DESIGN, CONSTRUCTION AND PERFORMANCE EVALUATION OF TRACTOR DRAWN POTATO PLANTER

By

Sagni Bedassa Miressa

DEPARTEMENT OF MECHANICAL SYSTEMS AND VEHICLE ENGINEERING

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIALS ENGINEERING

Thesis

A thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Agricultural Machinery Engineering

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

Adama, Ethiopia

September, 2018

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CANDIDATE'S DECLEARTION

I hereby declare that the work which is being presented in the thesis entitled "**Design, Construction and Performance Evaluation of Tractor Drawn Potato Planter**" for the partial fulfillment of the requirements for the award of the degree of Master of Science in Agricultural Machinery Engineering is an authentic record of my own work carried out from November 2017 to September 2018 under the supervision of Dr. Amana Wako Department of Mechanical Systems and Vehicle Engineering Program, Adama Science and Technology University, Ethiopia.

The matter embodied in this thesis has not been submitted by me for the award of any other degree or diploma. All relevant resources of information used in this thesis have been dully acknowledged.

Name: Sagni Bedassa Miressa Signature_______ Date ____________

ADVISOR'S DECLEARTION

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief. This thesis has been submitted for examination with my approval.

Advisor: Dr. Amana Wako Signature_______ Date _________

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Acronyms

ANSI	American National Standard Institute
ASTM	American Society for Testing and Materials
CC	Capital Cost
CRS	Cost of Repairs and Spares
CSA	Central Statistical Agency of Ethiopia
DBHP	Drawbar Brake Horse Power
Dg	Geometric mean diameter
DLW	Daily Labor Wage
Dm	Major diameter of seed
DTW	Daily Tractor Wage
Dp	Depreciation
EIAR	Ethiopian Institute of Agricultural Research
EARO	Ethiopian Agricultural Research Organization
FAO	Food and Agriculture Organization
I	Interest
MARC	Melkassa Agricultural Research Center
MS	Mild Steel
NAOHP	Number of the Annual Operational Hours of the Planter
RCBD	Randomized Complete Block Design
SVC	Selvage Value Cost

Abstract

Potato is one of the major staple food items in Ethiopia. Potato planting in Ethiopia is accomplished by traditional methods of planting the potato tubers on the field, which is labour intensive, time consuming and low yields of potato per hectare. This is due to lack of suitable row planting machine. In order to solve the above problem, this study aimed to design, construct and performance evaluation of a tractor drawn potato planter capable of plantings potato tubers in rows at desired depth and spacing. The developed tractor drawn potato planter consists of trapezoidal shape hopper, feed cup seed metering mechanism, shovel type furrow opener, ground wheel, three-point hitch and furrow covering device. The physical properties of five varieties of potatoes 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 $kg.ha^{-1}$ *which is laying in the acceptable range of 18 to 22* $quintal.ha^{-1}$*. The field test conducted at tractor speed 36 rpm of show 21* $quintal.ha^{-1}$ *seed rate. The theoretical field capacity, effective field capacity and field efficiency of the machine were 0.525* $ha.hr^{-1}$*, 0.351* $ha.hr^{-1}$ *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 18,845.21 ETB Birr. The saving in man power requirement and in terms of cost of planting were quite substantial and justified the use of planter.*

Key words: *Potato Planter, Design, Speed, Seed rate, Field test, Field efficiency, Performance*

CHAPTER ONE

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 tractor drawn 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

1.3.1. General Objective

The main objective of this study was to design, construct and conduct performance evaluation of multi-row tractor drawn potato planter.

1.3.2. Specific Objective

The specific objectives of the study are as follows:

- To find the physical properties of potato tuber related to multi-row potato planter.
- To design and fabricate tractor drawn potato planter.
- To conduct on station performance evaluation of the potato planter.

1.4. Significance of the Study

Manual method of potato planting, results in low seed placement, spacing efficiencies and serious back for the farmer which limits the size of field that was planted. So, there needs to be implement that match with the tractor power. The importance of design of potato row planter was to increase production of potato through uniform planting of potato seed in the field by saving the time, resources and money per hectare.

1.5. Scope of the Study

The scopes of this study is development of multi-row potato planter and fabricate at local workshop. In fact, the development of a reliable potato planter to suit the prevailing Ethiopian conditions still needs more attention, since there is shortage in the suitable machinery design, especially for planting potato tubers with growing buds. So developing a new planting machinery in Ethiopia fields must be adapted technically and economically for Ethiopian farmers, using the available local materials and the presence of experienced workshops.

CHAPTER TWO

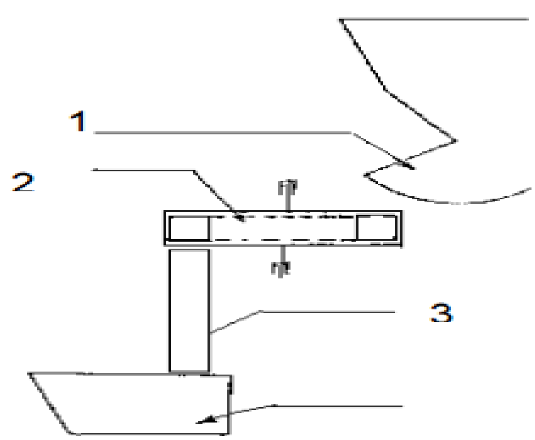
2. LITERATURE REVIEW

The design and development of potato planter has been the subject of interest for many researchers. Consequently, scientists must develop new transfer approaches to agricultural machinery. To clarify the attempts made to transfer appropriate machinery technology and to have better understanding of the previous potential systems of the potato planting machinery technology, the recent review of literature will be drawn as indicated below.

2.1. Potato planting

2.1.1. Method of Potato Planting

Bishop and Maunder (1980) indicated that potato planters are available in sex basic types according to their metering mechanism design feature. Those types are arranged from the simple hand-feed machine, the more complex automatic types. Also, they added that those types could be refereed as follows hand-feed, cup-feed, flat-belt-feed, molded-belt-feed, multi-belt-feed and finger-feed. They showed that hand- feed mechanism (Fig.2.1) consists of a drop tube for the seed to be placed by operators to the sound of a bell. The hands assist planter to use a segmented supply wheel into which the tubers are placed to be metered on to ground.

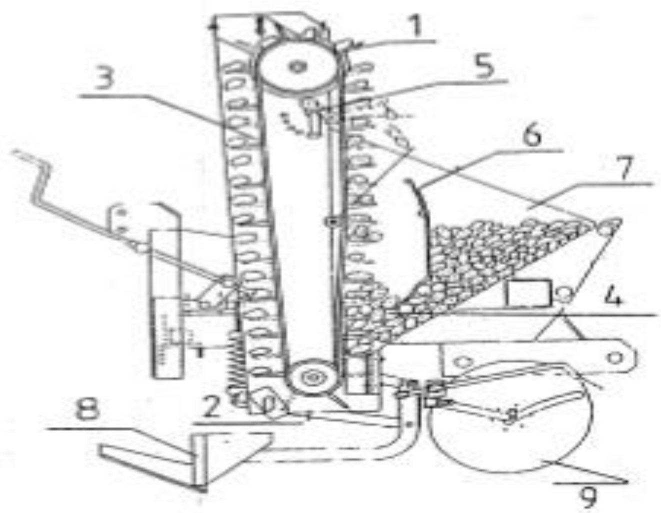


Source: Ismail, Z.E. (1991 in Arabic Ref.).

Fig 2.1. Schematic diagram of hand- feed mechanism automatic potato planter

1. Hopper
2. Horizontal feeding wheel
3. Drop tube
4. Furrow opener

They cleared that, steel or plastic cups mounted on chains or belts (Fig 2.2) collect the seed in the cup-feed mechanism from the hopper supply. He added that of modern planters of this type now have a twin set of cups need to pass though the supply hopper, reducing the risk of damage to spouted seed. Interchangeable cups or inserts are some machines to suit tubers size. Seed rate and spacing are controlled by adjusting the relative speed of the cups to ground speed, which is altered by changing from the ground wheel drive (Bishop and Maunder, 1980).



Source: Ismail, Z.E. (1991 in Arabic Ref.).

Fig 2.2. Schematic diagram of cup- feed mechanism automatic potato planter

1. Top sprocket wheel
2. Bottom sprocket wheel
3. Belt with feed cups
4. Bottom feeding
5. Control system for tubers on cup

6. Jack
7. Hopper
8. Opener
9. Convering disks

2.2. Physical Properties of Potato Tuber

Gamea et al., (2009) conducted study on physical characteristics and chemical properties of potato tubers under different storage systems. They found that bulk density of potato was maximum 668 $\mathrm{kg.m^{-3}}$, minimum 653 $\mathrm{kg.m^{-3}}$ and its average 658.3 $\mathrm{kg.m^{-3}}$ and angle of repose was maximum 37º, minimum 30º and its average 34º. Tucker (2013) found that the bulk density of whole, fresh potatoes in bulk storage piles or pallet boxes is 640 to 690 $\mathrm{kg.m^{-3}}$ depending on variety and tuber shape and its angle of repose is 37º.

Teye and Abano (2012) studied physical properties of two varieties of sweet potato grown in coastal savannah zone of Ghana. The bulk densities were higher in than in Ukerewe from 114.5 to 118 $\mathrm{kg.m^{-3}}$ and from 595 to 578 $\mathrm{kg.m^{-3}}$ the angle of repose was also higher in from 38º to 37º.

2.3. Tuber Spacing and Placement

Islam *et al.,* (2012) studied effect of tuber size and planting space on tuber yield and yield contributing characters of potato (Solanum tuberosum) in northern region of Bangladesh. It was found that days to emergence increased with closer spacing and small size seed tuber. Number of tubers per plant increased with increasing intra-row spacing and tuber size. They recommended 28-35 mm size seed tubers in 60 cm x 25 cm spacing was best method to farmers for getting higher income.

Getachew et al., (2013) investigated the effect of plant spacing and time of earthing up on tuber quality of Jalene potato variety for four levels of plant spacing (10, 20, 30 and 40 cm) and four times of earthing (15, 30, 45 days after plant emergence and no earthing). Data collected on tuber quality parameters were subjected to analysis of variance. In majority of tuber quality parameters 40 and 30 cm were preferable while significantly the highest tuber dry matter and specific gravity was found at 30 cm. Therefore, 30 cm plant spacing and earthing up at 15 days after complete plant emergence can be used at the study area, for the production of potato with improved and better tuber quality.

2.4. Machine Components

2.4.1. Seed Hopper

Klenin *et al.,* (1985) stated that seed boxes, barrels and hoppers not only serve as spaces to store seed material, but form an integral part of technological process setting up a flow of the seed material through feed hole to the sowing or planting device. In planter, the boxes were usually rectangular at the top and trapezoidal at the bottom. The slope of the side walls was, so adjusted that the seed flow is not hampered.

Bosoi *et al.,* (1987) explained certain points to be taken into consideration while designing seed hopper. Seed hopper must have an optimum capacity and must feed seeds uniformly and continuously to the seed metering mechanism independent of the direction of motion of the sowing unit. In practice trapezoidal almost hexahedral and combined forms of cross-sections of seed hoppers potato planter. The front and back walls of seed hoppers were set at an angle to base equal to the angle of friction of the sowing material with the covering surface.

2.4.2. Seed Metering Mechanism

Ryu and Kim (1998) developed a cup-type seed-metering device for precision sowing and efforts were concentrated on enabling the machine to place a desired quantity of potato seed at equally spaced intervals. Design parameters affecting the uniformity of seed placement were investigated with particular reference to the geometry of roller and tubes for potato seed deposition.

Metering mechanism is the heart of planting machine and its function is to distribute seeds uniformly at the desired application rates and controls seed spacing in a row. Proper election and/or design of the metering device is an essential element for satisfactory performance of the seed planter (Ikechukwu *et al.,* 2014).

2.4.3. Frame

Richy *et al.,* (1996) stated the importance of the frame design. The design of frame was particularly important in field machines because they must be as light as possible to reduce the cost, soil compaction and propelling power but yet strong enough to resist the shocks due to rough ground or obstacles. With light weight construction, there was often considerable deflection and as a rule" self-aligning bearings are necessary. Tubes or closed box sections were strongest for their weight and arc welding of connecting members make it possible to take full advantage of their strength both in torsion and bending.

Smith and Wilers (1977) had given some guidelines in fabrications of planter frame. The frame was usually made of mild steel angle, well braced and reinforced at the corners. It was necessary that the frame should be strong enough to prevent sagging and to hold the parts in alignment as all parts were connected to the frame.

2.4.4. Drive Mechanism

Bosoi *et al.,* (1987) described the drive mechanisms used on sowing machines. In modern sowing machines, motion was transmitted to the sowing shaft of seed hopper from the supporting transmission wheels or rollers. When there was planter with the seeding mechanism, for which the seed rate was adjusted by changing the length of the roller feed working length, motion was transmitted by gear-chain or sprocket-chain drives.

Verma (1986) reported that diameter of power transmission wheels of tractor drawn potato planter 40 to 60 cm.

2.4.5. Hitching

Srivastava (1990) stated that the method of hitching also affects the rate of sowing. Hitching too low resulted the furrow openers and boots to drop seeds back and upward to the ground line. Hitching too high caused the furrow openers to sow, the seeds forward and downward. Proper hitching not only drops the seeds at correct depth but also prevented plugging of furrow opener with grass, dust and wearing of boots.

2.4.6. Furrow Opener

A furrow opener cuts a furrow and allows the seeds or seedlings to be deposited before being partially covered by soil. The types of furrow openers used vary with soil and operating conditions. Chaudhuri, (2001). The opener may incorporate or enclose a portion of the seed delivery system and the seed boot that facilitates seed placement in the furrow. Furrow openers may be: runners, shovel, winged or shoes openers.

Furrow opener must maintain the seed furrow at uniform and proper depth in a variety of soil conditions. A furrow opener modifies conditions of seedbed. The aim of furrow opener design and selection must be to desired modifications, rather than impair conditions for emergence Murray *et al.,* (2006). The design of furrow openers is basically concentrated on their optimum rake angle. Studies made by Chaudhuri (2001) indicated that the optimum rake angle of furrow openers, for least draught requirement, should between 25º and 30º.

2.4.7. Seed Covering Devices

Seed covering devices are designed to promote soil flow back into the furrow to cover the seed after placement and firming. It plays an important role in promoting and stabilizing conditions conducive to rapid seed germination and influencing seed emergence and establishment through the manipulation of the depth of soil cover over the seed (Shaabanet *et al.,* 2009).

2.5. Performance Evaluation of Planting Machine

Numerous field and laboratory methods have been developed and used for evaluation of planter performance; each method has its own advantages and shortcomings. There are several techniques for determining planter performance (Kachman and Smith, 1995).

They concluded there was a significant difference in crop yield amongst three treatments at ($p<0.01$). The percentage of green potato in the yield was significantly higher in manual planting than potato planter ridger. The minimum man-hours (544 Man-h/ha) were in potato planter ridger and the maximum (2142 Man-h/ha) in manual planting and earthing twice by Kudali. The input-output ratios were 1:1.80, 1:1.26 and 1:1.23 in tractor operated potato planter ridger, manual planting with earthing by spade and manual planting with earthing twice by Kudali, respectively (Singh, 2004).

The potato planter was powered by fiat-480 tractor at low 3rd gear speed. The parameters were determined at moisture content of 15.73 %, fuel consumption was 24.04 $\mathrm{lit.ha^{-1}}$. The travel reduction was 5.04 percent field efficiency was 67.47 %, field capacity was 0.80 $\mathrm{ha.h^{-1}}$. They suggested farmers to plant more potato by using potato planter, because it covers more area in less time. It was labour saving machine (Singh, 2004).

Manually drawn two-row cup type potato planter designed and developed for more efficient planting and placing of potato tubers at uniform row to row and seed to seed distance. The machinery consisted of 2 numbers of 4 ply rating and 100 mm wide rubberized belts with 16 numbers of 45 mm diameter mild steel sheet cups riveted on each belt. Power to both metering mechanism and eccentric plate was given from the ground wheel through an arrangement of chains and sprockets. The effective field capacity of the planter was 0.5 ha/day (Gulati and Singh, 2003).

Tractor mounted semi-automatic two-row belt type potato planter ridger. Potato planting was done manually. Manual operation results in varying and non-uniform plant stand, requires large labour force in field preparation and planting, besides being less time-efficient due to unavoidable drudgery and competing demand for labors. To overcome these problems, a two-row tractor operated potato planter ridger widely in use in Punjab, Haryana and western Uttar Pradesh, was procured and tested. Necessary modifications were made in the machine based on the test results. The machine was introduced to the farmers and it has found wide acceptability among the potato growers in eastern Uttar Pradesh (Singh, 2004).

The tests conducted shown that the new small potato planter system performed well when dividing tuber pieces into rows: considering the best growth spacing for potatoes is 20-30 cm, the new system had a 68 % distribution versus the 50, 62 % of the old one. The tubers' spacing in rows is evaluated based on tuber voids and tuber doubles. The results also show that the machine was better to manage small tuber pieces. (Guidetti et al, 2011).

On the basis of reviews studied and need for farmers a tractor drawn potato planter was developed with the following features; spacing of row to row, fed cup metering mechanism, ridger, furrow openers, hopper and power transmission comprise of chain and sprocket. Beside this suitable hitching system, the frame to with standy the various loads accuring during operation of the planting.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. 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 Agricultural Engineering Research workshop, which was found in Melkasa Agricultural Research center.

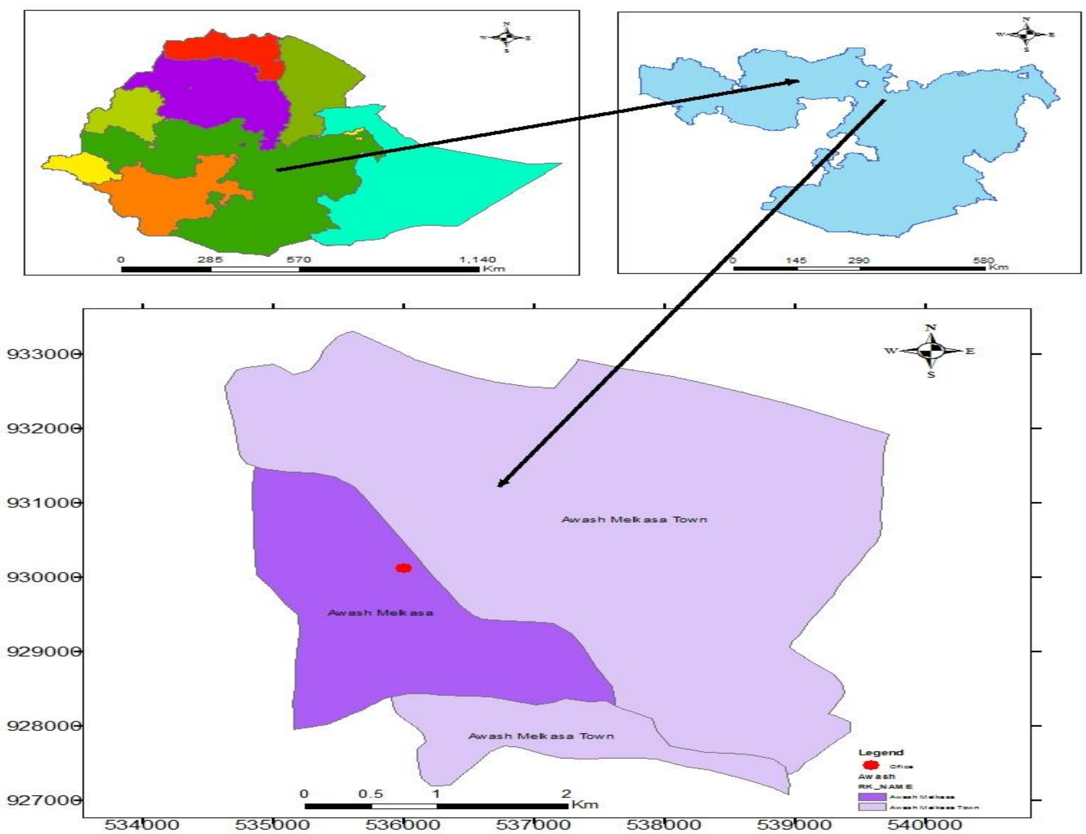


Fig 3.1. Map of study area

3.2. Experimental Materials

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

Table 3.1 Tools and machine used for the fabrication of the prototype

Sr. No.	Machine /tool name	Purpose
1	Drills machine	Hole / cell making
2	Lathe machine	Threading /cutting /finishing /shaping.
3	Grinding machine	Grinding /cutting tool
4	Cutting blade	Cut flat bar
5	Round file	Smooth rough edges
6	Electric welding machine	Welding
7	Steel scale	Measurement of linear distance
8	Steel tape	Measurement of linear distance
9	Vernier calipers	Measurement of outer and inner diameter
10	Center punch	Hole marking
12	Hammer	Used to strike an object
13	Chisel	Cutting
14	Scissors	Cutting sheet metal
15	Wrench	Tighting nut and bolt
16	Screw driver	Tighting screw
17	Hand grinder	Grinding metal sheet
18	Flat file	Smooth rough edges

In addition to these, plastic bags, weight balance (0.1gm accuracy), digital caliper of 0.01 mm accuracy, measurement tape (millimeter graduation) and stop watch instruments.

Table 3.2 Different components part, specification and material.

