4 | Ground wheel | Rubber tire |
| 5 | Cups | Mild steel rod metal |

| | | |
|---|---|---|
| 6 | Three point hitch system | Mild steel bar |
| 7 | Furrow opener | Carbon steel |
| 8 | Ridger | Mild steel bar |
| 9 | Seed tube | MS Sheet metal |

**2.3. Methods**

The methods were followed the following procedures.

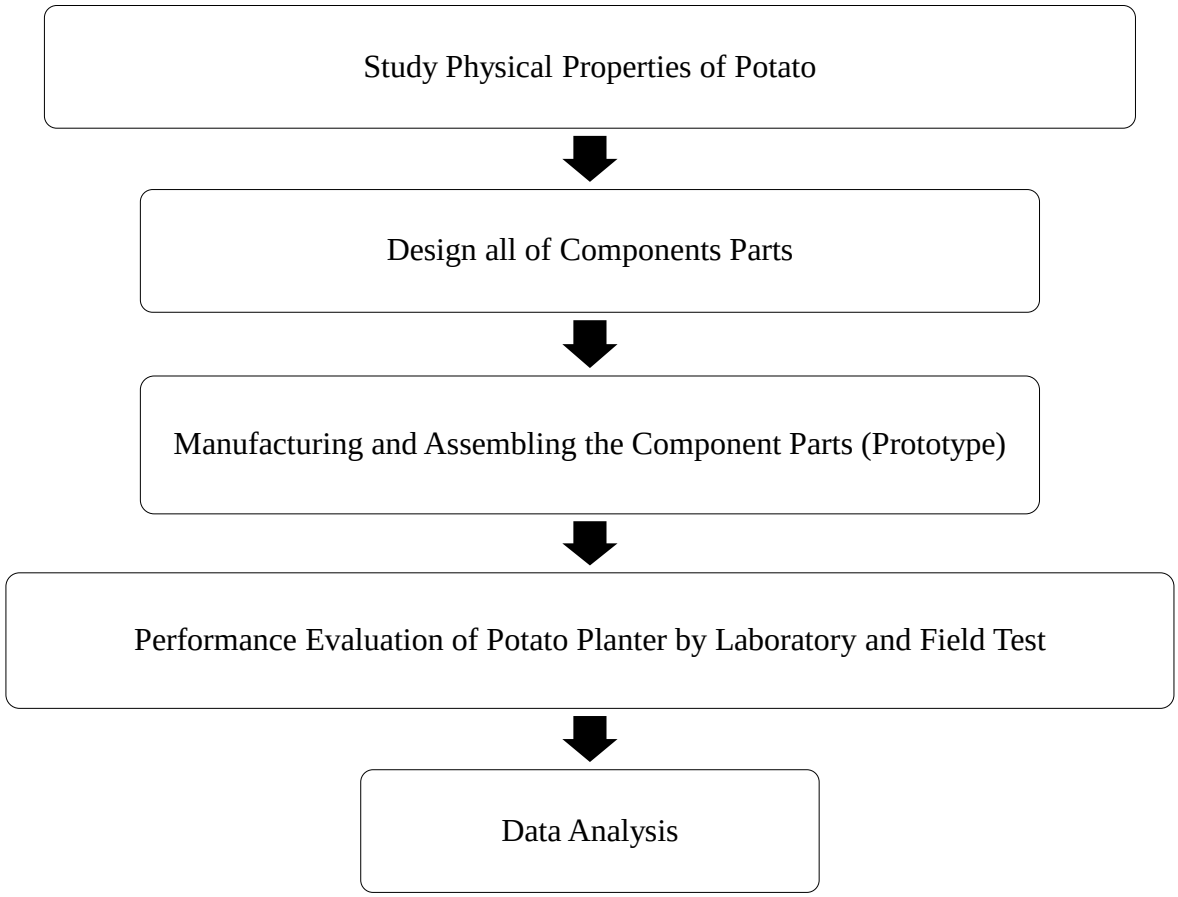



Fig 2.1. The stepsfollow to design potato planter

**2.3.1. Physical Properties of Potato**

Instrument used for determination of physical properties of tubers: Hopper, cone and vernier caliper. The physical properties of tubers are important factors for the design of potato planter. The potato varieties selected for the study were classified as small, medium and large variety based on the physical properties of tubers namely; geometric diameter, bulk density and angle of repose. The methods used for determination of physical properties are described as follows.