Sr.no	Components	Specification	Material
1	Ground wheel	Wheel diameter 600 mm, rim width 35 mm.	Rubber tire
2	Seed hopper	Rectangular at the top and trapezoidal at the bottom with dimensions 400x500x500 mm and 500x300x200 mm. Two number seed boxes provided of the same size of seed box.	MS sheet 18 gauge
3	Seed metering mechanism	Cup metering mechanism,18 cups around peripheral, distance between cups 100 mm.	MS sheet 18 gauge
4	Chain and Sprockets	Sprockets 45 teeth and 15 teeth 60 mm diam. chain pitch12.5 mm, total chain length 2037.5 mm.	Steel
5	Frame	Total length and width were 1,500 mm and 1000 mm respectively.	MS square pipe 60x60x3 mm
6	Tyne type of furrow opener	Adjustable row to row spacing and depth up to 15 mm, height of shank 200 mm, rake angle 120º	Medium carbon steel
7	Seed tube	Diameter 250 mm, thickness 2 mm	MS sheet 18 gauge
8	Ridger	MS. flat 70x6 mm having length and width 175 mm and 70 mm respectively.	Mild steel flat bar
9	Cups	Diameter 200 mm, thickness 3 mm	MS sheet metal
10	Three-point hitch system	-	Mild steel bar
11	Nuts and bolts	-	Low carbon steel
12	Ball bearing	Diameter 24 mm	

During the field test 12 quintals of Gudene varieties of potato seeds was used. During the laboratory experiments Gudene, Chala, Gera, Belete and Jalene varieties of potato seeds was used to study physical properties of potato.

3.3. Methods

The methods were the following procedures.

Study Physical Properties of Potato

↓

Design all of Components Parts

↓

Manufacturing and Assembling the Component Parts (Prototype)

↓

On Station Performance Evaluation of Potato Planter

↓

Data Analysis

Fig 3.2. The potato planter design procedures followed

3.3.1. Physical Properties of Potato

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. Instrument used for determination of physical properties of tubers were cone and vernier caliper.

3.3.1.1. Geometric Diameter

The geometric diameter was determined by measuring the dimension of the principal axes major, intermediate and minor of randomly selected tubers i. e. length, width and thickness are measured using a digital vernier caliper. The geometric diameter was calculated by equations (3.1) (Mohsenin, 1986).

$$Dg = \sqrt[3]{(L \times D \times T)} \quad \ldots\ldots (3.1)$$

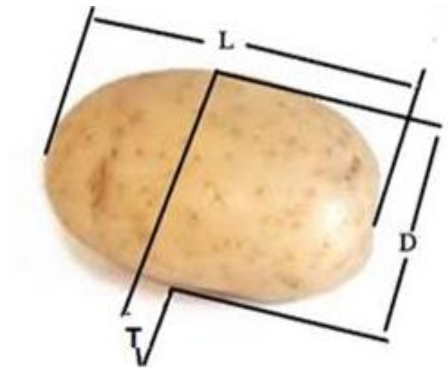


Fig 3.3. Potato seed

The volume and sphericity of the individual seeds were calculated using the measured length, width and thickness of the seeds and equations given by (3.2 and 3.3) (Singh *et al*, 2004).

$$Vm = \frac{\pi}{6}(L \times D \times T) \quad (3.2)$$

$$Sm = \frac{\sqrt[3]{L \times D \times T}}{L} \times 100 \quad (3.3)$$

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 (3.4) (Singh et al, 2004).

$$\text{Shape index, } k = \frac{L^2}{D \times T} \times 100 \quad (3.4)$$

Where: L = Mean length, (mm)

D = Mean width, (mm)

T= Mean thickness, (mm)

Vm = Mean volume, (mm^3)

Dg = Mean geometric diameter, (mm)

3.3.1.2. Bulk Density

The bulk density was found by taking tubers in a hopper trapezoidal shape. The volume of the hopper was found by measuring width and height hopper. The weight of the tubers in the hopper was found separately. The samples of each variety are taken and mean bulk density was calculated by equation (3.5) (Varnmakasti *et al.*, 2007).

$$\text{Bulk Density (kg/m}^3\text{)} = \frac{\text{weight of sample,kg}}{\text{volume occupied by the sample,m}^3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

3.3.1.3. Angle of Repose

The Potato tubers were filled in the feed hopper of the experimental set up. Tubers are allowed to fall vertically to form a natural inverted cone. The height of the inverted cone was measured. The angle of repose was the angle between the base and the slope of cone formed on a free vertical fall of the material to a horizontal plane. The angle of repose was calculated by equation (3.6 (Varnmakasti *et al.*, 2007).

$$\Theta = \tan^{-1}(\frac{2H}{D}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.6)$$

Where: Θ = angle of repose, (º)

H = height of cone, (cm)

D = diameter of cone, (cm)

Fig 3.4. Gudene varieties potato seed prepared for planting

3.4. Design Analysis of Major Components of the Planter

This assumption was on the basis literature reviews essential for the design that the three-bottom ridged planter also be used as two-row for potato planter. Power source was tractor which has 40 hp.

Brake horse power (BHP) = 40 hp (YTO tractor available in MARC).

Assumption Made (data obtained from agronomic requirements potato) (Mulatu *et al*.,2005).

1. Type of seed: Gudene varieties of potato seeds

2. Seed rate: 1800 -2500 $\mathrm{kg.\,ha^{-1}}$

3. Bulk density of potato: 650 $\mathrm{kg.\,ha^{-1}}$

4. Drawbar horse power (DBHP): 60 % of BHP of tractor

5. Speed of operation: 3^{rd} gear of tractor

We know, 4WD tractor drawbar horse power (DBHP) = 60% of BHP

Therefore, DBHP = 40 hp × 0.6 = 24 hp

The tractor drawbar horse power (DBHP), draught available (Df) and the number of the row (n) was calculated by equation (3.7), (3.8) and (3.9) (Sharma and Mukesh, 2010).

$$\mathrm{DBHP} = \frac{\mathrm{Df\ x\,V}}{270} \qquad (3.7)$$

Where: Df = Draft force, (kg)

V = Speed, ($\mathrm{km.\,hr^{-1}}$)

Generally, the speed of planting potato was done in the range of 3 to 5 $\mathrm{km.\,hr^{-1}}$. (ASABE, 2011).

Let the forward speed of planter be 3.5 $\mathrm{km.\,hr^{-1}}$.

Putting the values in the equation (3.7), Draught available for planting = $\frac{24 \text{ hp} \ \times 270}{3.5 \text{ km/hr}}$ = 1851 kgf

$D_f \geq CrG\cos\theta + \varepsilon.n.a.b.\ V^2 \pm G\sin\theta$ ……..………………..…...………………………..….. (3.8)

Where: Df = the draft force developed by the power source, (N)

Cr = coefficient rolling resistance

G = weight of the implement including seed, (N)

a = depth of furrow, (cm)

b = width of furrow, (cm)

ε = constant depending on the furrow opener surface, ($N\text{-}s^2/m^4$)

V = velocity of operation, ($m.s^{-1}$)

Ө = ground gradient, (°)

Soil and land characteristics

Soil type = heavy clay

Coefficient of resistance, μ = 0.03

Slope of the land, i= 2%, $\Theta = 1.718°$

Furrow opener and ridger characteristics

Unit draft, k = 0.5 $N.cm^{-2}$

Total weight of the implement and seed, G = 350 kgf

Df = 1851 kgf

b= 45 cm

a = 15 cm

ε= 1500 $N\text{-}S^2/m^4$

Calculate each component of the planter draft (take g = 9.81 $m.s^{-2}$)

$\mu G\cos\theta = (0.03) \times \frac{1}{2}(350 \times 9.81) \times (1) = 51.5$ N

k.a.b = (0.5 x 15 x 45) = 337.5 N, (ridger)

k.a.b = (0.5 x 15 x 30) = 225 N, (furrow opener)

ε. a.b. V^2 = (1500 x 0.15 x 0.45) x $(0.9722)^2$ = 95.7 N

Gsinθ = $\frac{1}{2}$ Gi = $\frac{1}{2}$ (350 x 9.81) x sin1.718 ° = 51.4 N

$$n \leq \frac{D-\left[\frac{z}{wd}\right]^{0.5} G\cos\theta - Gi}{k.a.b} \quad \text{.......................................} \quad (3.9)$$

$$n \leq \frac{1851-515-51.4}{562.5}$$

n ≤ 2.28

Therefore, the number of the row are two (to be safe)

Number of the row, n= 2

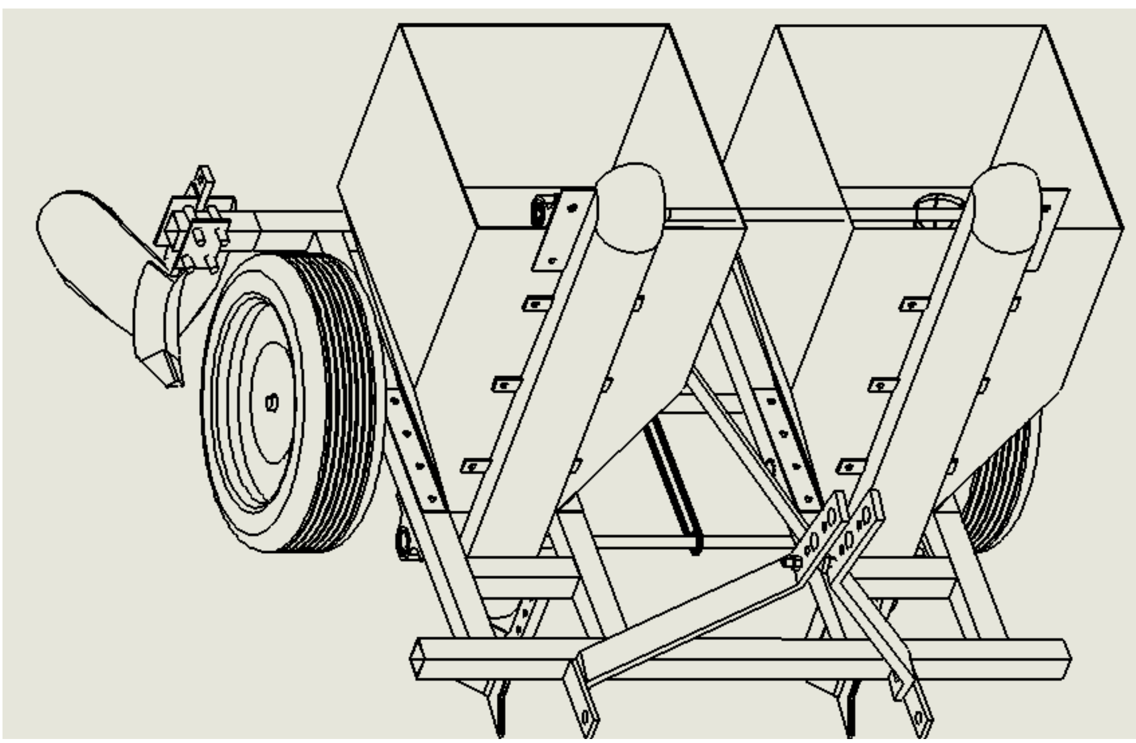


Fig 3.5. 3D view of the prototype potato planting machine

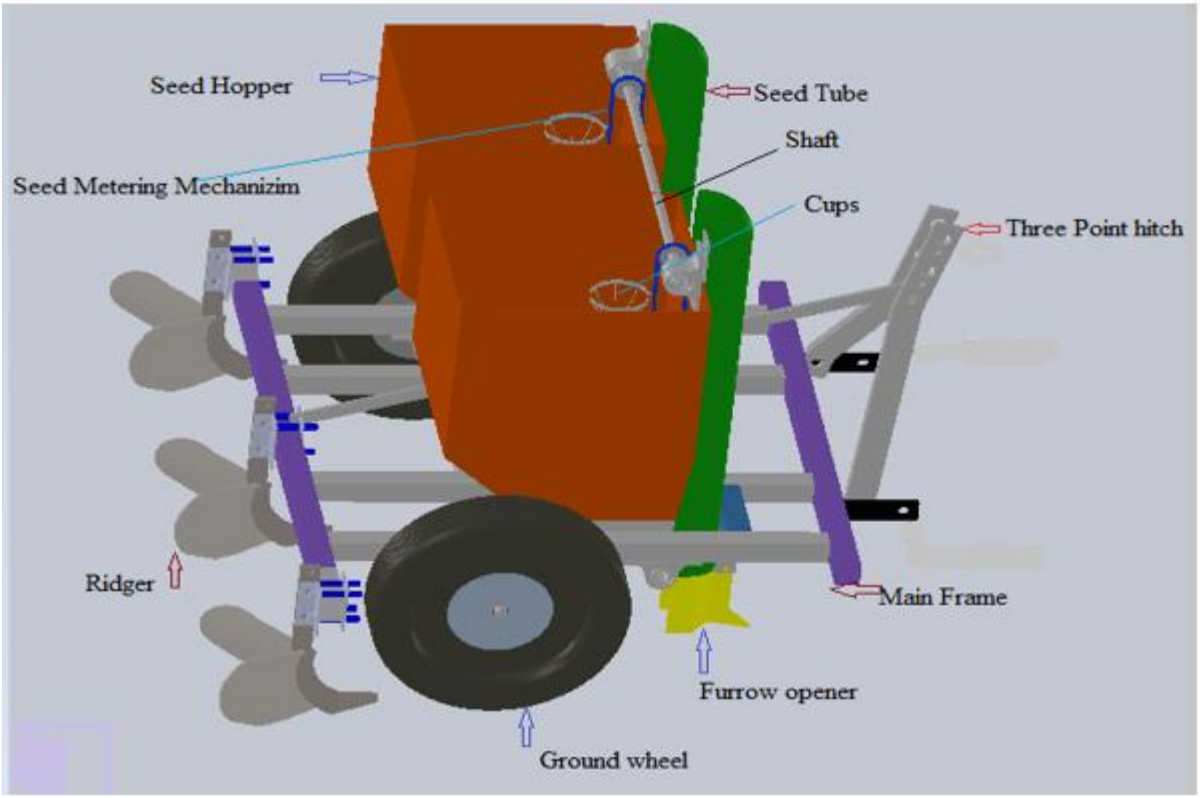


Fig 3.6. Diagram of the prototype potato planter

3.4.1. Design of the Seed Hopper

On the basis of reviews and studies of physical properties of Gudene potatoes variety, the average bulk density of potato seed was 650 $\mathrm{kg.m^{-3}}$ and the angle of repose was 37° had taken for designing the seed hopper. Rectangular shape at the top and trapezoidal shape at the bottom of seed box is used in the machine for free flow of seed in hopper bottoms. The capacity of the hopper was determined considering following factors.

Agronomic requirement Gudene potatoes variety:

- Row to Row distance: 60 cm
- Seed rate (assumed): 2500 $\mathrm{kg.ha^{-1}}$
- Capacity of hopper: cover 100 m length of run

Area covered in 100 m length of run = 2 × length of run × enter row spacing

= 2 x 100 x 0.6 x 2 = 240 $\mathrm{m^2}$

Potato seed required (kg) = Area covered × seed rate = 240 × 0.25 = 60 kg

Potato seeds are kept 15 kg more as to safe therefore the capacity of the hopper was kept 75 kg. As the angle of repose of potato seed was 37°, therefore the angle of the hopper side wall was kept as 53°. The volume of hopper was calculated by equation (3.10) (Klenin *et al.*, 1985).

$$\text{Volume of hopper} = \frac{\text{weight of potato tubers}}{\text{bulk density of potato tubers}} \qquad (3.10)$$

$$= \frac{75\ \text{kg}}{650\ \text{kg.m}^{-3}} = 0.115\ \text{m}^3$$

Based on the above stated of rates of seeding, the volume of the hopper was estimated using the equation given by equation (3.11) (Olaoye and Bolufawi, 2001).

$$v = \frac{\text{SR}}{\text{n x BD}} \qquad (3.11)$$

where: SR = seeding rate, (kg.ha^{-1})

n = number of refilling per hectare = 26.6

BD = bulk density of the seeds, (kg.m^{-3})

$$\text{Volume of hopper for potato} = \frac{2000\ \text{kg.ha}^{-1}}{26.6\ \text{x}\ 650\ \text{kg.m}^{-3}} = 0.115\ \text{m}^3$$

Thickness of hopper was estimated by equation (3.12) (Klenin *et al.*, 1985).

$$t = \sqrt[3]{\frac{(\text{Fs})\ \text{x}\ (3\text{hL}^2)\ \text{x}\ (\rho\text{s})\ (\text{g})}{\text{K}_{1\sigma\text{max}}}} \qquad (3.12)$$

Where: σ_{max}=maximum bending stress, (N.m^{-2})

Fs = factor of safety, (3)

h= height of hopper, (m)

L= length of hopper, (m)

g= acceleration due to gravity, (m.s^{-2})

ρs=seed bulk density, (kg.m^{-3})

t= thickness of the hopper, (mm)

K_1= constant, (1-1.5)

t= 2 mm

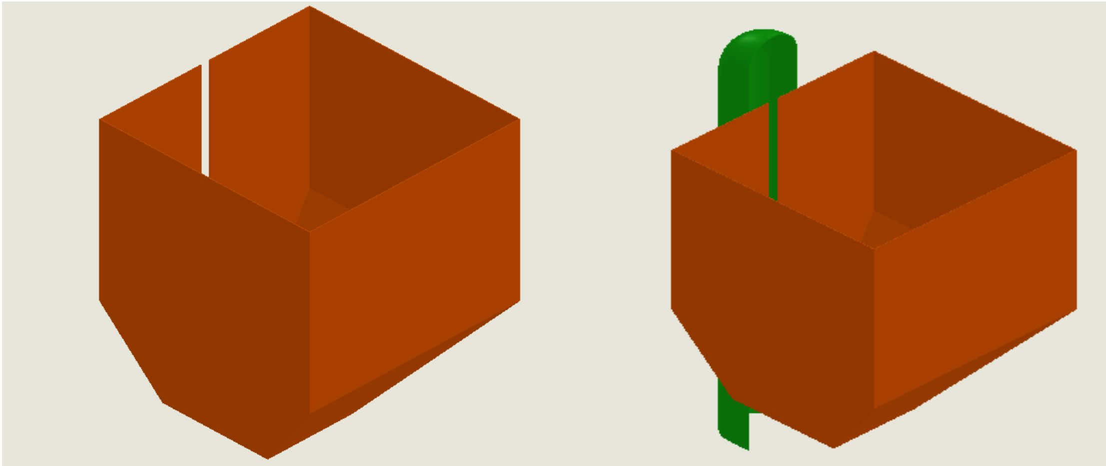


Fig 3.7. Seed hopper

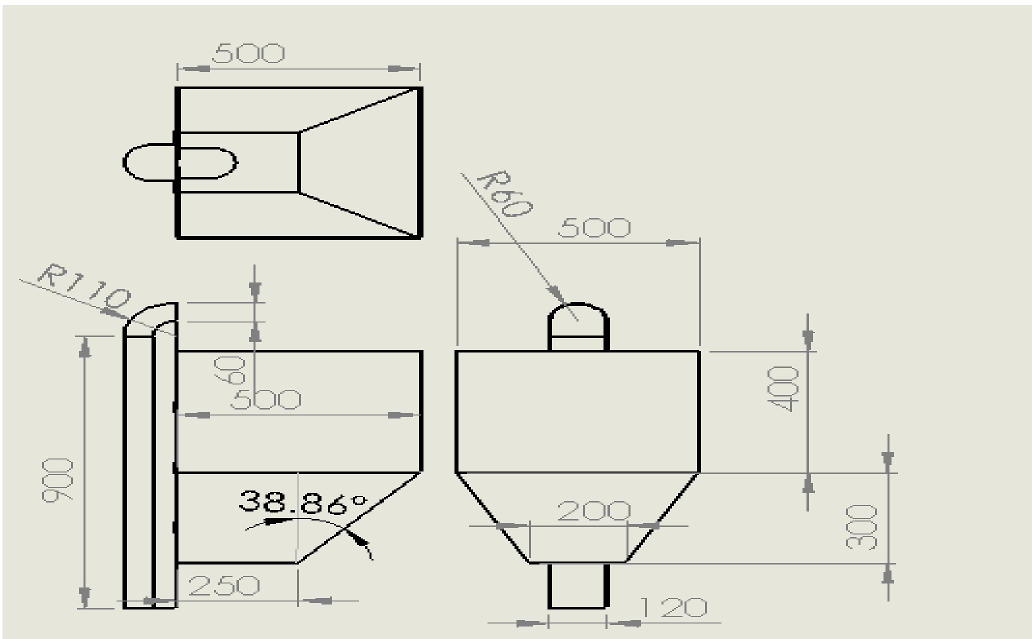


Fig 3.8. Isometric view seed hopper (all dimensions are in mm)

The specifications of seed box are:

Length of seed box = 500 mm

Bottom width of seed box = 200 mm

Top width of seed box = 500 mm

Height of seed box = 700 mm

Angle = 38.86°, (taking the maximum angle of response from five tested varieties)

3.4.2. Design of Main Frame

Design was based on the stresses produced in the frame. The consideration was given on lightweight mainframe but strong enough. To withstand the imposed loading during operation appropriate material sections and strength were kept in view for resistance against bending and twisting.

The frame of planter was made strong and convenient for proper assembling of various parts to it Fig 3.9. The furrow openers and ridgers were fitted with the help of c-clamps on MS square section (60 × 60 × 3 mm). To this hollow frame, two pieces of same MS square of length 100 cm were welded horizontal on the tool bar at 100 mm distance from both end of the tool bar. Another piece of same MS square section having length 280 mm was welded at the center of these two horizontal free ends. Four MS angle of (60 × 60 × 3 mm) were fitted with the help of nut and bolts at the end of the tool bar.

The seed hopper was fitted at vertical distance of 260 mm on four MS angles with the help of nuts and bolts. Two furrow openers were fitted on front beam of the frame at the distance of 150 mm from the both end of the front beam and three ridgers were fitted on the rear beam of the frame at the distance 60 mm from both side of furrow openers with the help of c-clamps. The three-point linkage was welded at the centre of front beam of the frame.

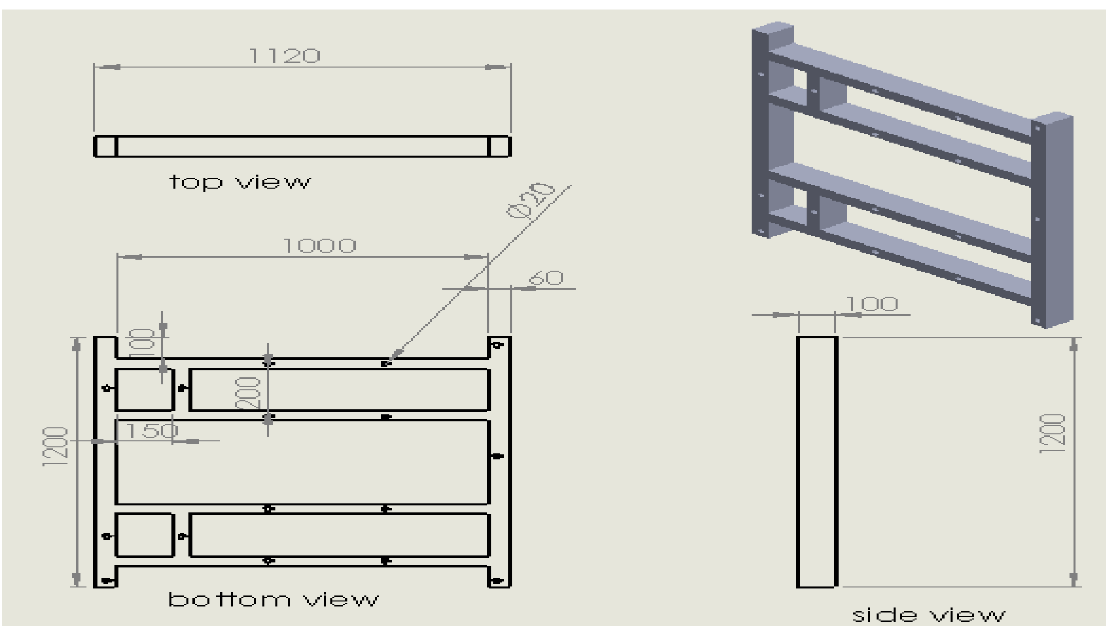


Fig 3.9. Isometric view of main frame (all dimensions are in mm)

The design was based on the total stress produced in the bar. To estimate total draft was given by equation (3.13) (Bosai, *et al.*, 1987).

Total draft = k.n.a.b ……………………….….….…………………………………. (3.13)

= (0.5 x 2 x 15 x 45) = 675 kg

= 675 x (factor of safety) = 675 x 2 (Factor of safety for M.S. = 2) = 1,350 kg

Where: k = unit draft

a = depth of furrow, (cm)

b = width of furrow, (cm)

Torque on the square bar = draft x ground clearance

Ground clearance = 30 cm

T = 1,350 x 30 = 40,500 kg-cm

In addition to the torque, bending moment would also be produced. The bar was considered as simple supported beam on the frame in between the two furrow openers. To estimate maximum bending moment was given by equation (3.14) (Bosai, *et al.*, 1987).

M_{max} = W x I ……………………………..……………………………...……………... (3.14)

Where: W = Total draft (total weight on frame) = 1,350 kg

I = Total length of frame = 150 cm

M_{max} = Maximum bending moment

=1,350 kg × 150 cm = 202,500 kg-cm \

Equivalent torque due to torsion and bending moment given by equation (3.15) (Khurmi and Gupta. 2003).

$Te = (M_{max}^2 + T^2)^{\frac{1}{2}}$……………………….…………………………………...………...… (3.15)

Where: Te= Equivalent torque, kg-cm = $(202{,}500^2 \ + 40{,}500^2)^{\frac{1}{2}}$ = 206,510.3 kg-cm

T = Torque on the bar, kg-cm = 206,510.3 kg-cm

M_{max} = Maximum bending moment (kg-cm)

The maximum shear stress and polar moment of inertia developed at the centre of the tool frame was obtained by equation (3.16 and 3.17) (Khurmi and Gupta. 2003).

$$\frac{1}{4}\frac{\text{fs x R}}{\text{d}} = \frac{\text{Te}}{\text{I}} \qquad (3.16)$$

Where: fs = Shear stress at any section

R = Distance of the section from neutral axis (assume = 10 cm)

Te = Torque produced

I = Polar moment of inertia, t = 9.6

The maximum working stress of 1120 kg.cm^{-1} was occurred at the centre of the frame.

For square section having each side measuring d,

$$\text{I = Polar moment of inertia} = \frac{d^4}{9.6} \qquad (3.17)$$

The factor of safety was taken as 4, Fs is 1,120 kg.cm^{-1}.

$$\frac{1120 \text{ x } 10}{\text{d x } 4} = \frac{206510.3 \text{ x } 9.6}{d^4}$$

$d^3 = \frac{206510.3 \text{ x } 9.6}{1120 \text{ x } 10}$ = 5.6 cm, taken the width of section = 60 mm

Therefore, considering availability of next higher section the square bar section 60 x 60 x 3 mm was selected to made the frame of potato planter.

3.4.3. Design of Furrow Opener

After a study of various available furrow openers, it is deciding on the basis of the soil type that a tyne type furrow opener will be most suitable for this planter because the tyne is to work in the till soil to form a furrow of sufficient width to facilitate proper placement of potato seeds and shovel type furrow openers forms a good furrow.

It is assumed that the draught force on furrow opener is 50 to 100 kgf/tyne and acting and a height of h/3 from the bottom of the furrow opener where, the h is total length of furrow opener and tyne. Standard will be in bending so, it will design for easy operation and proper balancing of machine, maximum height of furrow opener tyne is taken as 20 cm (Bosai, *et al.,* 1987).

Considering the available draft of kgf from a tractor as exerted on the tip of the furrow openers of 30 cm length by equation (3.18) (Bosai, *et al.*, 1987).

Total draft = k.n.a.b …………………………………………………………...……..… (3.18)

$$= (0.5 \text{ x } 2 \text{ x } 15 \text{ x } 30) = 450 \text{ N}$$

$$= \frac{450}{2} = 225 \text{ N for each furrow opener.}$$

Bending moment = draft x length of shank

$$= 450 \text{ N x } 30 \text{ cm} = 13{,}500 \text{ N-cm}$$

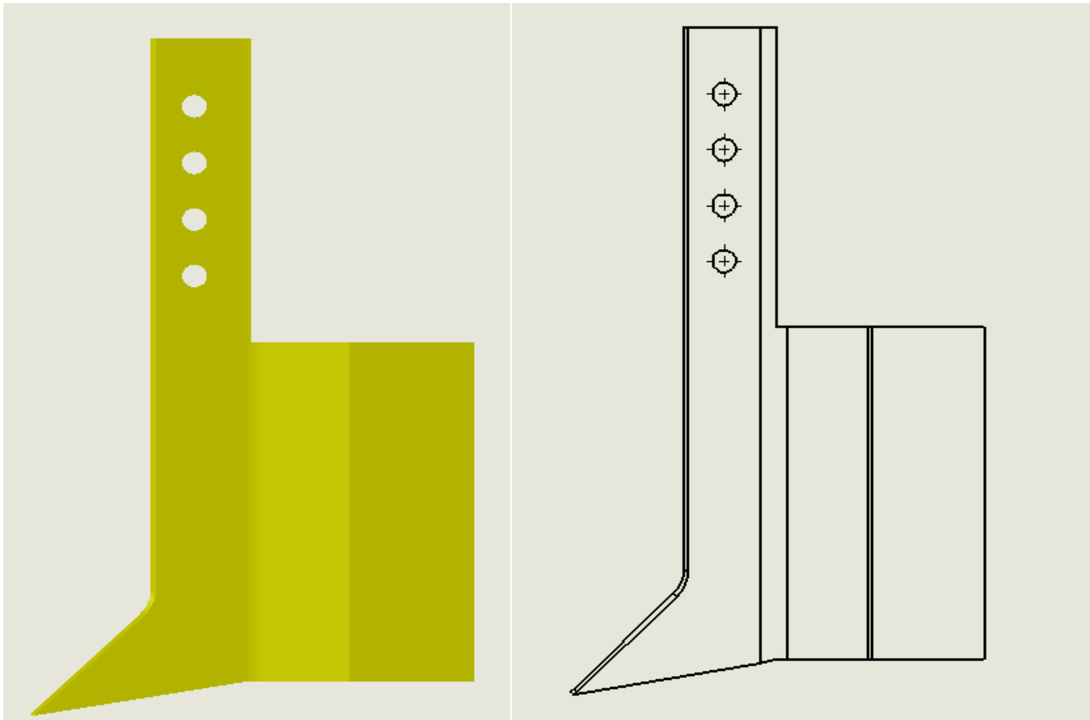


Fig 3.10. Furrow opener

To estimate bending stress, section modulus and width of shank by equation (3.19,3.20,3.21 and 3.22) (Bosai, *et al.*, 1987).

$$f = \frac{M \times C}{I} \qquad (3.19)$$

Where: f = Bending stress, $(\mathrm{kg.\,m^{-2}})$

I = Moment of inertia, $(\mathrm{m^4})$

M = Bending moment, (kg-cm)

c = Distance from neutral axis to the point at which stress is determined, (cm)

The section modulus axis was computed by using formula

$$Z = \frac{M}{C} \qquad (3.20)$$

Assuming the bending stress is equal to 1120 $\mathrm{kg.\,m^{-2}}$.

$Z = \frac{13,500}{1120} = 12.08\ m^3$

Section modulus of the furrow

$$Z = \frac{bh^2}{6} \quad \text{……………………………………………………………………………………} (3.21)$$

Width of shank was considered as 1:4, i.e. (h: 4b) (Bosai, *et al.*, 1987).

$$Z = \frac{b\ x(\ 4b)^2}{6} \quad \text{……………………………………………………………………………} (3.22)$$

$12.08 = \frac{16\ b^3}{6}$

b = 1.65 cm = 16.5 mm

Considering the factor of safety and availability of material is standard size.

The thickness of shank furrow opener was selected =10 mm

Therefore, the width of the shank = 4 x 10 = 40 mm.

Therefore, a Mild steel flat tyne of 40 × 10 mm size was selected.

3.4.4. Seed Metering Mechanism

The feed cup type seed metering was selected for the machine for sowing of this for five different potato varieties. The dimensions of each feed cup were decided by maximum size of potato tubers from five varieties can be put in the feed cups considering the mean geometric diameter of the potato tubers and shape cup was determined based on shape index of potato seed.

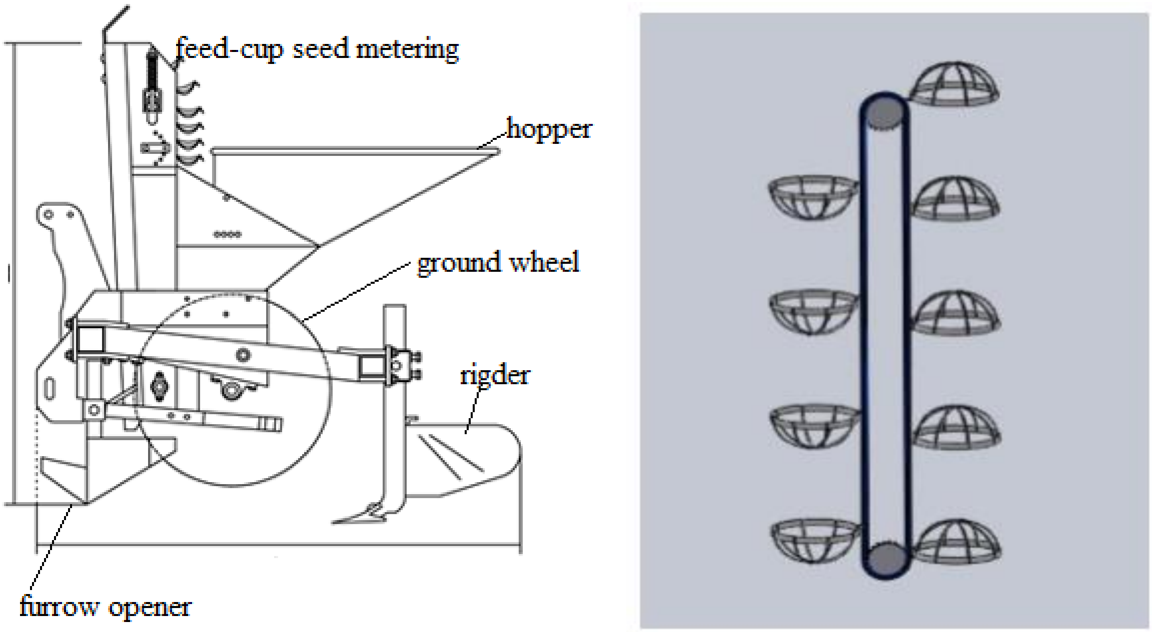


Fig 3.11. A schematic diagram of the feed cup metering mechanism

The number of cups on metering cup (n) was calculated by equation (3.23) (Sharma and Mukesh, 2010).

$$n = \frac{\pi \text{ x } D}{Nr \text{ x } S} \quad (3.23)$$

Where: D = diameter of transmission wheel, (cm).

Nr= speed ratio, transmission wheel to cup.

S = spacing required between two seeds, (cm).

The diameter of transmission wheel was taken as 60 cm considering the availability of the sprockets, the speed ratio, Nr was kept 1:3. Substituting required from agronomic requirement of five potato varieties spacing of 30 cm in combination with D, Nr and in above equation (3.23), the number of cups were calculated as:

$$n = \frac{3.14 \text{ x } 60}{1:3 \text{ x } 30} = 18$$

Therefore, eighteen cups were provided on the periphery of each metering chain. The metering chain has 18 numbers of cups on its periphery.

The dimensions of each cup were decided by maximum size of potato seeds could be put in the cells considering the dimension of the potato seeds.

The design methods seed metering mechanism selected for sowing potato seeds. The diameter of seed metering was determined by equation (3.24) (Sharma and Mukesh, 2010).

$$dr = \frac{Vr}{\pi Nr} \quad (3.24)$$

Where: dr = Diameter of seed metering, (m)

Vr = Peripheral velocity, ($m.min^{-1}$).

Nr = rpm of metering mechanism

The spacing between consecutive cups was calculated using equation (3.25) (Sharma and Mukesh, 2010).

$$t = \frac{\pi dr}{n} \quad (3.25)$$

The gear ratio was calculated using equation (3.26) (Sharma and Mukesh, 2010).

$$\text{Gear ration} = \frac{\text{Number of teeth on sprocket of seed metering shaft}}{\text{Number of teeth on sprocket of ground wheel}} \quad (3.26)$$

$$\text{Gear ration} = \frac{15\ \text{teeth}}{45\ \text{teeth}} = 1:3$$

Based on (ASABE, 2011) recommendation operation speed of tractor drawn potato planter was 3 up to 5 $km.h^{-1}$.

- Speed selected for design 3.5 $km.h^{-1}$.
- Number of teeth on sprocket of ground wheel was 45.
- Number of teeth on sprocket of seed metering shaft was 15.

3.4.4.1. Design of Seed Metering Cups

The dimensions of each feed cup were decided by average size of five varieties potatoes tubers can be put in the feed cups taking into accounted the dimension of the potato tubers. Diameter cup 62 mm and thickness of rod 5 mm it made from MS rod metals.

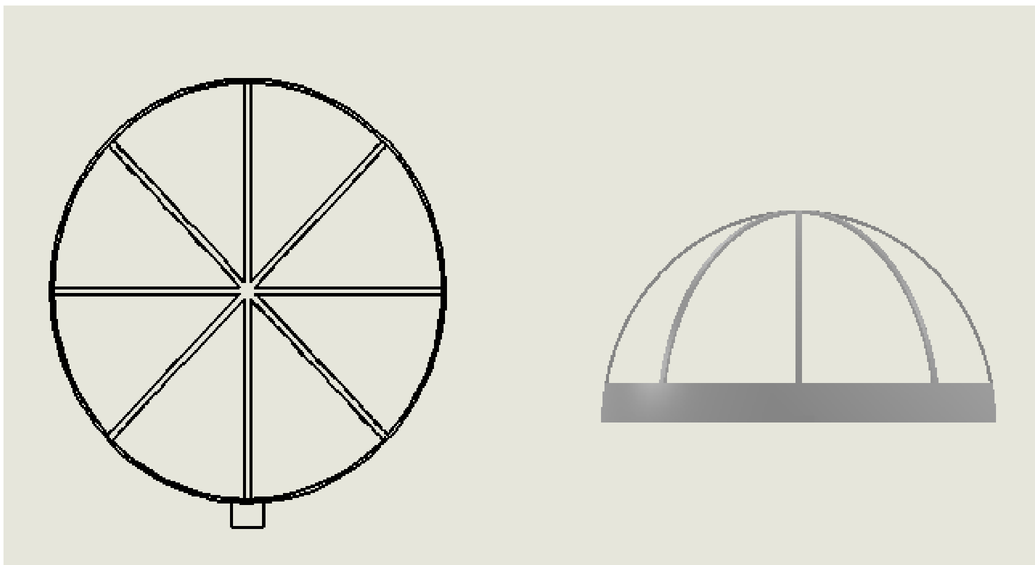


Fig 3.12. Isometric view of seed metering cups

3.4.5. Estimation of Weight the Planter using Solidwork Software

3.4.5.1. A Solidwork Software Weight Determination Output of Each Components

The weight of each part designs was calculated using Solidwork software 2013. The input of the software was part design equipped with dimensions and material type selection. The software has its own material types with their densities. Once the part design was feed with dimensions and material type, the Solidwork 2013 gave the output of the selected component area, volume and mass.

Table: 3.3. A Solidwork2013 weight determination analysis for each components of potato planter

Sr. No.	Components	Quantity	Area (m^2)	Volume(m3)	Density (kg/m^3)	Unit mass (kg)	Total mass (kg)
1	Main shaft	1	1.72	0.00172	8000	13.74	13.76
2	Seed hopper with outlets	2	2.62	0.00262	8000	20.96	20.96
3	Frame	1	2.26	0.003384	7870	26.62	26.62
4	3-pt Linkage	1	0.52	0.00225	7870	17.70	17.70
5	Ground wheel	2	0.77	0.0023	7870	22.18	26.20
6	Metering shaft	2	0.059	0.00295	7870	4.64	6.69
7	Bearing	6	0.294	0.0162	7870	12.72	12.72
8	Ridger	3	0.36	0.0172	7870	20.4	20.4
9	Seed tube	2	0.028	0.00104	7870	1.64	1.64
10	Angle iron	5	0.021	0.0045	7920	0.362	1.81
11	Metering Devices	2	0.012	0.00106	7870	1.66	1.67
	Total weight of component parts						151
12	2% for bolts, nuts and other						3.02
	Total weight including wheels and wheel shaft						155

Total mass of all components which lay on the wheel shaft was 155.0 kg.

Weight of seed potato = 75 kg + 75 kg = 150 kg

The weight of planter was calculated by using equation (3.27) (Sharma and Mukesh, 2010).

$$W = m \times g \quad \ldots\ldots (3.27)$$

Where: W= weight, (N)

m=total mass of the parts, (kg)

g= acceleration due to gravity, ($9.81\ m.s^{-2}$)

W = 155 kg x 9.8 $m.s^{-2}$= 1,520.55 N

Total weight of a 4WT drawn potato planter was becoming:

WT = Weight of parts + weight of potato

WT = 1,520.55 N + 1,471.5 N = 2,992.05 N

The total weight of the prototype planter including the weights of seed hopper, seed hopper, frame, seed metering roller, metering shaft, furrow opener, furrow coverer, seed tube, seed and three-point hitch was estimated. Assume 2% margins for the weights of welding bolts, nuts, chains, etc. the total weight was found to be 2,992.05 N.

3.4.6. Chain and Sprocket

Locally available chain and sprocket were selected for transmitting power from ground wheel shaft to shaft of metering mechanism. The chains are mostly used to transmit motion and power from one shaft to another. The power required to operate the seed metering mechanism was transmitted from the drive wheel through chain drive. Since the power transmitted in the potato planter is very low, the smallest size available chain, i.e. motor bicycle chain was used for tractor drawn potato planter. For power transmission, 45 teeth size sprocket was fitted on drive wheel. Another sprocket of 15 teeth size was used for driving shaft so that the transmission ratio of approximately 1:3 was maintained.

3.4.6.1. Calculation of Chain Length

The length of chain was calculated using equation (3.28 and 3.29) as number of links x chain pitch i.e. by (Singh and Sadhu, 1988).

$$L = m \times p \quad (3.28)$$

Where: m = number of chain links

p = chain pitch, (mm)

But, Number of chain links

$$m = 2Cd + \frac{(N1+N2)}{2} + \left(\frac{(N1-N2)}{2\pi Cd}\right)^2 \quad (3.29)$$

Where: Cd = Centre distance, (mm)

P = Chain pitch, (mm).