Fig 2.2 Potato prepared for planting

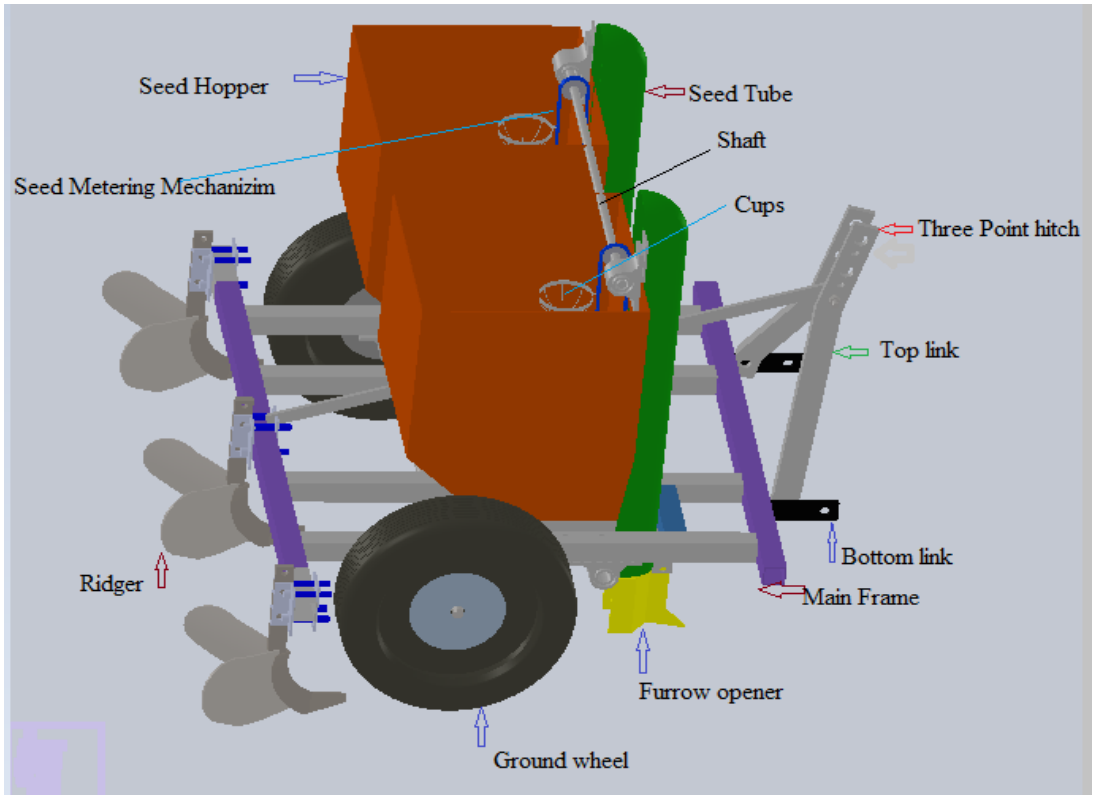



Fig2.3. Diagram of the prototype potato planter

**2.4. Performance Evaluation of Potato Planter**

In order to evaluate the performance of potato planter, it was essential to check it with respect to seed rate, seed distribution, seed placement, power requirement and field efficiency. It was evaluated for above mention parameter by performing the following tests in the laboratory as well as in the field.