N1 = Number of teeth of pinion.

N2 = Number of teeth of sprocket.

Putting the values in eqn.3.37

M = 2 x 35.7 + $\frac{(45+15)}{2} + (\frac{(45-15)}{2\pi x 35.7})^2$ = 101.418 pitches

The nearest even number of pitches for the chain is 102 pitches

Therefore, the corrected length of chain is L= 102 x 12.5 mm = 1,275 mm

Exact center to center distance between the sprockets expressed by equation (3.30, 3.31 and 3.32) Singh, Sadhu, 1988).

C = (e + $\sqrt{e2 - 8m}$ x $\frac{p}{4}$……………………………………………………………………………… (3.30)

e = Lp – $\left(\frac{N1+N2}{2}\right)$……………………………………………………………………………… (3.31)

e = 90 – $\left(\frac{45+15}{2}\right)$ = 60

m = $\left(\frac{N2-N1}{2}\right)2$……………………………………………………………………………… (3.32)

m = $\left(\frac{45-15}{2}\right)2$ = 225

Therefore, the corrected center to center distance between the sprockets was

C = (60+ $\sqrt{(60)2 - 8(225)}$ x $\frac{12.5}{4}$

C = 320.6 mm $\approx$ 440 mm

3.4.6.2. Chain Velocity

Average chain velocity estimated by equation (3.32) (kurtz et al. 1984).

$$Vav= \frac{n \text{ x } p \text{ x } rpm}{376} \qquad (3.33)$$

$$Vav = \frac{45 \text{ x } 0.25 \text{ in x } 36}{376}$$

$= 1.077$ m/sec

Where: n = the driven sprocket no. of teeth, (45)

rpm = maximum revolution of the driving sprocket, (3.5 $\mathrm{km.h^{-1}}$ = 36 $\mathrm{rev.min^{-1}}$)

P = commercially available chain pitch, (6.35 mm = 0.25 in)

Vav = Average chain velocity, ($\mathrm{m.s^{-1}}$)

3.4.6.3. Chain Force

The total load (force) on the driving side of the chain was calculated by using equation (3.34, 35, 36 and 37) (Sharma and Mukesh, 2010).

$$FT= F + Fc + Ff \qquad (3.34)$$

Where: FT= the total force, (N)

F = the force due to power transmission, (N)

Ff= Frictional force, (N)

Fc= Centrifugal force on the chain, (N)

$$F = \frac{P}{Vav} \qquad (3.35)$$

$$F = \frac{481.02 \text{ kW}}{0.5744 \text{ m.sec}^{-1}} = 837.43 \text{ N}$$

$$Fc = \frac{W \text{ X } (Vav)^2}{g} \qquad (3.36)$$

$$Fc = \frac{24\ x\ (0.5744)2}{9.81 \text{ m.s}^{-2}} = 0.807 \text{ N}$$

$$Ff = W \times kf \times Cc \qquad (3.37)$$

Ff = 24 N/m × 1 × 0.277 m

Ff = 1.83 N

Where: Cc = Nominal center to center distance between the sprockets, (0.277 m)

P = Power at the potato planter wheel/ power to be transmitted, (481.02 w = 0.48 hp)

kf = Friction factor= 4 for horizontal drive, 2 for inclined drive and 1 for vertical drive, Since the sprockets are vertical aligned, kf = 1 (Norton, 2005).

W = Weight per meter of the chain, (24 $\mathrm{N.m^{-1}}$)

g = Gravitational acceleration, (9.81$\mathrm{m.s^{-2}}$)

Thus, FT = 837.43 N + 0.807 N + 1.83 N

FT = 840.067 N

According to ANSI standard, the minimum tensile strength of the chain was 3,470 N. To avoid breakage or failure of the chain, the safety factor should be more than one. Checking safety factor, Sf by using equation (3.37) (Sharma and Mukesh, 2010).

$$\mathrm{Sf} = \frac{\text{Tensile strength}}{\mathrm{FT}} \quad \text{(3.38)}$$

$\mathrm{Sf} = \frac{3470\ \mathrm{N}}{840.067\ \mathrm{N}}$ = 4.13, the value is greater than unity. It was safe.

3.4.7. Estimation of Force and Torque Required to Drive the Planter

3.4.7.1. Estimation of Force Required to Drive the Planter

A rolling resistance force (F), which was assumed to act horizontal at the wheel and ground interface or ground and wheel contact patch, was estimated using the Eq. (3.39 and 3.40) (Reece,2002)

$$F = (C_R + i) \times N \quad \text{(3.39)}$$

$$F = \left(\left(\frac{z}{d}\right)^{1/2} + i\right) x\, N \quad \text{(3.40)}$$

Where: CR = coefficient of rolling resistance

d = wheel diameter, (60 cm)

z = maximum wheel sinkage depth, (on a soft surface z$\approx$ 0.05d = 3 cm)

N = weight of the planter on each wheel, $(\frac{2992.05}{2})$ = 1,496.025 N

i = gradient of the ground, (let i = 5%, Reece,2002)

F = $\left(\frac{3\text{cm}}{60\text{cm}})^{1/2} + 0.05\right) \times 1{,}496.025 = 409.32$ N

3.4.7.2. Torque on the Ground Wheel

Torque on the ground wheel estimated by using equation (3.41) (Sharma and Mukesh, 2010)

T = F $(\frac{d}{2})$ ………………………………………………………………………………. (3.41)

T = 409.32 $(\frac{0.6}{2})$ = 122.8 Nm

Where: T = torque, (Nm)

F = Rolling resistance force, (N)

d = diameter of ground wheel, (m)

3.4.7.3. Power Requirement of the Planter

The wheel covers 1.884 m in one revolution and taking a 0.9722 m.s^{-1} (36rpm) forward speed of tractor drawn planter.

Power requirement of the planter given by using equation (3.42) (Sharma and Mukesh, 2010).

P = T × Nw……………………………………..................…....................................…… (3.42)

Where: Nw= wheel revolution, (36 rpm)

P = (122.8 Nm) × (36 x $\frac{2\pi}{60}$)

P = 462.7 w = 0.4627 kw

3.4.8. Design of Shaft

Metering shaft was made of mild steel rod. The length of the bar was kept as 1500 mm to facilitate pinion of the bevel gear on the both ends and sprocket at the middle of shaft. The shaft was rested on two hubs which was fitted on the frame.

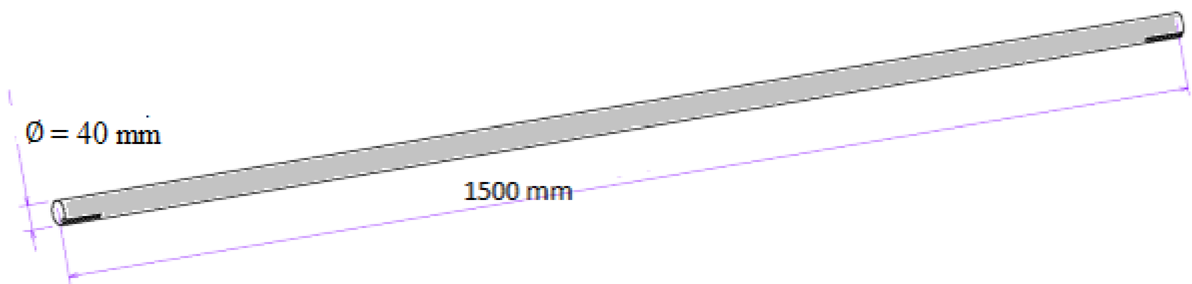


Fig 3.13. Isometric view of shaft

The shaft was initially decided to be fabricated from ductile material (mild steel rod). Hence, the design was based on ductile material whose strength is controlled by maximum shear stress. For a shaft having little or no axial loading, the diameter of the shaft was obtained using the ASME code equation (Eq. 43), (ASME, 1995) given as:

$$\emptyset = \sqrt[3]{\frac{16}{\pi \text{ x} Ss} \quad ((Kb \text{ x } Mb)2 + (KtMt)^2)^{1/2}} \quad \ldots\ldots\ldots\ldots \quad (3.43)$$

Where: $\emptyset$ = diameter of the shaft, (mm)

Mt= torsional moment, (Nm)

Mb= bending moment, (Nm)

Kb= combined shock and fatigue factor applied to bending moment;

Kt= combined shock and fatigue factor applied to torsional moment;

Ss= allowable stress, $(\mathrm{MN.m^{-2}})$

a) Vertical Forces Distribution on the Shaft

The vertical load diagram on the driven wheel shaft was showed below

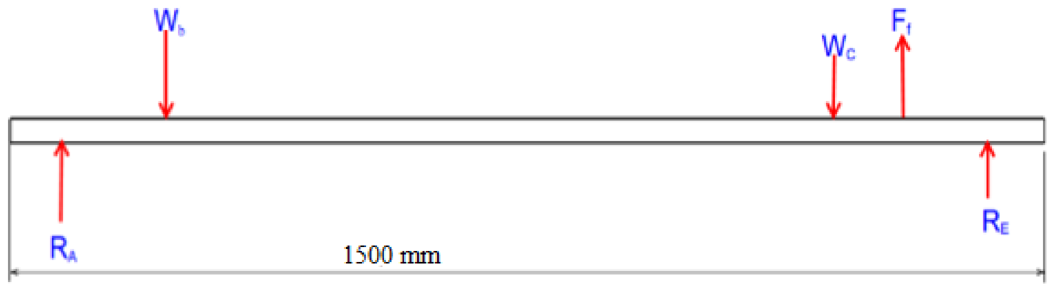


Fig 3.14. Vertical forces distribution on the shaft

Where: RA=Vertical reaction at wheel A

RE= Vertical reactions at wheel E

Wb = Half of the total weight acting at bearing B, (1,496.025 N)

Wc = Half of the total weight acting at bearing C, (1,496.025 N)

Ff = Vertical chain force

Total weight of the potato planter which lay on the shaft was 2,992.5 N refer section 3.4.5.1

WB=WC = 1,496.025 N ……………. are half of total weights

To know the unknown forces of RA and RB, used equilibrium equations methods.

$\sum MA = 0$

RE x 1.080 m + Ff x 1.5 – Wb x 0.21 m – Wc x 0.88 m= 0

RE x 1.080 m + 840.067 N x 1.5 – 1,496.025 N x 0.21 m – 1,496.025 N x 0.88 m=0

RE= 343.11 N

The summation of all forces gave RA and RB value.

RA+ 343.11 N + 840.067 N -1,496.025 N -1,496.025 N =0

RA= 1,809.32 N

b) Vertical Shear Force and Bending Moment Distribution

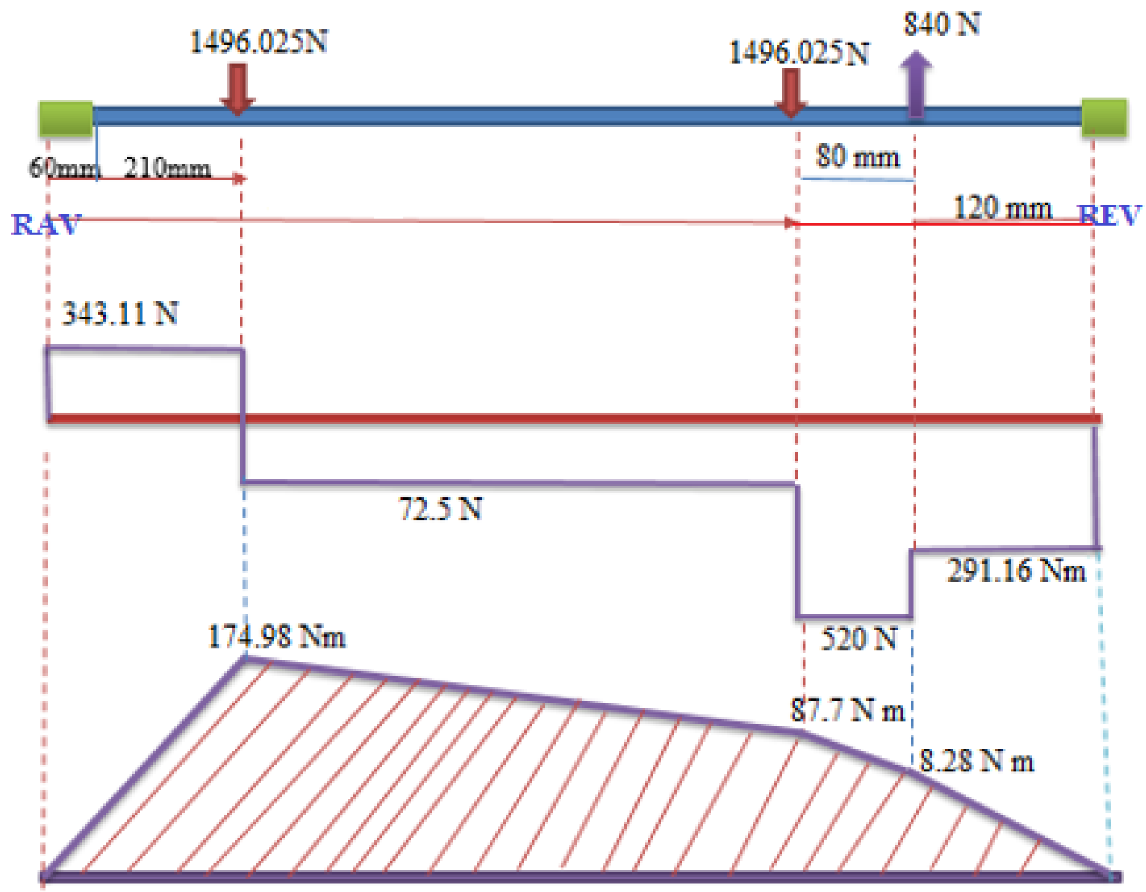


Fig 3.15. Shear force and bending moment diagram representation

The maximum moment was 174.98 Nm.

c) Horizontal Force Distribution on the Shaft

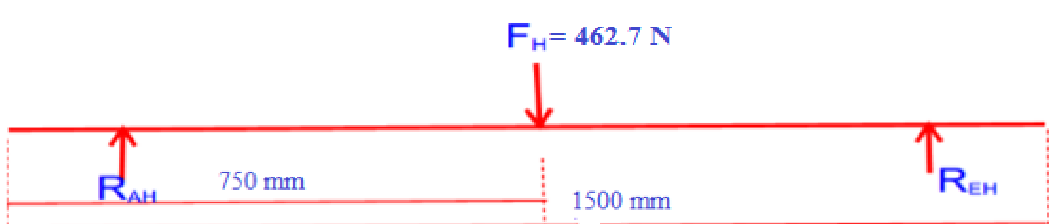


Fig.3.16. Horizontal force distribution

d) Horizontal Shear Force and Bending Moment Distribution

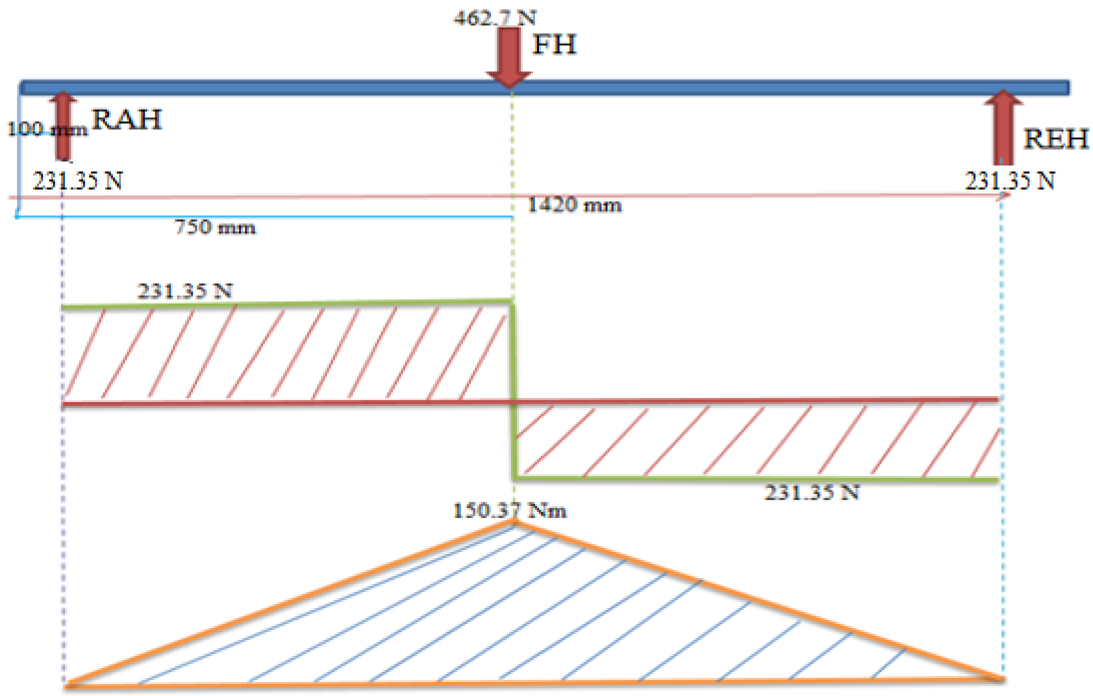


Fig 3.17. Horizontal shear force and bending moment diagram

REH + RAH = 462.7 N REH = RAH = $\frac{462.7\ \text{N}}{2}$ = 231.35 N

FH = 462.7 N REH = RAH = 231.35 N

Where: RAH= Horizontal reaction at wheel A

REH= Horizontal reactions at wheel E

FH = Horizontal force

For rotating shafts, when load was suddenly applied with minor shock, Khurmi and Gupta (2003) recommended that values of Kb = 1.2 to 2.0 and Kt = 1.0 to 1.50 to be used. Furthermore, it was noted that for shaft without key way, the allowable stress (Ss) must be 55 $\mathrm{MN.m^{-2}}$, and for the shaft with key way the allowable stress (Ss) should not exceed 40 $\mathrm{MN.m^{-2}}$.

Torsional moment (Mt) on the shaft was calculated using Equation (3.44 and 3.45) (Ryder, 1989).

$$Mt = \frac{P \text{ x } 60}{2\pi \text{ x } N} \quad \ldots\ldots (3.44)$$

$$P = V \text{ x } F \quad \ldots\ldots (3.45)$$

P = 0.9722 m/s x 462.7 N = 449.83 W

$$Mt = \frac{449.83 \text{ x } 60}{2\pi \text{ x } 36} = 119.38 \text{ Nm}$$

Where: P = power required to drive the machine, (449.83 W)

N = speed of the shaft, (36 rpm)

V = forward speed, (0.9722 ms^{-1})

F = force required to drive the machine, (462.7 N)

The maximum bending moment on the shaft was determined from the following expressions given by equation (3.46) (Richard et.al, 2011).

$$Mb = \sqrt{(Mv)^2 + (Mh)^2} \quad \ldots\ldots (3.46)$$

Where: Mb = Maximum bending moment, (Nm)

Mv = Vertical bending momentum= 174.98 Nm from bending moment diagram

Mh = Horizontal bending momentum = 150.37 Nm from bending moment diagram

$$Mb = \sqrt{(174.98)^2 + (150.37)^2}$$

= 230.71 Nm

Using equation (3.43)

$$\emptyset = \sqrt[3]{\frac{16}{\pi \text{ x } 55 \text{ x } 10^6} \text{ x } ((2 \text{ x } 230.71)2 + (1.5 \text{ x } 119.38)2)^{1/2}}$$

$\emptyset$ = 35.8 mm

Therefore, the standard size of 40 mm shaft diameter has been used.

3.4.8.1. Design of Seed Metering Shafts

The vertical load diagram on the driven wheel shaft was as showed below.

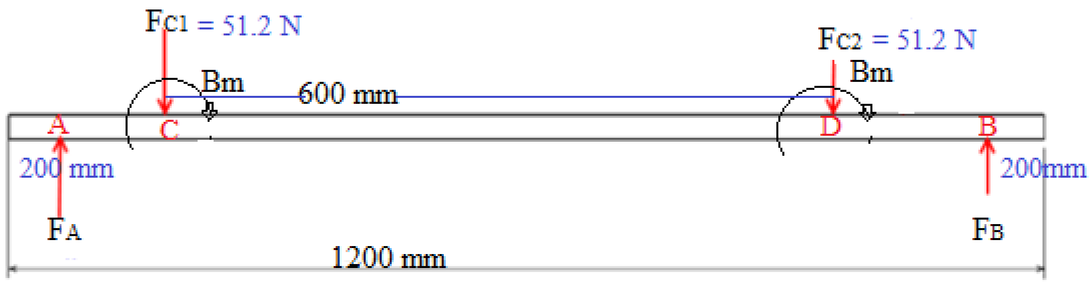


Fig 3.18. Vertical forces distribution on the shaft

Weight of seeds on 18 cups + weight of chain + weight of 18 cups

FA = 1.55 kg + 1.67 kg + 2.0 kg = 5.22 kg = 5.22 x 9.81 $\mathrm{m.s^{-2}}$ = 51.2 N

Let FA and FB = Reactions at A and B respectively.

∴ FA + FB = Total load acting downwards at C and D

= 51.2 + 51.2 = 102.4 N

Now taking moments about A,

RB × 800 = 51.2 × 700 + 51.2 × 100 = $\frac{40{,}960}{800}$ = 51.2 N

RB = 51.2 N and RA = 102.4– 51.2 = 52.1 N

A little consideration was showed that the maximum bending moment would be either at C or D. We know that bending moment at C,

MC = RA × 100 = 51.2 × 100 = 5,120 N-mm

Bending moment at D,

MD = RB × 100 = 51.2 × 100 = 5,120 N-mm

∴ Maximum bending moment transmitted by the shaft, M = Mb = 5,120 N-mm

From above equation: Torsional moment (Mt) on the shaft was calculated using Equation (3.43 and 3.44).

P = 0.9722 m/s x 51.2 N = 49.8 W

$$Mt = \frac{49.8 \text{ x } 60}{2\pi \text{ x } 36} = 13{,}210 \text{ N-mm}$$

The equivalent twisting moment on the shaft was determined from the following expressions given by equation (3.47) (Khurmi, R. and Gupta, J. 2003.)

$$Te = \sqrt{(\text{Km x M})^2 + (\text{Kt x T})^2} \quad \text{……………………………………………………..……… (3.47)}$$

Where: d = Diameter of the shaft.

Te = Twisting moment (or torque) acting up on the shaft

$$Te = \sqrt{(1.5 \text{ x } 5{,}120)^2 + (1.2 \text{ x} 13{,}210)^2}$$

Te = 17,614.4 Nmm

From above section (3.4.8) using equation (3.43)

$$\emptyset = \sqrt[3]{\frac{16}{\pi \text{ x } 55 \text{ x } 10^6} \text{ x } ((2 \text{ x } 5.21)2 + (1.5 \text{ x } 17.6144)2)^{1/2}}$$

$$\emptyset = 13.8 \text{ mm}$$

Therefore, the standard size of 20 mm seed metering shafts diameter has been used.

3.4.9. Design of Ground Drive Wheel

The planter's ground wheel, with external diameter of 600 mm, was designed as an integral part of the seed metering mechanism connected to the seed metering device directly.

The wheel was chosen depend on:

- Support the weight of the implement while limiting the sinkage into the soil surface and the resultant rolling resistance.
- Tread pattern which, together with the surface characteristics, determines the engagement and contact with the surface.
- Rubber tire tread form wide, low pressure and surface- low sinkage is suitable for agricultural machine.

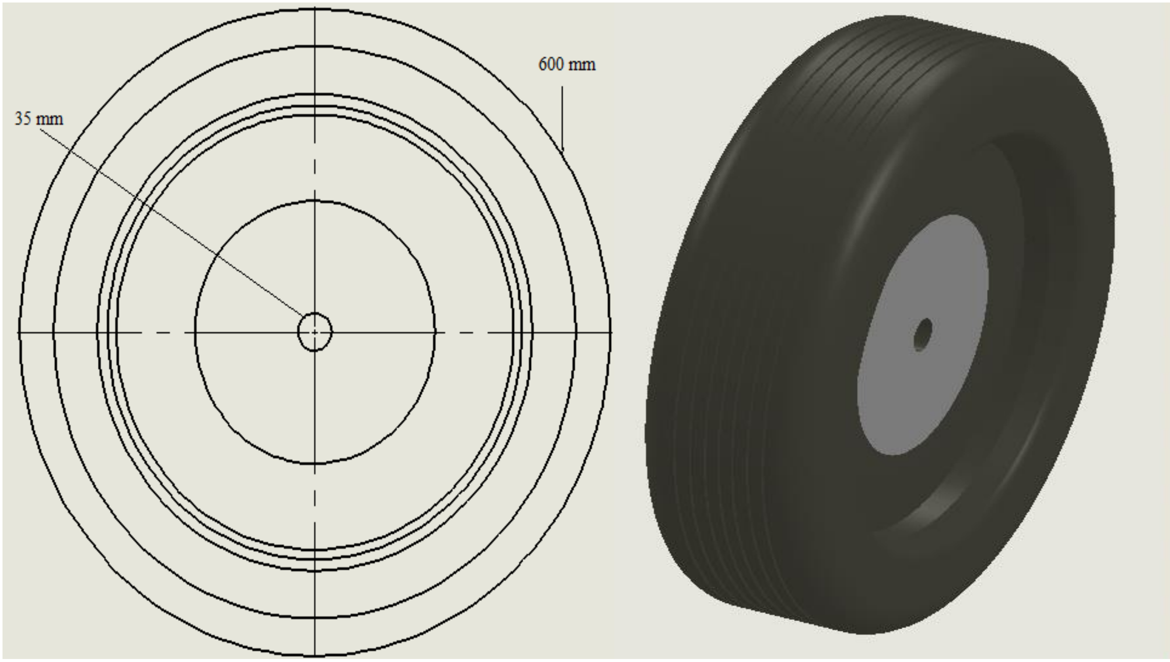


Fig 3.19. Isometric view of ground wheel drive

Estimation of the force required to drive the planter using equation (3.48) (Sharma and Mukesh ,2010)

$$ff = \left(\sqrt{\frac{Z}{Wd}} + i\right) \times Mwe \quad \text{……………………………………………………………………} (3.48)$$

Where: ff = Force required to drive the planter, (N)

Z = Maximum tolerable wheel sinkage depth, (let z=3 cm)

wd = Wheel diameter, (60 cm)

M_{we} = Machine weight on each wheel, (3384.45 N/2 = 1,496.025 N)

i = Gradient of the ground, (let i=5%, Reece,2002)

$$ff = \left(\left(\frac{3cm}{60cm}\right)^{1/2} + 0.05\right) \times 1{,}496.025 = 409.32 \text{ N}$$

Torque, shear stress and the area of the ground wheel, given by equation (3.49,3.50 and 3.51) (Sharma and Mukesh ,2010).

$$T = f_f \times \left(\frac{wd}{2}\right) \quad \text{…………………………………………………………………} (3.49)$$

$$T = 409.32 \times \left(\frac{0.60}{2}\right)$$

T = 122.8 N m

$$t = \frac{T}{2\ Am\ tw} \quad \ldots\ldots (3.50)$$

Where: T = the torque produced by the wheel, (122.8 Nm)

Am = the area of the wheel calculated based on the median diameter of the wheel, (m^2)

tw = thickness of the wheel wall, (0.005 m)

rm = the median radius of the wheel, (m)

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

$$Am = \pi \times r\ (rm)^2 = \pi\ (r - 0.5 \times tw)^2 \quad \ldots\ldots (3.51)$$

Am = 3.14 $(0.3 – 0.5 \times 0.005)^2$

Am = 0.28 m^2

Therefore, the shear stress (τ) on the wheel

$$\tau = \frac{122.8}{2 \times 0.005 \times 0.28} = 43.85 \text{ kPa}$$

Comparing this shear stress with the maximum allowable shear stress of the rubber, <<   max, 20-25 MPa, which tells us the wheel was safe for operation.

3.4.10. Bearing Selection

The optimal bearing must be selected to suit the nature of the machine, the area within the machine, the spindle specification, bearing type, lubrication system and drive system of the intended machine through considerations of the design life, precision, rigidity and critical speed, etc. of the bearing.

For shaft diameters from 15 to 100 mm, the housings have a square flange and four drilled holes for attachment bolts. Bearing units for metric shafts are available in two series, depending on the housing design (ASTM, 2014).

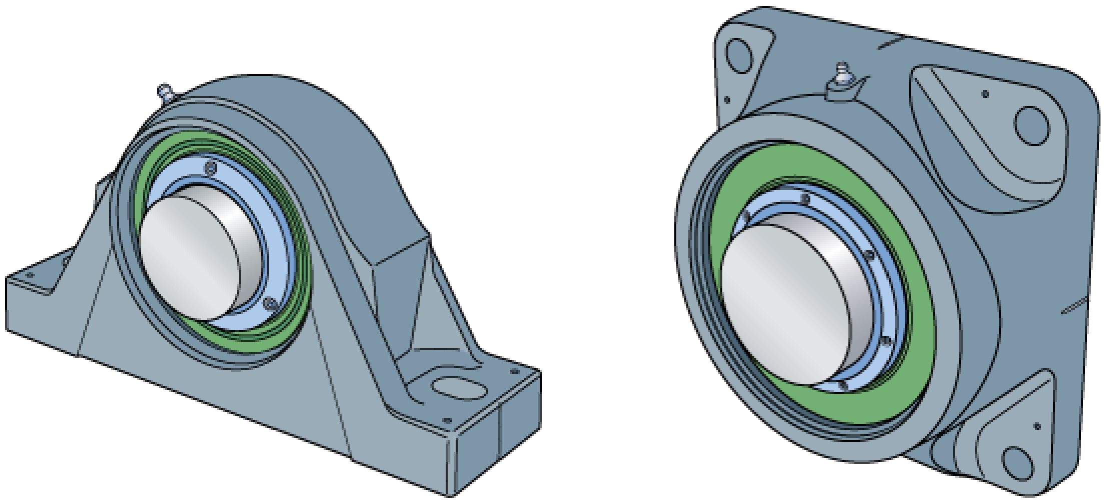


Fig 3.20. ASTM Standard Selection of Bearing

3.4.11. Design of Ridger

The ridger was one of the important parts of the planter, it covers the potato seed and forms a ridge of suitable dimensions for proper growth of crop. As the planter was design for two rows, three ridgers are provided. As the planter moves further, the ridger attachment then covers the seeds and makes a ridge. The ridger consists of tyne, shovel and wings.

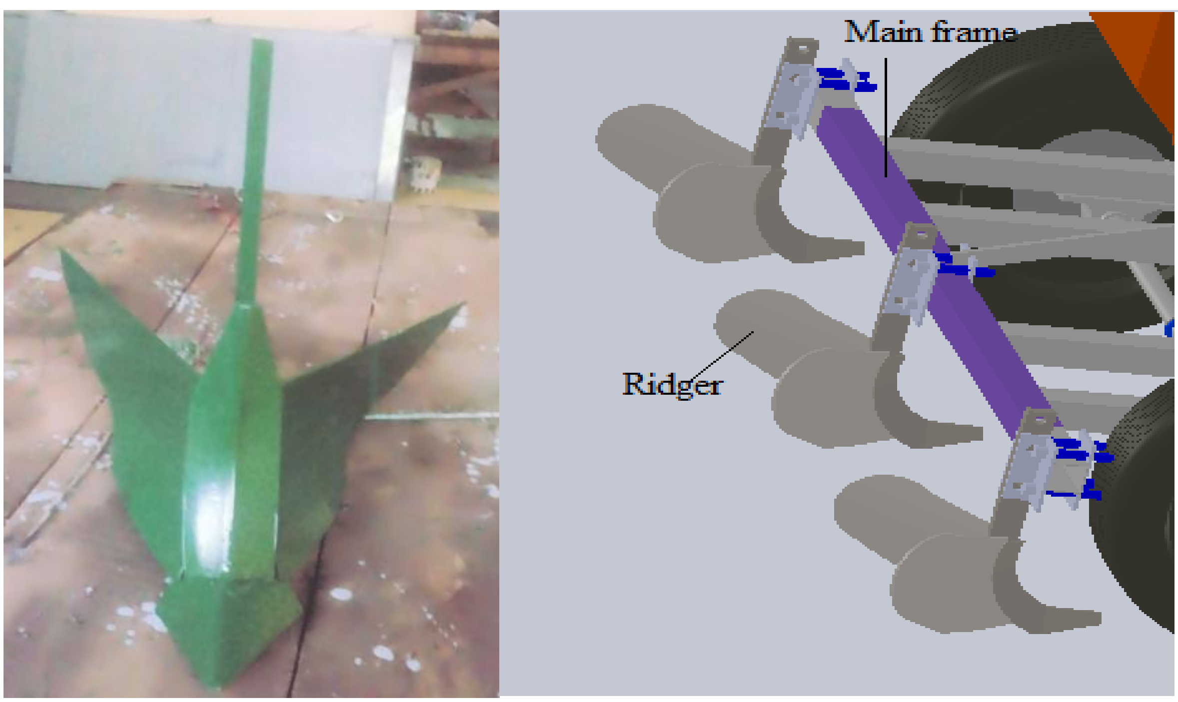


Fig 3.21. Ridger

3.4.11. Seed Tube

Seed tube was the main unit that conveys the seeds from the hopper-through metering device to the furrow opener. It was fitted to connected the feed cup outlet to the furrow opener. The seed tube carries the potato seeds discharge from metering device to the furrow openers. It is easy to fixed and remove the seed tubes as it was made from galvanized sheet metal. The uniformity of seed distribution, along and across the rows, was influenced by the seed tube. Keeping the above consideration, a sheet metal tube with an inner diameter of 70 mm was selected. The length of seed tube was kept 1,100 mm.

3.4.12. Three Point Linkage

Three-point linkages were provided to connect the frame of potato planter to the tractor. Three-point linkages consist of two lower arms and one upper arm. To attach the implement with tractor lower and upper arms was made on the frame. Tractor 40 hp available in MARC it under category (1) three-point hitch specification.

Table 3.4 Three-point hitch specifications

Category	Hitch pin size		Lower hitch	Tractor drawbar
	upper link	lower links	spacing	power
0	17 mm	17 mm	500 mm	<20 hp
1	19 mm	22.4 mm	718 mm	20-45 hp
2	25.5 mm	28.7 mm	870 mm	40-100 hp
3	31.75 mm	37.4 mm	1010 mm	80-225 hp
4	45mm	51 mm	1220 mm	180-400 hp

Source: American Society of Agricultural Engineers (ASAE S217) (2018)

3.6. Performance Evaluation of Potato Planter

In order to evaluate the performance of potato planter, it was essential to conduct tests such as seed rate, seed distribution, seed placement, power requirement and field efficiency.

Fig 3.22. Fabrication pictures of tractor drawn potato planter

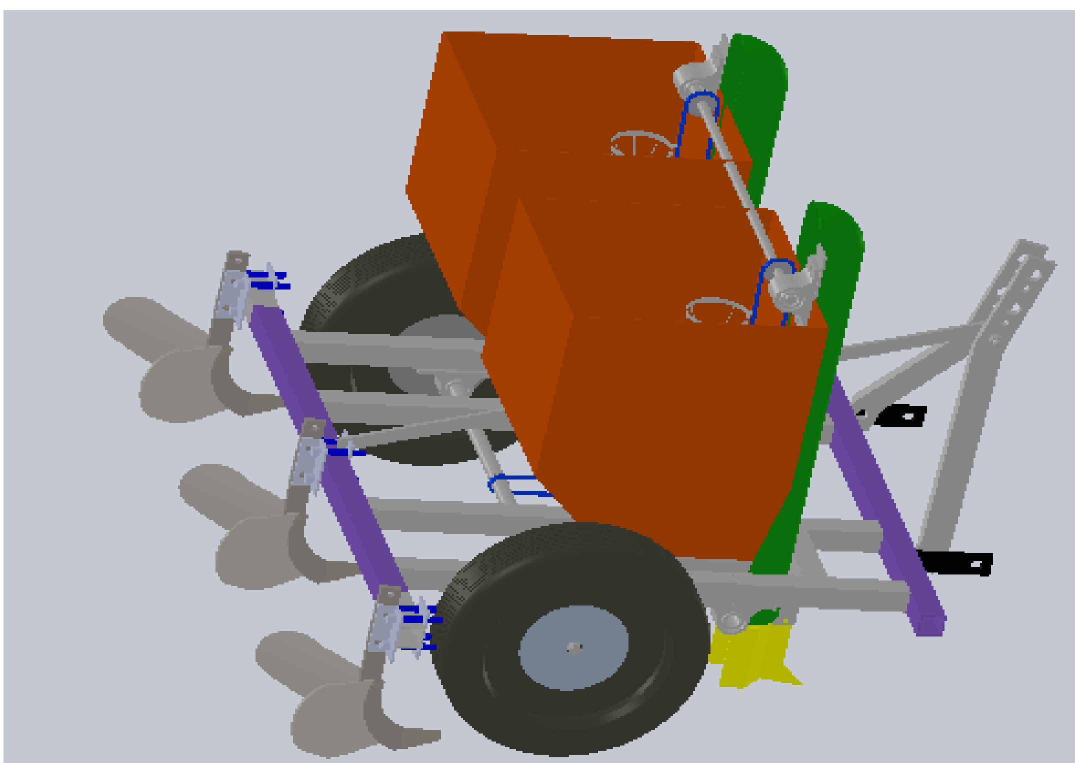


Fig 3.23. Isometric drawing of tractor drawn potato planter

3.5. Working Principle of Potato Planter

For operating the potato planter in the field, three-point linkage of planter was attached to the tractor with the help of pin. Seed hopper filled with good quality of potato seeds. The whole unit was taken to field having well prepared seedbed. The potato planter was operated by tractor. The potato planter consists of chain and cup type seed metering mechanism, which gets drive from the ground wheel. As the planter moves forward, the chain and cup assembly start moving through the seed hopper in which seeds are stored. As the chain moves up it carries seeds in the cup, which are located at some distance from each other. As the chain moves further up the cup gets invert inside a chute which drops the seed to the ground. At the same time the furrow opener opens up a furrow in which the seeds are planted. As the planter moves further, the ridger attachment then covers the seeds and makes a ridge.

3.6.1. Laboratory Test

3.6.1.1. Calibration of Planter

To determine the seeding rate obtainable at different hopper capacity and the variation among furrow openers when the machine was stationary.

1. The width of coverage of planter is equal to the product of the number of furrow openers and the spacing between two consecutive openers (Appendix-E)
2. Area covered in 10 revolution of ground wheel was determined (Appendix-I).
3. The planter was jacked up so that the ground wheel runs freely. A mark was made on the drive wheel and at some convenient place on the body of planter so as to count the revolution of the drive wheel easily.
4. The seeds were filled in the hopper and containers were placed under the furrow openers.
5. The quantity of seeds dropped from furrow openers for 10 revolutions were collected and weighed.
6. This test was repeated for 3.0 $\mathrm{km.h^{-1}}$,3.5 $\mathrm{km.h^{-1}}$and 4.0 $\mathrm{km.h^{-1}}$speed for potato seeds beyond $\mathrm{km.h^{-1}}$speed the Gudene potato planting operation could not be conducted smoothly and more slippage were observed (Appendix-F).
7. The quantity of seeds dropped was converted on hectare basis i.e. $\mathrm{kg.ha^{-1}}$.
8. Three replications were taken for 3.0 $\mathrm{km.h^{-1}}$,3.5 $\mathrm{km.h^{-1}}$and 4.0 $\mathrm{km.h^{-1}}$speed for potato seeds were observed (Appendix-D).

3.6.1.2. Mechanical Damage Test

The test was conducted to find out percentage of damage of seeds that takes place during actual operation. The percentage of damage of seeds during calibration was found out by rotating the ground wheel for 10 revolutions. The amount of seeds collected was weighed. Out of this, the damage seeds were separated. The metered seed were identified and treated as damaged seeds were weighed separately and percentage damage was calculated as follows:

$$\text{Damage percentage} = \frac{\text{Weight of damaged seed}}{\text{total weight of seed collected}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.52)$$

3.6.1.3. Seed Germination Test

Three samples of 100 seeds each were taken randomly and kept in the seed germinator on water soaked germination paper and water was sprinkled every day. The temperature of seed germinator was maintained at 28°C. The sprouts of seeds were observed after sixth day and number of sprouts was counted daily. The counting of sprouts was stopped when the number remained constant for three consecutive days. Since, the sample was of 100 seeds, therefore, the number of sprouts straight away gave germination percentage of seeds. The germination percentages of potato seeds were determined before and after the laboratory tests of metering systems (Belcher *et al.,* 1995).