Fig2.3. Fabrication pictures of tractor drawn potato planter

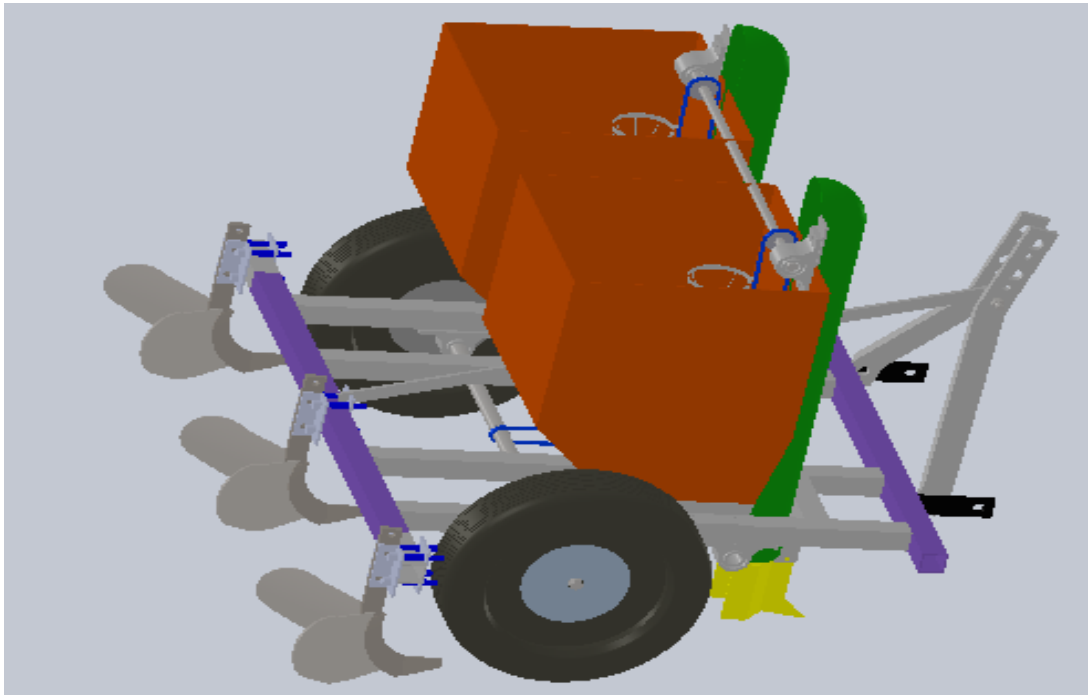


Fig 2.4. Isometric drawing of tractor drawn potato planter

**2.5. Field Test**

The potato planter was attached to the tractor. Three different operating speeds were found out at different gear and throttle position. The planter was operated in a well-prepared seed bed. The planter was operated in the field by side to centre method of operation. At each speed three replications were taken. The potato planter was calibrated, theoretical field capacity, effective field capacity, field efficiency and power requirement were found out.

### 2.5.1. Field Description

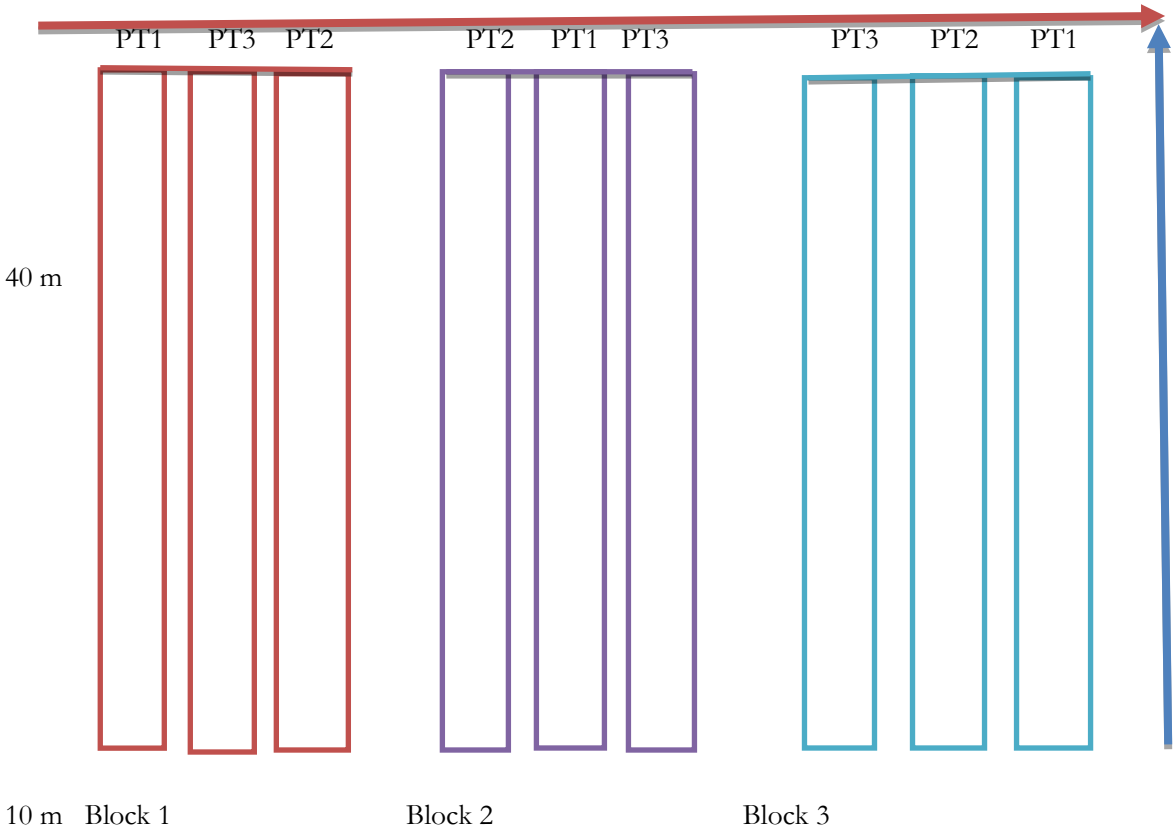
The condition of field was effect on seed germination and tuber yield. Therefore, field condition is important for sowing operation. The following parameters were determined before sowing.