3.6.1.4. Soil Moisture Content

The samples were collected from five randomly selected sites across the field in each plot. The moisture content was determined in the laboratory by oven dry method and the samples were collected from the field. The moisture content (Dry basis) was determined by equation (3.53) (Belcher *et al.,* 1995).

$$\text{Moisture content (\%)} = \frac{Ww - Wd}{wd} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.53)$$

Where: Ww= Mass of wet soil sample

Wd = Mass of dry soil sample

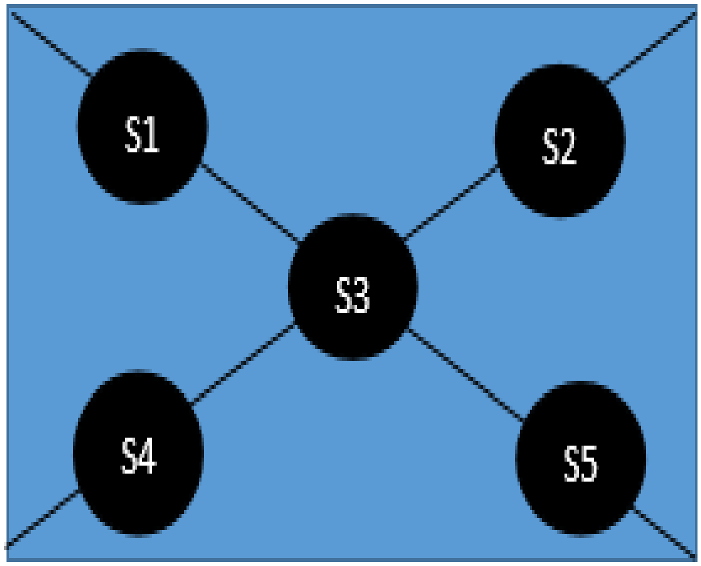


Fig 3.24. Soil sample taking method on field

3.6.1.5. Bulk Density of Soil

To determine bulk density of a soil, metallic core sampler was used to take sample from field having 10 cm diameter and 6 cm height. The bulk density was the weight of soil is to its volume. The bulk density depends upon various factors viz., soil, texture and organic matter, history of tillage and moisture content. The ratio of dry weight of soil to the volume gave the bulk density. Bulk density of soil was calculated by using following formula (Rangapara, 2014).

$$\text{Bulk density of soil } (\mathrm{g.\,cm^{-3}}) = \frac{\text{weight of dry soil sample (g)}}{\text{volume of core sampler (cm3)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.54)$$

3.6.2. Field Test

3.6.2.1. Field Description

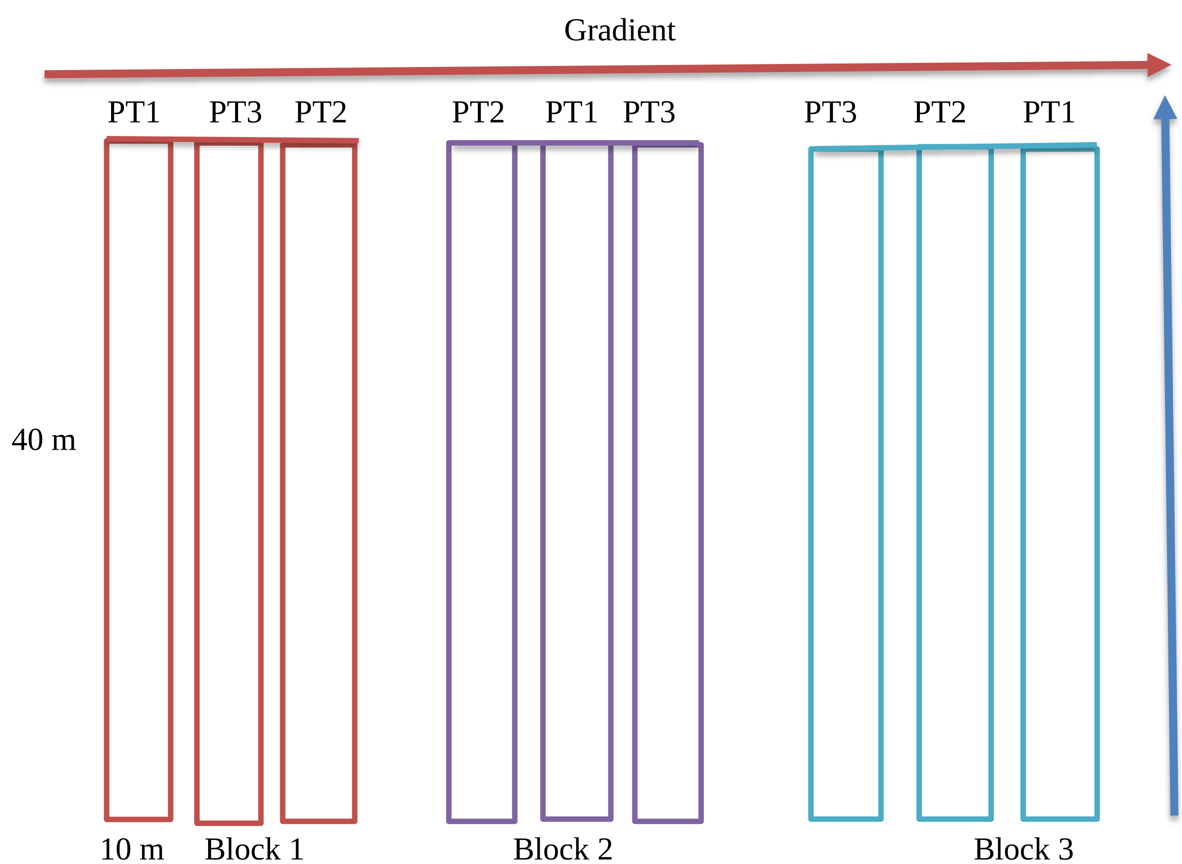
Field condition is important for sowing operation. The following parameters were determined before sowing.

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.

3.6.2.2. Experimental Design

The Experiments were conducted in the field with Gudene potato variety (P) and three forward speed of tractor of 3.0 $\mathrm{km.\,h^{-1}}$,3.5 $\mathrm{km.\,h^{-1}}$and 4.0 $\mathrm{km.\,h^{-1}}$ with forming three treatments. Each treatment replicated three times with Randomized Complete Block Design (RCBD).



Where: P- Potato

T-Treatment with index number 1, 2, 3

Fig 3.24. 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 m net size of each plot).. After preparing the field plot, the potato planter was prepared and adjusted for sowing operation. The tractor drawn potato planter was adjusted at throttle position and sowing operation was carried out for each randomly selected plot samples by taking a performance evaluation data.

3.6.2.3. Seed Distribution Test

This test was conducted to study furrow-to-furrow variation in seed metering. The total number of seeds collected from each furrow opener was counted. The test was replicated 3 times with potato tubers.

3.6.2.4. Percentage of Missing

The planter was operating in the field and the distance between two consecutive seeds was measured in a span of 10 m. If the is distance between two consecutive seed exceeded 1.5 times of the theoretical spacing, then this was considered as missing. The observations are tabulated in Appendix-F.

3.6.2.5. Percentage of Double

If the distance between two seed was found less than 5 cm at the time of measuring distance between two seeds, then this was considered as number of doubles. The observations are tabulated in Appendix-F.

3.6.2.6. Placement of Seed

The planter was operated in field under the good seed bed condition. Then the soil was removed carefully without disturbing the seed at several spot in each row. The depth of the seed below the soil surface was measured. The observations are tabulated in Appendix-G.

3.6.2.7. Draft Requirement Test

Draft was measured using a digital drawbar dynamometer attached to the front of the tractor on which the implement was mounted. Another auxiliary tractor was used to pull the implement mounted tractor through the drawbar dynamometer. The auxiliary tractor pulls the implement-mounted tractor which was in neutral gear but with the implement in the operating position. Draft was recorded in the measured distance of 20 m. On the same field, the implement was lifted off the ground and the draft recorded. The difference between the two readings, gave the draft of the implement. This procedure was repeated for all the speed considered in the study.

3.6.2.8. Wheel Slippage

A mark was made on the tractor drive wheel with colored tapes and the distance the tractor moves forward at every 10 revolutions under no load condition and the same revolution with load on same surface was measured. Wheel slip for any given load was determined by equation (3.56) (Rangapara, 2014). The observations are tabulated in Appendix-H.

Wheel slippage = $\frac{\mathrm{M1-M2}}{\mathrm{M1}}$ x 100 ……………..……………………………………….. (3.56)

Where: M1 = Distance covered at 10 revolutions of the tractor drive wheel at no load, (m)

M2 = Distance covered at 10 revolution of tractor drive wheel with load, (m)

3.6.2.9. Fuel Consumption

The fuel consumption was measured as per the standard method. A known measuring cylinder is directly attached to fuel tank and was filled up full level by keeping the tractor on level land and after completing the operation the note down the final measurement of cylinder. The volume of fuel used was taken into accounted as fuel consumed for a particular time period.

3.6.2.10. Determination of Field Capacity and Field Efficiency

The standard tractor drawn potato planter effective field capacity: 0.4 $\mathrm{ha.\,hr^{-1}}$, operating speed: 3.0 -5.0 $\mathrm{km.\,hr^{-1}}$ and field efficiency: 60-80%. (ASABE, 2011).

Theoretical field capacity, effective field capacity and field efficiency were computed by using the following equation (3.57 and 3.58) (Hancock, 1991).

Theoretical field capacity ($\mathrm{ha.\,hr^{-1}}$) = $\frac{\mathrm{W\times S}}{10}$…..……………………………...………...… (3.57)

Where: W= Width of planter, (m)

S = Speed of operation, ($\mathrm{km.\,hr^{-1}}$)

10 = factor calculated as $\mathrm{1ha.\,1hr^{-1}}$ = 10000/1000 = 10

Effective field capacity ($\mathrm{ha.\,hr^{-1}}$) = $\frac{\text{Area of plot (ha)}}{\text{Time taken(hr)}}$……..……........………...……..… (3.58)

Field efficiency was the ratio of the effective field capacity to the theoretical field capacity calculated by using equation (3.59) (Hancock, 1991).

$$Ef = \frac{FCe}{FCt} \times 100 \quad (3.59)$$

Where: Ef = field efficiency, (%)

FCe = effective field capacity, $(ha.hr^{-1})$

FCt = theoretical field capacity, $(ha.hr^{-1})$

3.7. Operation Cost of Machine

The cost of operation for the machine was worked out by calculating the fabrication, fixed and variable costs as presented in Appendix G. Estimation of hourly operational costs of the planter were based on capital cost of the planter, interest on capital, cost of repairs and spare parts, labor cost, and depreciation. The operational cost components of the prototype planter were estimated in Birr (ETB) by using equation (3.60) (Goense & Blaauw, 1995).

Depreciation (Dp), was calculated as follows:

$$Dp = \frac{cc - svc}{El}, (ETB.hr^{-1}) \quad (3.60)$$

Interest on capital (IC) and labour wages (LW) were calculated by using equation (3.61) and (3.62) ASABE (2011).

$$IC = \left(\frac{cc + svc}{2}\right) \times \left(\frac{1\%}{NAOHP}\right), (ETB.hr^{-1}) \quad (3.61)$$

Labor wages (LW), was calculated as follows:

$$LW = \frac{DLW}{DWH}, (ETB.hr^{-1}) \quad (3.62)$$

Cost of repairs and spares (CRS), Wage of tractor (WT) and hourly operational costs were calculated by using equation (3.63), (3.64) and (3.65) (Goense & Blaauw, 1995).

$$CRS = \frac{CC \times 6\%}{AWHP}, (ETB.hr^{-1}) \quad (3.63)$$

Wage of tractor (WT), was calculated as follows:

$$WT = \frac{DTW}{DWH}, (\mathrm{ETB.\,hr^{-1}})) \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.64)$$

Hourly operational costs = (Dp + IC + LW + CRS + WT) ……………………………..…… (3.65)

Where: Dp = Depreciation

CC = Capital cost

SVC = Selvage Value Cost

CRS = Cost of repairs and spares

EL= Estimate life, (hr)

I = Interest, (%)

DLW = Daily labor wage

DWH = Daily working hours, $(\mathrm{ETB.\,hr^{-1}})$

IC = Interest on capital, $(\mathrm{ETB.\,hr^{-1}})$

WT = Wage of tractor

DTW = Daily tractor wage, $(\mathrm{ETB.\,hr^{-1}})$

LW = Labor wages

NAOHP = Number of the annual operational hours of the planter, $(\mathrm{ETB.\,hr^{-1}})$

AWHP = Annual working hours of the planter

The currency exchanges Ethiopian Birr (ETB), August ,2018.

• The currency exchange of the US Dollar (USD) to Ethiopian Birr (ETB) exchange rate.

• 1 dollar = 27.50 ETB

3.8. Data Analysis

The data obtained from laboratory experiment and field test were analyzed, in to tables and graphs by using software Microsoft Excel (2016) and statically analysis SPSS: 20 version.

CHAPTER FOUR

4. 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.

4.1. Laboratory Test Results

4.1.1. 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 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. The mean length (L), width (D), thickness (T), geometric diameter and sphericity (Sp) of different potato variety was found as ranges from 53.86 to 63.55 mm, 50.89 to 44.81 mm,38.47 to 43.48 mm,45.57 to 51.56 mm and 79.2 to 86.6 % respectively. Angle of repose potato was maximum 38º, minimum 33º and its average 35.5º.

Gamea et al., (2009) found a bulk density of potato was maximum 668 $\mathrm{kg.m^{-3}}$, minimum 653 $\mathrm{kg.m^{-3}}$and its average 658.3 $\mathrm{kg.m^{-3}}$. The average values obtained for arithmetic mean of volume, geometric diameter and sphericity of the selected potato seed became 58,468.06 $\mathrm{mm^3}$, 48.58 mm and 82.19 % respectively. The result obtained in Table 4.1 showed that potato seed had more or less spherical shape (sphericity= 82.19). Hence, metering devices with circular shaped cups were used to accommodate it.

Table 4.1. 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	º	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).

$$\text{Shape index, } k = \frac{L^2}{D \times T} \times 100 \qquad (4.1)$$

Jalene, k = 137.1 round

Chala, k =201.65 oval

Belete, k = 187.21 oval

Gera, k = 200.06 oval

Gudene, k = 165.97 oval

4.2. 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.

Fig 4.1. Calibration of Potato Planter

4.2.1. Hopper Filling Effect on Mechanical Damage

Three replications were carried out for calibrating the potato planter in the laboratory. Table 4.2 indicates the effect of hopper filling on seed damage for different observation varied with the hopper filling (full, ½ fill and ¼ fill). The percent of external damage of the seeds were tested at three levels of hopper fills.

Table 4.2. Effect of hopper filling on seed damage of potato seeds

Operating Speed ($km.h^{-1}$)	No.	¼hopper fill	½ hopper fill	Complete hopper fill
		% damage	% damage	% damage
3	3	1.78	2.26	3.94
3.5	3	3.12	3.89	4.52
4.0	3	3.56	4.01	4.92
CV		32	28	11
Mean		2.83	3.38	4.46
Standard deviation		0.927	0.977	0.492

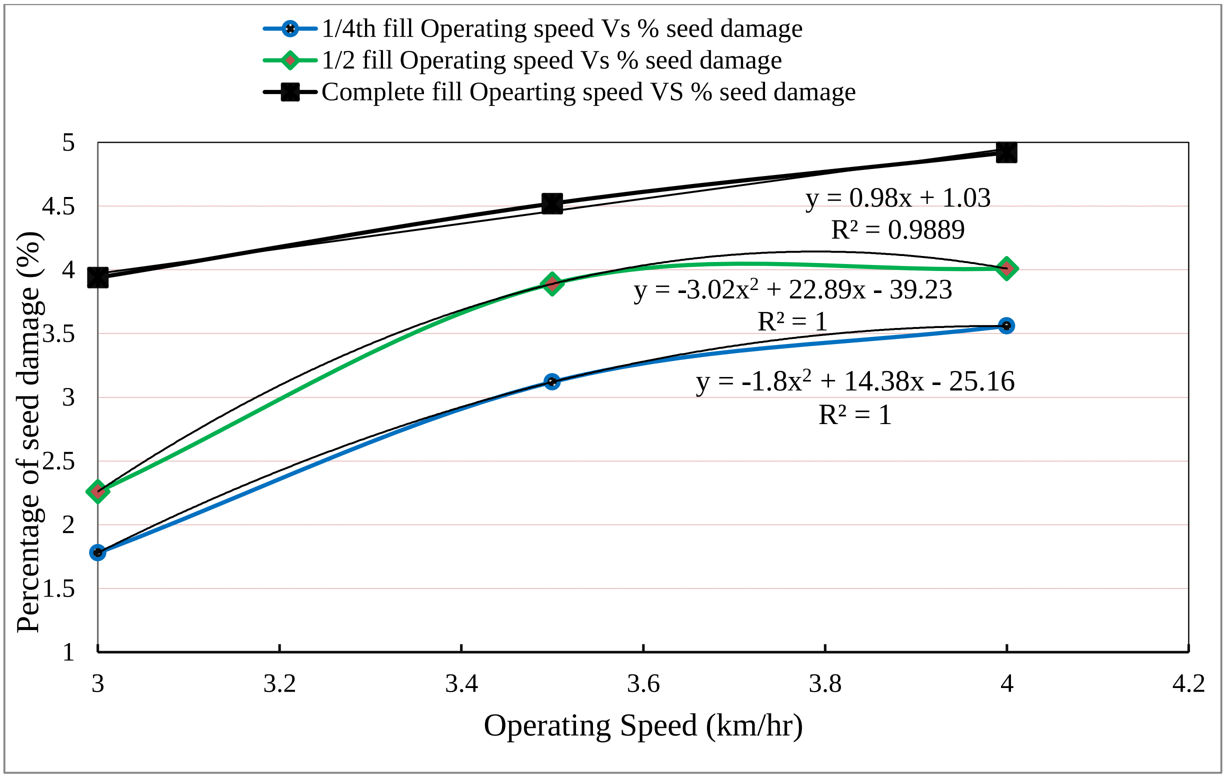


Fig 4.2. Effects of planter forward speeds on seeds damage

The coefficient of variation (CV) is the ratio of the standard deviation to the mean. The higher the CV, the less the precision of the experiment for a determined parameter. From table 4.2, it is show that as the speed increase the mechanical damage of potato seed increase. The mechanical damage of seed was due to higher rotational speed of the metering roller at high speed. At high rotational speed the cup strikes the seeds with greater impact resulting in mechanical damage.

The correlation between seed damage at different level of hopper fill and operating speed was showed in Fig. 4.2. The data obtained from the testing were analyzed, first and second-degree polynomial regression showed good correlation between seed damage and operating speed in all trials, high coefficient of determination (R^2 = 0.988, R^2 = 1 and R^2 = 1) were observed with ¼ fill, ½ fill and completed fill respectively.

4.2.2. Hopper Filling Effect on seed rate

Table 4.3 indicates the effect of hopper filling on seed rate ($\mathrm{kg.ha^{-1}}$) of potato seeds for different observation varied with the hopper filling (full, ½ fill and ¼ fill). The seed rate of the planter seeds was tested at three levels of hoppers fills.

Table 4.3. Effect of hopper filling on seed rate of potato seeds

Replication	¼ fill	½ fill	Complete fill
	Seed rate ($\mathrm{kg.ha^{-1}}$)	Seed rate ($\mathrm{kg.ha^{-1}}$)	Seed rate ($\mathrm{kg.ha^{-1}}$)
1	1,956	2,003	2,094
2	1,963	2,019	2,101
3	1,969	2,028	2,114
CV	0.33	0.63	0.48
Mean	1,962.67	2,016.67	2,103
Standard deviation	6.50	12.66	10.15

Seed rate increased with the increase in hopper fill as shown in Table 4.3. The mean seed rate from the calibration were observed 1962.67, 2016.67, 2103 $\mathrm{kg.ha^{-1}}$ at 36 rpm tractor at 3rd gear speed. The increase in seed rate with the increase in hopper fill might be due to decrease in exposure time to pick the seed and due to slip of seed from the cup due to higher speed of metering device.

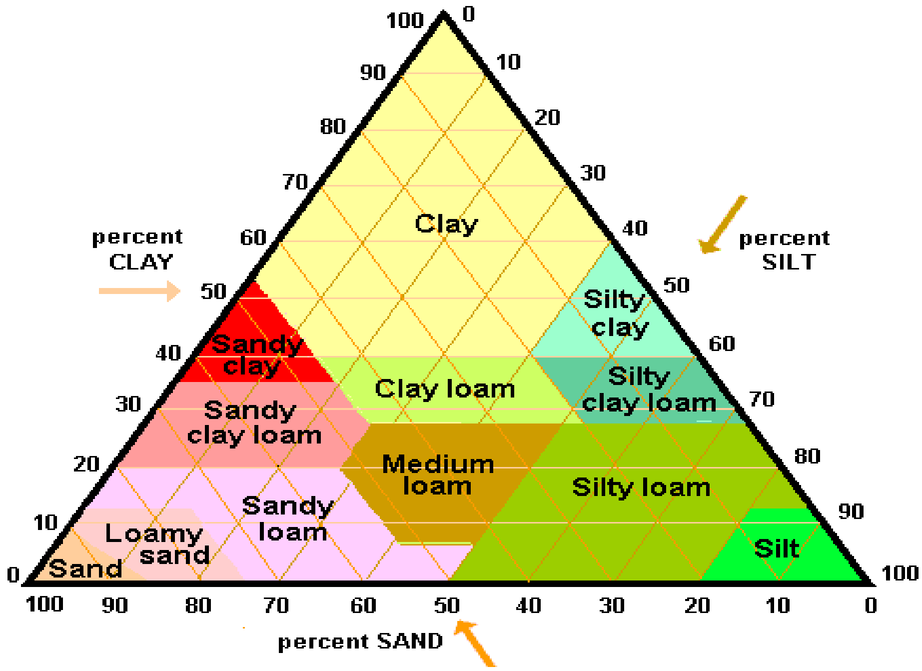
This may be due to the hopper's sizes were larger and their shapes were different, e.g. trapezoidal, there would have been significant variations among the means of the respective parameters due to the weight of the seeds, the potential greater variability of the potato seeds in size and shape, and the friction between the metering chain and potato seeds at the picking zone (due to speed of revolution).

4.3. Physical Properties of Soil

The detailed study of physical properties of soil was presented under this subtitle which is as follows:

4.3.1. Type of Soil

< 0.002 mm clay   0.002- 0.05 mm silt   0.05- 2.0 mm sand



Source the U.S. Department of Agriculture soil textural triangle (Soil Survey Division Staff 1993).

Figure 4.3. Soil classifications

Identify the soil texture of soil sample using the texture triangle


Fig 4.4. Measurement of soil density by core sampler

The results are an average of several core samples taken to the 20 cm cultivation depth achieved. With the different of site no. each site was considered a test for potato planter. site no. which was a sand-loam soil, all soils fell into the sand-loam soil category.

4.3.2. Moisture Content and Bulk Density of Soil

During carrying out the experiments, the soil conditions of the experimental field were studied and different parameters were calculated Table 4.4. The soil of the field was sandy loam soil. Moisture content of soil was measured by oven dry method. Five soil samples were taken randomly at 5 different locations in the plot using core sampler of 10.0 cm diameter and 6 cm height. The mean data on soil moisture content after tillage operations at 0 to 20 cm depth are recorded and presented. Average value of moisture content (Dry basis) and bulk density of experimented plot was found 15.83 % (Db) and 1.347 $\mathrm{gm.cm^{-3}}$ respectively.

Volume of cone sampler (v) calculated by using equation (4.2) (Rangapara, 2014).

$$v = \pi r^2 h \qquad (4.2)$$

Table 4.4. Moisture content and bulk density of soil

Sample No.	Weight of a soil (gm)	Weight of soil after oven dried (gm)	Soil moisture Content (Db) (%)	Volume of Core Sampler ($\mathrm{cm^3}$)	Bulk Density ($\mathrm{gm.cm^{-3}}$)
1	720	620	16.12	471	1.316
2	721	624	15.54	471	1.324
3	742	636	16.66	471	1.350
4	732	643	13.84	471	1.365
5	763	652	17.02	471	1.384
Average	735.6	635	15.83	471	1.347

4.4. Field Performance of Potato Planter

4.4.1. Description of Field Evaluation

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 $\mathrm{gm.cm^{-3}}$
- Depth of seed bed - 20 cm
- Size of each plot - (40 x 10) $\mathrm{m^2}$

Fig 4.5. Potato Planter under Operation

4.4.2. Placement of Seeds

The placement of seeds in all the furrows opened by the planter was shown in Appendix- G. The average depth of seed was 12.18 cm in furrow openers, which indicated that the placement in the furrow openers were uniform. The depth obtained by the planter was therefore within the desirable limit.

Fig 4.6. Measurement of Seed Placement

4.4.3. Percentage of Missing and Percentage of Double

Percentage of missing slightly increased as operating speed increased showed in Table 4.5. Percentage of missing also affected by skill of labour to fill the cup with potato seeds.

The seed missing and percentage of double were depending on hopper fill level and forward speed of operation.

Fig 4.7. Measurement of Seed Spacing

The data recorded the effect of different speed on determination of seed spacing, number of missing and number of doubles are presented in Appendix – F.

Table 4.5. Number of Missing and Number of Double

Speed (km/h	Avg.Spacing between two consecutive seeds (cm)	Number of missing	% of missing	Number of doubles	% of double
3	31.3	2	6.25	3	9.37
3.5	30.95	3	9.37	3	9.37
4	29.92	3	9.37	4	12.50
CV	2.33	21.6	21.6	17.3	17.3
Mean	30.72	2.66	8.33	3.33	10.41
SD	0.717	0.577	1.801	0.577	1.807

Percentage of double slightly increases with speed increased. It is mainly affected by the skill of labour. Increased in double as speed increases was due to availability of less time to fill the cup by labour.

4.4.4. Row to Row Spacing

The data recorded the effect of different speed on determination of seed distribution in furrow opener at different seed size are presented in Appendix – E

Table 4.6. Row to Row Spacing

No.	Row to row spacing (cm)
1	60
2	60.8
3	60.7
4	60.2
5	60.5
Average	60.44

The distance of row in all furrows by the planter was showed in Table 4.6. The distance between rows was 60 to 60.8 cm and average distance was 60.44 cm.

4.4.5. Draft and Power Requirement of Planter

The data recorded the effect of different speed on the draft (kg) and power (hp) are presented in Appendix – I. Draft increased with the increase in operating speed as shown in Table 4.7 and Fig 4.8. The net draft observed were 300, 308.33, 316 (kg) at forward speed of 3.0, 3.5 and 4.0 ($\mathrm{km.hr^{-1}}$) respectively. As speed increased volume of the soil mass per unit time through the planter was increased and therefore soil resistance was also increased which resulted into draft value.

The tractor requires more power at higher speed due to overcome more resistance developed at tractor and at working place.

Table 4.7. Draft and Power Measurement

Operation Speed ($\mathrm{km.hr^{-1}}$)	Draft (kg)			Power (hp)		
	load Condition	unload Condition	Net draft	load Condition	unload Condition	Net power
3	496.33	196.33	300	5.51	2.18	3.33
3.5	507.33	200.66	308.33	6.60	2.6	4.05
4	519.33	208.33	316	7.73	3.05	4.68
CV	2.26	3.0	2.60	16.64	16.6	16.8
Mean	507.66	201.77	308.11	6.61	2.61	4.02
Standard deviation	11.5	6.07	8.0	1.11	0.435	0.675

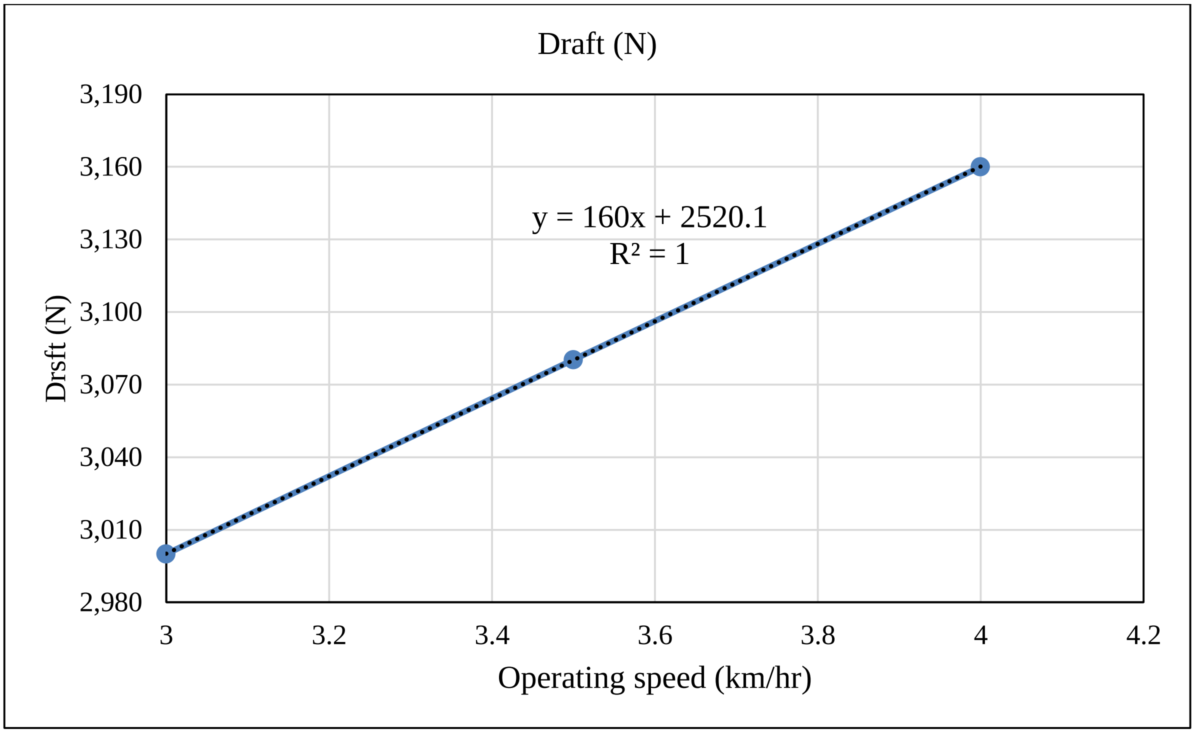


Fig 4.8. Effect of Operating Speed on Draft

The data showed in Fig 4.8 good correlation between draft and operating speed in all trials, with a high coefficient of determination (R^2= 0.999).

4.4.6. Wheel Slip

The data concerning the effect of different speed on the wheel slippage are presented in Appendix – H. Wheel slippage increased as the speed increase. As speed increased the time to contact traction wheel to the soil mass of the field reduced which increased the wheel slippage due to less soil resistance on the traction wheel.

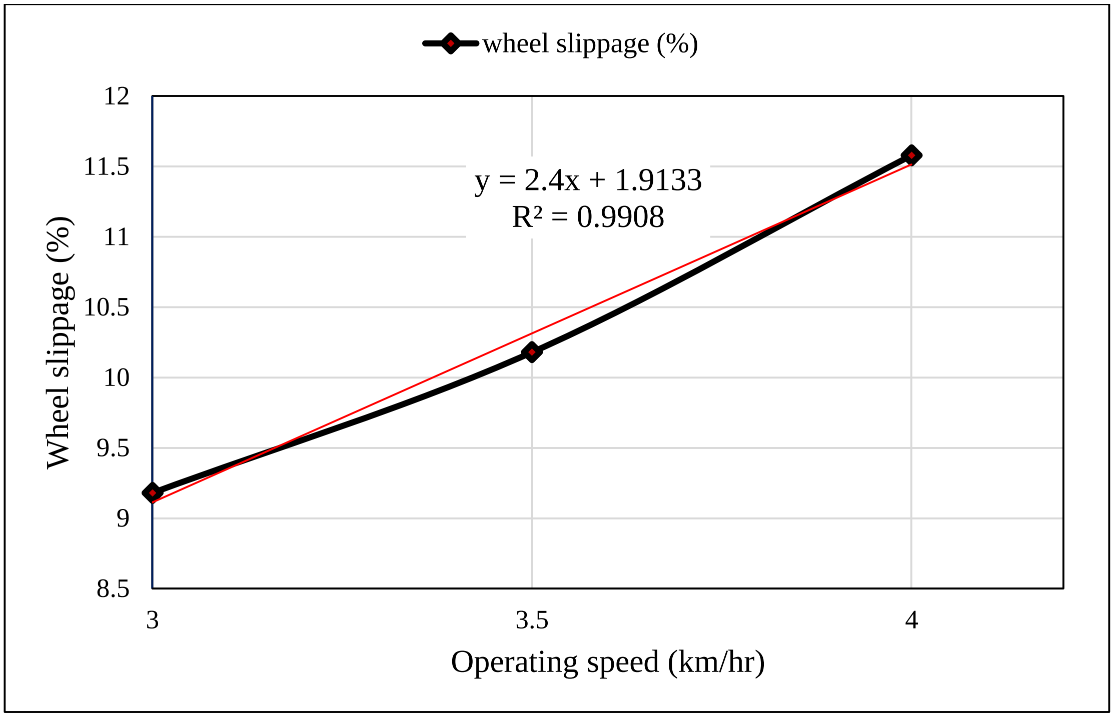


Fig 4.9. Effect of Operating Speed on Wheel Slip

The data showed in Fig 4.9 good correlation between wheel slippage and operating speed in all trials, with positive and high coefficient of determination (R^2= 0.9908).

4.4.7. Fuel Consumption

The data stated the effect of operating speed of tractor 3^{rd}gear of on the fuel consumption were determined for the area of 400 m^2 and are presented in Table 4.8. From field data collected fuel consumption was 0.42 lit. for each plot.

Table 4.8. Fuel Consumption

3rd gear speed	Avg. fuel consumption to cover 400 m^2 (lit)	Avg. fuel consumption ($lit.ha^{-1}$)
1	0.45	11.25
2	0.42	10.50
3	0.39	9.75
CV	7.14	7.14
Mean	0.42	10.5
Standard deviation	0.03	0.75

Fuel consumed by planter per unit area ($\mathrm{lit.\,ha^{-1}}$) decreased as speed of the operation increased. As speed increased the field capacity increased because at higher speed more area per unit time was covered hence fuel consumption per unit area decreased.

4.4.8. Time and Labour Requirement

The data concerning the effect of different speed on the time to cover 1 ha area are presented in Table 4.9. Time consumed by the planter per unit area (ha) decreased as speed of the operation increased. As speed increased the field capacity increased because at higher speed more area per unit time was covered hence time per unit area decreased.

Table 4.9. Time and labour requirement

Operating Speed ($\mathrm{km.\,hr^{-1}}$)	Time to cover 400 $\mathrm{m^2}$(sec)	Time to cover 1 ha (h)	No. of Labour
3.0	454	3.15	2
3.5	406	2.81	2
4.0	378	2.62	2
CV	9.3	10	0
Mean	825.33	2.86	2
Standard deviation	76.8722	0.2865	0

The labour requirement for sowing on hectare on field with potato planter showed the effect of different speed on labour requirements. Based on turning time at the headlands, no significant variations among the means of the treatments observed. It is clear that as speed increase time decrease to cover 1 ha area.

4.4.9. Determination of Field Capacity and Field Efficiency

The data about the effect of different speed on the theoretical field capacity, effective field capacity field efficiency to cover 1 ha area are presented in Table 4.10.

Size of plot = 40 × 10 = 400 $\mathrm{m^2}$

Width of Planter = 1.5 m

Table 4.10. Theoretical Field Capacity, Effective Field Capacity and Field Efficiency

Speed ($km.hr^{-1}$)	Total time required (Sec)	Theoretical field capacity ($ha.h^{-1}$)	Effective Field Capacity ($ha.h^{-1}$)	Field Efficiency (%)
3	454	0.45	0.317	70.44
3.5	406	0.525	0.355	67.61
4	378	0.60	0.381	63.50
CV	9.3	14	9.1	5.2
Mean	412.66	0.525	0.351	67.18
Standard deviation	38.43	0.075	0.03218	3.489

Theoretical field capacity was increased as the speed increase. Effective field capacity was increased as the speed increase. Field efficiency was decrease as the speed increase.
Rangapara (2014) suggested that the field size was decreased; number of passes of the planted increased too, which leads to increase in time losses and give lower values of field efficiency. The major reason for the reduction in field efficiency by increasing forward speed was due to the less theoretical time consumed in comparison with the other test plots.

The field efficiency test is presented in Table 4.10. The field efficiency was varied from 63.5 to 70.44 (%) at the three speeds. It shows that average field efficiency to cover 1 ha area was 67.18 % and average effective field capacity of tractor drawn potato planter was 0.351 $ha.hr^{-1}$. ASABE (2011) reported that standard tractor drawn potato planter effective field capacity: 0.4 $ha.hr^{-1}$, operating speed: 3.0 -5.0 $km.hr^{-1}$and field efficiency: 60-80 %.

4.4.10. Plant population Test in Field

The plant population test was presented in Table 4.11. The seed germination percentage was varied from 87.5 to 90.625 % at the three plots which each plot area was $400\ m^2$. It shows that there was no effect of speed germination on field.

Fig 4.10. Seed germination in Field

Table 4.11. Seed Germination Test in Field

3rd gear speed	No. of Seed planted	No. of Seed germinated	Percentage of germination
1	32	29	90.625
2	32	28	87.5
3	32	28	87.5
CV	0	2.03	2.03
Mean	32	28.33	88.54
Standard deviation	0	0.577	1.804

The seed germination rate in the field was not affected with the speed which indicated that even at higher speed the planter places the seed with proper handling/metering of the seeds. The lower the CV, the higher the precision of the experiment for a determined parameter.

4.5.1. Manual Method Potato Planting

According to Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia (CASCAPE) (2015) project demonstration manual planting 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 tones/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 4.12. Performance of potato planter was compared with conventional practice.

Sr. No.	Parameters	Units	Tractor drawn potato planter	Manual planting
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	$\mathrm{km.hr^{-1}}$	3.0 – 5.0	-
7	Germination count	%	88.54 %	75 - 95 %
8	Seed rate	$\mathrm{quintal.ha^{-1}}$	21	18- 22

4.6. 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 as given in Appendix-B.

Table 4.13. Cost summary

No.	Cost variables	Summary
1	Raw material cost	7,388 ETB
2	Material wastage 2.5 %	300 ETB
3	Machine cost	4000 ETB
4	Labor cost	2500 ETB
5	Overhead cost 5 % (3+4)	709.4 ETB
6	Profit 10 % (1+2+3+4+5)	1,489.74 ETB
7	Sells tax 15 % (1+2+3+4+5+6)	2,458.07 ETB
8	Selling price	18,845.21 ETB

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

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

A prototype of tractor drawn potato planter was developed for sowing operation suitable for medium (model) farmers and its performance was evaluated. The machine was powered by 40 hp WTO 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 field test tractor drawn potato planter was operated 3rd gear speed at with 3.0, 3.5 and 4 $\mathrm{km.\,hr^{-1}}$.

The following conclusions are made from the study.

1. The planter was evaluated in laboratory as well as in real field condition.
2. The seed rate for seeds at different hopper filling and they were recorded were 1,962.67, 2,016.67 and 2,103.0 $\mathrm{kg.\,ha^{-1}}$ respectively.
3. The meter seed were observed average mechanical damage at different hopper filling level (¼ fill, ½ fill and full fill) were 2.83, 3.38 and 4.46 % in of potato seeds respectively.
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 (N) of the planter at speed ($\mathrm{km.\,hr^{-1}}$) of 3.0, 3.5 and 4.0 were as 3,000, 3,083 and 3,160 respectively.
7. Under normal moisture content (15.83 %) the average wheel slip was observed 10.31 % with diameter of ground wheel of 60 cm (tractor operated at 3rd gear).
8. The average fuel consumption ($\mathrm{lit.\,hr^{-1}}$) of the planter was observed 10.50.
9. The average field efficiency (%) and effective field capacity ($\mathrm{ha.\,hr^{-1}}$) were 67.18 and 0.351 respectively.
10. The cost of fabrication of the planter was estimated in the of approximately 18,845.21 ETB Birr.

The conclusions revealed that the prototype of the tractor drawn potato planter works satisfactory and saves time.

5.2. 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.

REFERENCES

ASABE, (2011). The measured performance values of the Agricultural machinery. *American Society of Agricultural and Biological Engineers*, New York, USA.

ASME, (1995). Design of transmition shafting. *American Society of Mechanical Engineering, New York*, USA.

ASTM, (2014). American Society for Testing and Materials, *New York*, USA.

Belcher, D. J., Cuykendall, T. R., and Sack, H. S. (1995) The measurement of soil moisture and density by neutron and gamma-ray scattering: Technical Development Report No. 127, U.S. Civil Aeronautics Administration, Technical Development and Evaluation Center, Indianapolis, Indiana, 20 pp.

Berga, L., Gebremedhin, W., Terrisa, J. and Bereke, T. (1994). 'Potato agronomy research. Proceedings of the 2nd National Horticultural Workshop of Ethiopia', December 1-3, 1992, *Institute of Agricultural Research and Food and Agriculture Organization*, Addis Ababa, Ethiopia.

Bishop C.F.H and W.F. Maunder., 1980. "Potato mechanization and storage". Chapters 3 and 6 Great Britain.

Bosai, E. C; Verniar, O. V. land Shaikh, H. S. (1987). Theory, Constuction and Calculations of Agricultural Machines, *Oxohian Press, Pvt. Ltd*. 246-247.

Chaudhuri, D. (2001). Performance evaluation of various types of furrow openers on seed drills. *A review Journal of Agricultural Engineering Research*, **79**(2): 125–137.

CSA. (Central Statistical Authority). (2016). Agricultural sample survey 2015/16. Volume I. Report on area and production of major crops for private peasant holdings, meher season. *statistical bulletin* 578, Central Statistical Agency, Addis Ababa, Ethiopia.

CASCAPE. (Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia) (2015). Best Fit Practice Manual for Potato Production and Utilization. working paper 8.

Culpin C., 1986: "Farm machinery". Eleventh edition. Great Britain. 117-250.

FAO. (2008) International Year of the potato http://www.potato2008.org/en/world/african.htmllast(visited November 29/2017).

Gamea, G. R., Abd El-Maksoud, M.A., and Abd El-Gawad, A.M. (2009). Physical characteristics and chemical properties of potato tubers under different storage systems. *Misr J. Ag. Eng.*, **26**(1): 385- 408.

Geonse, D.& Blaauw, S.k. (1995). Cost of Farm Operation in Fundamentals of Agricultural Mechanization System, lecture note, Wagringen Agriculture University, the Netherlands, pp 84-114.

Getachew, T., Belew, D. and Tulu, S. (2013). Combined Effect of Plant Spacing and Time of Earthing up on Tuber Quality Parameters of Potato (Solarium tuberosum L.) at Degem District, North Showa Zone of Oromia Regional State. *Asian Journal of Crop Science*,**5** (1): 24-32.

Guidetti, R.; Amer, E. and Ebrahem, A. H. (2011). A new small potato planter for Egyptian agriculture. *Journal of Agricultural Engineering,* **3**: 7-13.

Gulati, S. and Singh, M. (2003). Design and development of a manually drawn cup type potato planter. *Journal of the Indian Potato Association*, **30**(1& 2): 6162.

Hancock, J. N.; Swetnam, Larry D.; and Benson, F. J., "Calculating Farm Machinery Field Capacities" (1991). *Agricultural Engineering Extension Publications*. 20

Ikechukwu I.B., Gbabo A. and Ugwuoke I.C. (2014). Design and Fabrication of a single row maize planter for garden use. *Journal of Advancement in Engineering and Technology*, **1**(2):2348-2931

Islam, M. S., Moonmoon, S., Islam, M. Z., Waliullah, H. and Hossain, M.S. (2012). Studies on seed size and spacing for optimum yield of potato in northern region of Bangladesh. *Bangladesh J. Prog. Sci. & Tech.***10**(1): 113-116.

Ismail Z, E. and A.E. Abou El –Magd., (1991).” Evaluation of mechanical potato planting”. Mis J. Agric.Eng., **11**(1): 3-18.

Kachman, S.D & Smith, J.A. (1995). Alternative measures of accuracy in plant spacing for planters using single seed metering. *Transaction of the ASAE*, **38**(2): 379–387.