i. Type of soil
ii. Soil moisture content in per cent
iii. Bulk density
iv. Size of plot
v. Depth of seed bed
vi. Method of sowing

The calibration test in the field was conducted same as laboratory test. The same procedure was adopted for calibration tests and determines the seed rate and seed damage of developed tractor drawn potato planter in the field.

### 2.5.2. Experimental Design

The Experiments were conducted in the field with Gudene potato variety (P) and three forward speed of tractor of 3.0 km/h, 3.5 km/h and 4.0 km/h with forming three treatments. Each treatment replicated three times with using Randomized Complete Block Design (RCBD).




Where: P- Potato

T-Treatment with index number 1, 2, 3

Fig 2.5. RCBD plot size sample representation

The well-prepared experimental field was divided into 9 plots each having an area of 400 $m^2$ (i.e. 40 m x 10 mnet size of each plot). Various adjustments in the machine were done to get required seed depth and plant to plant distance before testing. After preparing the field plot, the potato planter was prepared and adjusted for sowing operation. The tractor drawn potato planter was adjusted at 3.0 km/h, 3.5 km/h and 4.0 km/h throttle position and sowing operation was carried out for each randomly selected plot samples by taking a performance evaluation data.

### 3.6.2.13. Determination of Field Capacity and Field Efficiency

The standard tractor drawn potato planter effective field capacity: 0.4 ha/h, operating speed: 3.0 -5.0 km/h and Field efficiency: 60-80%. (ASABE, 2011).

Theoretical field capacity, effective field capacity and field efficiency were computed by using the following equation (3.1 and 3.2) (Hancock, 1991).

$$\text{Theoretical field capacity(ha/hr)} = \frac{W \times S}{10} \quad \ldots\ldots (3.1)$$

Where: W= Width of planter, (m)

S = Speed of operation, (km/h)

10 = factor calculated as $\frac{1\text{ha}}{1\text{km}}$ = 10000/1000=10

$$\text{Effective field capacity(ha/hr)} = \frac{\text{Area of plot (ha)}}{\text{Time taken(hr)}} \quad \ldots\ldots (3.2)$$

Field efficiency was the ratio of the effective field capacity to the theoretical field capacity calculated by using equation (3.3) (Hancock, 1991).

$$Ef = \frac{FCe}{FCt} \times 100 \quad \ldots\ldots (3.3)$$

Where: Ef = field efficiency, (%)

FCe = effective field capacity, (ha/hr)

FCt = theoretical field capacity, (ha/hr)

## 3. RESULTS AND DISCUSSIONS

A tractor drawn potato planter was designed and fabricated. The physical properties of potato seed were determined and used for the design of various components of planter. The performance of developed machine was evaluated in the laboratory as well as in the field. The data were analyzed and results are discussed in this chapter.

### 3.1. Laboratory Test Results

#### 3.1.1. Physical Properties of the Seeds

In order to get some of the physical properties of the potato seed, 100 sample seeds were of randomly taken from different variety of potato and their length, width and thickness were measured using digital vernier caliper. The geometrical parameters namely dimension of the principal axes (L is length, D is the width and T is the thickness) of randomly selected potato seeds were measured using digital vernier caliper. Geometric diameterand sphericity were calculated.

Table3.1. Mean values of physical properties of five different potato varieties

| Physical properties | units | Different variety of potato available in Ethiopia | | | | | |
|---|---|---|---|---|---|---|---|
| | | Jalene | Chala | Belete | Gera | Gudene | Average |
| Mean Length | Mm | 53.86 | 58.96 | 63.55 | 60.61 | 53.96 | 58.18 |
| Mean Width | Mm | 48.26 | 44.81 | 50.89 | 46.51 | 44.81 | 47.05 |
| Mean Thickness | Mm | 43.84 | 38.47 | 42.39 | 39.37 | 39.15 | 40.64 |
| Geometric mean Diameter | mm | 50.88 | 46.88 | 51.56 | 48.05 | 45.57 | 48.58 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Volume | $mm^3$ | 59,665.5 | 53,217.47 | 71,781.25 | 58,110.64 | 49,565.36 | 58,468.0 |
| Sphericity | % | 86.6 | 79.51 | 81.13 | 79.27 | 84.46 | 82.19 |
| Angle of response | ° | 38 | 37 | 34 | 33 | 35.5 | 35.5 |

The obtained shape index was compared with the recommended limits and classified into different classes (k, from 100 to 160 as round, 160 to 240 as oval, 240 to 340 as long, and higher than 340 as very long).The shape index of potato tubers was calculated by equation (4.1) (Singh*et al*, 2004).

Shape index, $k = \frac{Lm^2}{D\,X\,T} \times 100$…….. (4.1)

### 3.2. Laboratory Performance of Potato Planter

The newly developed tractor operated potato planter was tested in the laboratory to evaluate its performance. The results are discussed in the following paragraphs.

Fig3.1.Calibration of Potato Planter

### 3.3. Field Performance of Potato Planter

#### 3.3.1. Description of Field Evaluation

The field calibration of tractor drawn potato planter was carried out at the experimental field of Melkassa Agricultural Research Center. Three plots of size 40 m length x 10 m wide were selected for each plot field testing. The field was well prepared which was at 20 cm deep, firm, fine structure, smooth and level, relatively free of surface trash.

The field was well prepared for sowing by tractor drawn disc plough ploughing and disc harrow operation. The details of field used for field test are as follows.

- Type of soil - sandy loam
- Soil moisture content in per cent - 15.83 %
- Bulk density - 1.347 $gm/cm^3$
- Depth of seed bed - 20 cm
- Method of sowing-center to center
- Size of each plot- (40 x10)$m^2$

Fig 3.2. Potato Planter under Operation

### 3.3.2. Placement of Seeds

The average depth of seed was 12.18 cm in furrow openers, which indicated that the placement in the furrow openers were uniform. According to Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia (CASCAPE)(2015)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 10 to 15 cm. The depth obtained by the planter was therefore within the desirable limit.

### 3.3.3. Percentage of Missing and Percentage of Double

Percentage of missing also affected by skill of labour to fill the cup with potato seeds. The seed missing and percentage of doublewere depending on hopper fill level and forward speed of operation.

Fig 3.3. Measurement of Seed Spacing

### 3.3.4. Seed Germination Test in Field

The seed germination percentage was varied from 87.5 to 90.625 % at the three plots. It shows that there was no effect of speed on seed germination test.

Fig 3.4. Seed germination in Field

### 3.4. Manual Method Potato Planter

According to Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia(CASCAPE) (2015)project demonstration results, inter row spacing of 60 cm and intra row spacing of 30 cm was found to be optimum for were potato production which resulted in 225 g tuber weight, 5.5 cm tuber diameter, 37 t/ha tuber productivity and 173,000 tuber number/ha. The seed potato inter row spacing should be 60 cm, while plant to plant space and seed potato should be 30 cm and 20 cm.

Table 3.2. Performance of potato planter was compared with conventional practice.

| Sr. No. | Parameters | Units | Tractor drawn potato planter | Manual planting According to CASCAPE |
|---|---|---|---|---|
| 1 | Row to row space | mm | 600 | 600 |
| 2 | Plant to plant space | mm | 300 | 200-300 |
| 3 | Effective working wide | mm | two rows | One row |
| 4 | Field Efficiency | % | 67.18 | - |
| 5 | Depth of planting | cm | 12.4 | 10-15 |
| 6 | Travel speed | km/hr | 3.0 – 4.0 | - |
| 7 | Manpower required in planting | Man-h/ha | 6 | 32 |
| 8 | Germination count | % | 88.54 % | 75 - 95 % |
| 9 | Seed rate | quantal/ha | 21 | 18- 22 |

### 3.5. Cost Estimation and Cost of Operation

The unit cost of a tractor drawn potato planter was determined by calculating the cost of different components and their fabrication cost.

Table 3.3. Cost summary

| No. | Cost variables | Summary |
|---|---|---|
| 1 | Raw material cost | 7,388 ETB |

| | | |
|---|---|---|
| 2 | Material wastage 2.5 % | 300 ETB |
| 3 | Machine cost | 400 ETB |
| 4 | Labor cost | 500 ETB |
| 5 | Overhead cost 5 % (3+4) | 45 ETB |
| 6 | Profit 10 % (1+2+3+4+5) | 863.80 ETB |
| 7 | Sells tax 15 % (1+2+3+4+5+6) | 1,425.27 ETB |
| 8 | Selling price | 10,927.07 ETB |

The result showed that the developed tractor worked satisfactory functionally as well as economically and therefore proposed its use for the planting of the potato using 35- 40 hp tractor.

## 4. CONCLUSION AND RECOMMENDATION

### 4.1. Conclusion

A prototype of tractor drawn potato planter was developed for sowing operation suitable for medium(model) farmers and to evaluate its performance. The machine was powered by 35-40 hp tractor. The planter consists of seed metering mechanism, seed tube, furrow openers, drive wheel and power transmission. The field testing of tractor drawn potato planter was carried out at the field of MARC. The field was well prepared which was 20 cm deep, firm, fine structure, smooth and level, relatively free of surface trash. In Preliminary test tractor drawn potato planter was operated with 3.0, 3.5 and 4 km/h speed.

The following conclusions are made from the study of tractor drawn potato planter.

1. The planter was evaluated in laboratory as well as in real field condition.
2. The seed rate for seeds affected by the speed of operation and they were recorded for speed (km/h) of 3.0, 3.5, 4.0 were 1962.67, 2016.67 and 2103.0 kg/harespectively.
3. The meter seed were observed average mechanical damage at differenthopper filling level (¼ fill, ½ fill and full fill)were 2.83, 3.38 and 4.46% in of potato seedsrespectively.
4. The average germination of the metered seed was observed 88.54 % seeds.
5. The average depth of seed placement was found 12.18 cm whereas the seed spacing varied from 29.92 to 31.3 cm.
6. The net draft (kgf) of the planter at speed (km/h) of 3.0, 3.5 and 4.0 were as 300, 308.3 and 316 respectively.
7. Under normal moisture content (15.83 %) the average wheel slip was observed 10.31 % with diameter of ground wheel of 60 cm.
8. The average fuel consumption (l/ha) of the planter was observed 10.50.
9. The average field efficiency (%) and effective field capacity (ha/hr) for the were 67.18 and 0.351 respectively.
10. The cost of fabrication of the planter was estimated in the of approximately 10,927.07 ETB Birr.

### 4.2. Recommendations

The performance evaluations made indicated that the prototype planter can be used successfully on farms. Nonetheless, the following issue must be addressed to make the planter popular, adaptable and usable among the farmers.

- Popularization of the new potato planter technology need to be made.
- Systematic, coordinated and relentless efforts be made to get the planter adopted, effectively and efficiently used by the farmers.

### Suggestions for future work

The following suggestions help improve the performance of developed tractor drawn potato planter.

- Number of rows covered be increased to improve field capacity and field efficiency of developed tractor drawn potato planter.
- The planter may be tested for different other related crops and feedback received may be used for further design refinements, if any.

- Grade potato before planting so, to solve this problem make adjustable seed metering cup for all size of potato seeds, if any.

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