Khurmi, R. and Gupta, J. (2003). A text book of machine design. Eurasia Publishing House (Pvt.) Ltd. Ram Nagar, New Delhi, India.

Klenin, N. I.; Popov, I. P. and Sakun, V. A. (1985). Agricultural Machines. *American Publishing Co. Pvt. Ltd.*, 129-131.

Kurtz, Gary; Thompson, Laster and Clwar, Paul. (1984). Design of agricultural machinery. John Willey and Sons, Singapore, pp 245 – 255.

Mohsenin, N. N. (1986). Physical properties of plant and animal materials. *Golden and Breach Science Publishers*, New York, 51-58.

Mulatu and Hirpa. (2010). 'Improving potato seed tuber quality and producer's livelihoods in Hararghe, Eastern Ethiopia', *Journal of New Seeds*, **7**(3), pp.31–51.

Murray, J.R., Tullberg, J.N. and Basnet B.B. (2006). Planters and their components: types, attributes, functional requirements, classification and description. *Australian Centre for International Agricultural Research (ACIAR) Monograph* No. 121.

Mustafa, G. B. and Faith, U. (2012). Influence of seed physical properties and speed on the external mechanical damage index and in-row spacing uniformity in an automatic potato planter. *Journal of Agriculture Science*, **18**: 126-136.

Norton, M.L. (2005). Design of machinery: An introduction to the synthesis and analysis of mechanisms and machines, Mc-Graw-Hill, Inc. New York,3rd ed.

Olaoye, J.O. and Bolufawi, S.J. (2001). Design, fabrication and performance of multipurpose row planting machine. J. Sustain. Agric. Environ, **3**(1): 7-20.

Pandya, N. C. and Shah, C. S. (2014). Elements of Machine Design Charotar Book Stall, Juloi Sadan, Anand, India, 275-28.

Rangapara, D. J. (2014). Development of mini tractor operated picking type pneumatic planter Anand agricultural university, Godhra.

Reece A.R. (2002). The Mechanics of Tractor Implement Performance. Publishers R. H. Macmillan, Melbourne, Australia.

Richard G. Budynas and J. Keith Nisbett (2011). Shigley's Mechanical Engineering Design. *Ninth edition, McGraw-Hill, New York*, USA.

Richy, C. B.; Jacobcon, C. B. and Hall, C. W. (1996). Agricultural Engineer's Handbook. *First Edition, McGraw-Hill Book Company, New York*. 172 -186.

Ryder G.H. (1989): Strength of Materials, 3rd ed. Macmillan, Nigeria.

Ryu, I. H. and Kim, K. N. (1998). Design of roller type metering device for precision planting, *Transactions of the ASAE*,**41** (4): 923-930.

Santos, B.M. and Rodriguez, P.R. (2008). Optimum in-row distance for potato minituber production. *HoriTechnology*,**18**(3): 403-406.

Shaaban, U.A., Afify, M.T., Hassan, G. E. and El-Haddad, Z.A. (2009). Development of a vacuum precision seeder prototype for onion seeds. *Misr Journal of Agricultural Engineering*, **26**(4): 1751-1775.

Sharma, D. N. and Mukesh S (2010): Farm machinery design principles and problems, second edition. Jain brothers.

Singh, R. D. (2004). Tractor mounted semi-automatic two-row belt type potato planter ridger. *Agricultural Engineering Today*, 28: 69-74.

Singh, Sadhu, (1988). Machine Design. Khanna Publishers, Delhi, pp. 324-354.edition. Jain brothers.

Shigley's; Richard G. and J. Keith Nisbett. (2011). Mechanical engineering design, 9th edition. (McGraw-Hill series in mechanical engineering).

Smith, H. P. and Wilers. L. H. (1977). Farm Machinery and Equipment. *Sixth edition, Tata McGraw-Hill Publishing Co. Ltd, New Delhi*. pp.183-210.

Srivastava, A. C. (1990). Element of Farm Machinery, *Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi*, 89 - 117.

Teye, E. and Abano, E. E. (2012). Physical properties of two varieties of sweet potato grown in coastal savannah zone of Ghana. *I.J.S.N*. **3**(1): 105-109.

Thomas, H. and Brown, J. (2005). Marks Calculation for Machine Design, McGraw-Hill, New York.

Tucker, E. R. (2013). A Potato Glossary.

Verma, S. R. (1986). Small Farm Equipment for developing countries. *The International Rice Research Institute, Manila Philipines,* 255.

Varnmakhasti, et al. (2007). Some engineering properties of Potato tubers (var. Sazandagi). *International J. of Agriculture and Biology*, **9**(5): 763-766.

APPENDICES

Appendix - A

Specification of tractor drawn potato planter

Sl. No.	Parameter	Specification
1	Power source	35 - 40 HP tractor
2	Overall dimensions:	
A	Length, mm	1500
B	Width, mm	1200
C	Height, mm	1357
D	Weight, kg	155 kg
3	Furrow openers	Shovel type
4	Ridger maker	Ridger type
5	Potato Seed metering mechanism	
	Type	Cup on chain
	Number of cups on each roller	18
6	Driver system	Chain and sprocket
7	Transmition ratio (metering shaft to drive wheel axle)	1:3
8	Potato hopper capacity (kg) and shape of hopper	75 kg one hopper capacity and rectangular with trapezoid shape
9	Number of rows	Two
10	Row to row space (mm)	600
11	Plant to plant space (mm)	300
12	Ground drive wheel and tread form	Rubber type with wide tread, low pressure and low sinkage is required and 600 mm of diameter
13	Machine cost	10,927.07 ETB

Appendix - B

B.1. Materials for constructions of the planter and its cost.

Sr.no.	Material and Specifications	Quantity used m	Total quantity used m	Total cost Birr.
1	M.S. Square, 60 × 60 × 3 mm	5.60	5.8 m	849.00 ETB
2	M.S. Flat, 40 × 5 mm	4.2	4.66 m	284.00 ETB
	50 x 12 mm	0.80	0.78 m	68.00 ETB
	20 × 5 mm	0.52	0.52 m	47.00 ETB
3	M.S. Sheet, 18 gauge	3 No.	3 No.	720.00 ETB
4	M.S. Angle, 35 × 35 × 3 mm	2.0	2.0 m	240.00 ETB
5	Motor chain, 12.5 mm pitch	4 No.	4 No.	600.00 ETB
6	3- point hitching	2.68	2.68	280.00 ETB
7	Ridger	3 No.	3 No.	300.00 ETB
8	Furrow opener	2 No.	2 No.	150.00 ETB
9	M.S. Sprocket, 20 teeth	6 No.	6 No.	400.00 ETB
10	Ball bearing	9 No.	9 No.	690.00 ETB
11	M.S. Nuts, Bolts and washer	7 kg	7 kg	230.00 ETB
12	Paint	1.5 lit	1.5 lit.	400.00 ETB
13	Rubber wheels	2 No.	2 No.	2,000.00 ETB
14	Electrode	Ø 2.5	Ø 2.5	130.00 ETB
15	Fabrication Charges	14 %		1,200.00 ETB
	Total cost planter			**8,588.00 ETB**

B.2. Calculation of operational cost tractor drawn potato planter

The cost of operation for developed tractor drawn potato planter was calculated by following procedure. The operating cost includes fixed and variable cost.

Calculation of operational cost tractor drawn potato planter

No.	Cost variables	Summary
1	Raw material cost	7,388 ETB
2	Material wastage 2.5 %	300 ETB
3	Machine cost	4000 ETB
4	Labor cost	2500 ETB
5	Overhead cost 5 % (3+4)	709.4 ETB
6	Profit 10 % (1+2+3+4+5)	1,489.74 ETB
7	Sells tax 15 % (1+2+3+4+5+6)	2,458.07 ETB
8	Selling price	18,845.21 ETB

Assumptions: Yearly working hour (NAOHP) Number of the annual operational hours of the planter (ETB/h) = 250

Rate of interest, I = 8%

B.2.1. Operational cost of the planter

I. Fixed cost of applicator

A) Depreciation (Dp), was calculated as follows:

$$\mathrm{Dp} = \frac{\mathrm{CC} - \mathrm{SVC}}{\mathrm{EL}}$$

Capital cost, CC = 18,845.21 ETB

Salvage cost, SVC = 10 % x 18,845.21 (considering 10 % of Capital cost)

SVC = 1,884.52 ETB

Assume, Economic Life, EL = 11 years.

$$\mathrm{Dp} = \frac{18{,}845.21\ \mathrm{ETB} - 1{,}884.52\ \mathrm{ETB}}{250\ \mathrm{x}\ 11\ \mathrm{hr}}$$

Dp = 6.16 ETB/hr

B) Interest on capital (IC), was calculated as follows:

$$IC = \left(\frac{CC + SVC}{2}\right) x \left(\frac{I\ \%}{NAOHP}\right)$$

$$IC = \left(\frac{18{,}845.21\ ETB + 1{,}884.52\ ETB}{2}\right) x \left(\frac{8\ \%}{250\ hr}\right)$$

IC = 3.31 ETB/hr

Total fixed cost = DP + IC

Total fixed cost = 6.16 ETB/hr + 3.31 ETB/hr

Total fixed cost = 9.47 ETB/hr

II) Variable cost of applicator

A) Labor wages (LW), was calculated as follows:

$$LW = \frac{DLW}{DWH}$$

$$LW = \frac{60\ ETB}{8\ hr}$$

LW = 7.5 ETB /hr

B) Cost of repairs and spares (CRS) was calculated as follows:

$$CSR = \frac{CC\ X\ 6\%}{NAOHP}$$

$$CSR = \frac{18{,}845.21\ ETB\ x\ 6\%}{250\ hr}$$

CSR = 4.52 ETB /hr

C). Wage of Tractor (WT), was calculated as follows:

$$WT = \frac{DTW}{DWH}$$

$WT = \frac{1{,}600\ \text{ETB}}{8\ \text{hr}}$

WT = 200 ETB /hr

DTW - Daily Tractor wage (ETB)

DWH - Daily working hours (hr)

Total Variable cost = LW + CRS +WT

Total Variable cost = 7.5 ETB/hr + 4.52 ETB/ hr + 200 ETB/ hr

Total Variable cost = 212.02 ETB / hr

Total operational cost = Fixed cost + Variable cost

Total operational cost = 9.47 ETB /hr + 212.02 ETB /hr

Total operational cost = 221.49 ETB /hr

Appendix - C

Table C.1. Physical properties of coarse size potato variety Jalene.

Sr.no.	L, mm	W, mm	t, mm	Sphericity(%)	Geometric Diameter, mm	Volume $(mm)^3$
1	45.78	42.65	41.25	94.3	43.18	42,171.43
2	65.44	53.22	51.72	86.2	56.47	94,314.03
3	56.60	50.96	44.32	88.9	50.37	66,933.76
4	66.89	57.23	46.24	83.9	56.14	92,641.92
5	40.17	38.68	35.94	95.14	38.22	3,035.29
6	44.43	42.62	38.98	94.3	41.94	38,267.51
7	53.35	50.22	46.23	93.42	49.84	64,853.68
8	48.32	43.01	39.67	90.1	43.56	43,167.63
9	47.60	43.12	41.80	92.5	44.06	44,922.26
10	46.97	41.02	40.17	90.7	42.61	40,514.62
11	69.50	64.67	50.90	88.0	61.16	119,785.71
12	54.71	45.23	43.72	87.1	47.64	56,646.55
13	57.53	51.39	50.27	92.0	52.96	77,818.20
14	54.79	49.45	45.82	91.0	49.86	65,001.33
15	52.30	45.25	44.27	90.2	47.14	54,856.61
16	58.88	52.90	50.92	91.9	54.12	83,044.64
17	50.27	47.77	43.60	93.7	47.13	54,821.41
18	60.53	52.27	47.70	87.8	53.24	79,020.75
19	53.65	48.03	43.43	89.8	48.19	58,596.51
20	49.63	45.57	42.21	92.0	45.70	46,963.38
Mean	**53.86**	**48.26**	**43.84**	**86.6**	**50.88**	**59,665.57**
Minimum	40.17	38.68	35.94	83.9	38.22	3,035.29
Maximum	69.50	64.67	51.72	95.14	61.16	119,785.71

Table C.2. Physical properties of coarse size potato variety Belete.

Sr.no.	L, mm	W, mm	t, mm	Sphericity(%)	Geometric Diameter, mm	Volume $(mm)^3$
1	85.14	60.63	55.37	77.3	65.87	150,196.99
2	50.26	45.21	35.89	86.28	43.36	42,700.21
3	60.98	45.01	30.22	71.51	43.61	43,107.98
4	98.53	74.81	61.44	77.93	76.79	237,125.89
5	64.76	54.93	43.43	82.85	53.65	80,892.06
6	60.98	41.11	32.34	70.97	43.28	42,449.69
7	68.12	53.48	40.12	77.32	52.67	76,529.09
8	65.34	48.66	39.46	76.61	50.06	65,691.31
9	62.42	45.80	37.44	76.06	47.47	56,043.43
10	79.98	66.74	54.33	82.76	66.19	151,847.25
11	35.69	35.14	31.13	95.05	33.92	20,442.17
12	70.78	55.81	46.70	80.42	56.92	96,591.54
13	39.07	34.98	31.09	89.31	34.89	22,247.62
14	55.60	49.58	45.16	89.80	49.93	65,183.08
15	64.73	53.88	40.16	80.22	51.93	73,337.57
16	45.54	40.08	40.01	91.78	41.79	38,237.45
17	60.59	50.20	44.22	84.56	51.23	70,424.38
18	90.42	66.28	48.90	73.46	66.42	153,445.97
19	76.90	65.09	55.46	84.82	65.23	145,351.69
20	35.33	30.44	35.04	94.89	33.52	19,731.13
Mean	**63.55**	**50.89**	**42.39**	**81.13**	**51.56**	**71,781.25**
Minimum	35.33	30.44	30.22	70.97	33.52	19,731.13
Maximum	98.53	74.81	61.44	94.89	76.79	237,125.89

Table C.3. Physical properties of coarse size potato variety Gudene.

Sr.no.	L, mm	W, mm	t, mm	Sphericity (%)	Geometric Diameter, mm	Volume $(mm)^3$
1	57.59	51.39	41.42	86.24	49.67	64,185.27
2	58.15	49.97	44.10	86.69	50.41	67,096.10
3	54.05	44.45	40.12	84.82	45.85	50,469.38
4	49.94	42.83	39.47	87.84	43.86	42,333.87
5	51.39	42.78	37.80	84.91	43.63	43,512.17
6	59.22	44.66	37.90	78.44	46.45	52,483.88
7	61.79	46.82	35.64	75.88	46.89	53,986.71
8	63.59	40.65	39.07	73.23	46.56	52,880.11
9	54.88	44.78	37.73	82.47	45.26	48,549.48
10	52.08	45.96	44.15	90.76	47.26	55,300.75
11	58.82	49.09	45.61	86.49	50.87	68,956.90
12	69.76	60.45	53.03	87.00	60.69	117,091.14
13	87.94	60.49	45.88	71.04	62.48	127,788.89
14	78.62	50.14	40.18	68.81	54.10	82,932.91
15	60.67	44.81	33.56	74.20	45.01	47,771.68
16	40.45	30.19	28.55	80.76	32.66	18,255.23
17	44.42	31.60	26.89	75.51	33.54	19,763.14
18	59.81	45.70	36.08	77.24	46.20	51,636.42
19	76.90	50.89	41.34	70.85	54.48	84,708,87
20	72.19	52.63	38.96	73.26	52.89	77,504.87
Mean	**60.61**	**46.51**	**39.37**	**79.27**	**48.05**	**58,110.64**
Minimum	40.45	30.19	26.89	68.81	32.66	18,255.23
Maximum	87.94	60.49	53.03	90.76	62.48	127,788.89

Table C.4. Physical properties of coarse size potato variety Chala.

Sr.no.	L, mm	W, mm	t, mm	Sphericity (%)	Geometric Diameter, mm	Volume (mm)^3
1	72.00	59.66	48.49	82.32	59.27	109,060.52
2	71.98	52.98	46.43	78.01	56.15	92,709.04
3	65.08	60.73	40.60	83.49	54.34	84,948.33
4	35.67	30.94	35.87	95.54	34.08	20,727.85
5	44.86	40.08	34.95	88.62	39.75	32,902.87
6	48.98	38.56	31.34	79.56	38.97	30,992.34
7	70.16	53.54	42.62	77.39	54.29	83,826.44
8	72.15	54.87	48.65	80.04	57.74	100,844.86
9	38.23	30.18	34.93	89.68	34.28	21,101.90
10	54.69	47.81	40.17	86.27	47.18	54,995.62
11	45.80	40.29	36.85	89.91	40.81	35,604.08
12	60.61	50.83	43.22	84.25	51.06	69,718.62
13	38.54	29.45	22.56	76.47	29.47	13,407.12
14	50.21	41.96	38.40	86.13	43.24	42,360.05
15	68.32	46.96	37.78	72.43	49.48	63,465.47
16	45.89	40.53	34.27	87.04	39.94	33,374.01
17	39.68	32.74	27.42	82.92	32.90	18,651.65
18	44.86	40.49	38.61	91.92	41.23	36,720.32
19	71.53	53.21	43.85	76.96	55.05	87,387.78
20	60.11	50.31	42.44	83.91	50.44	67,201.04
Mean	**58.96**	**44.81**	**38.47**	**79.51**	**46.88**	**53,217.47**
Minimum	35.67	29.45	22.56	72.43	29.47	13,407.12
Maximum	72.15	60.73	48.65	95.54	59.27	109,060.52

Table C.5. Physical properties of coarse size potato variety Gera

Sr.no.	L, mm	W, mm	t, mm	Sphericity(%)	Geometric Diameter, mm	Volume $(mm)^3$
1	45.48	40.12	40.34	92.1	41.90	38,548.93
2	59.89	48.98	45.01	85.0	50.92	69,132.41
3	54.86	50.55	44.76	90.9	49.88	64,993.01
4	60.05	49.98	43.59	84.5	50.76	68,500.82
5	39.88	33.54	29.84	85.69	34.17	20,898.57
6	44.28	37.04	30.82	83.50	36.97	26,467.37
7	49.05	42.21	39.43	88.4	43.38	22,381.04
8	53.56	44.94	40.11	85.65	45.87	50,550.55
9	51.69	43.78	37.72	85.18	44.03	44,694.45
10	56.69	49.18	40.48	85.24	48.32	59,092.87
11	56.01	43.85	38.44	81.29	45.53	49,433.13
12	98.55	76.81	60.41	78.17	77.04	239,432.37
13	65.12	50.48	40.11	78.15	50.89	69,037.65
14	60.67	48.09	41.65	81.64	49.53	63,627.28
15	70.14	56.81	44.70	80.21	56.26	93,260.49
16	38.14	33.16	30.05	88.15	33.62	19,899.36
17	40.40	32.38	28.97	83.14	33.58	19,842.95
18	50.18	41.77	36.62	84.69	42.49	40,189.54
19	48.12	41.98	35.98	86.72	41.73	38,056.50
20	36.56	30.67	34.16	92.20	33.70	20,055.68
Mean	**53.96**	**44.81**	**39.15**	**84.46**	**45.57**	**49,565.36**
Minimum	36.56	30.67	28.97	78.15	33.58	19,842.95
Maximum	98.55	76.81	60.41	92.20	77.04	239,432.37

Appendix - D

Calibration of planter test in laboratory.

Speed	Seed type	Seed rate ($kg. ha^{-1}$)			
		1	2	3	Avg.
	Gudene	2133	2119	2120	2124
36 rpm	Gudene	1998	2010	2001	2003
	Gudene	1961	1942	1956	1953

Appendix - E

Seed distribution in furrow opener at different seed size

Potato tuber	Test No.	Number of seed discharge in 10 revolution of ground wheel	
		Furrow No.1	Furrow No.2
	1	60	60.8
	2	60.8	60
Potato seed	3	60.7	60.7
	4	60.2	60.2
	5	60.5	60.5
	Average	60.44	60.44

Appendix- F

Determination of number of missing and number of doubles

Name and Variety of Seeds = Potato seeds and Gudene and Length of Furrow = 10 m

Table 4.7. Number of Missing and Number of Double

Speed (km/hr)	Spacing between two consecutive seeds (cm)		Number of missing	% of missing	Number of doubles	% of double
3.0	R1	31.6	2	6.25	3	9.37
	R2	31.0	2	6.25	3	9.37
	R3	31.3	2	6.25	3	9.37
	Avg.	**31.3**	**2**	**6.25**	**3**	**9.37**
3.5	R1	30.90	3	9.37	2	6.25
	R2	31.0	2	6.25	3	9.37
	R3	30.95	4	12.5	4	12.50
	Avg.	**30.95**	**3**	**9.37**	**3**	**9.37**
4.0	R1	30.02	2	6.25	3	9.37
	R2	29.82	3	9.37	4	12.5
	R3	29.92	4	12.50	5	15.62
	Avg.	**29.92**	**3**	**9.37**	**4**	**12.5**

Appendix - G

Depth of tuber's placement and row to row distance under different treatments.

Sr. No.	Depth, cm	Spacing,cm	Depth,cm	Spacing,cm	Depth,cm	Spacing,cm
1	11.8	61.5	11.50	61	12.08	59.5
2	12.4	60	12.24	60.5	12.14	60.5
3	12.78	59.7	12.50	61	12.23	60
4	12.6	60.5	12.34	60.5	11.87	61.5
5	11.94	60.6	12.43	60.5	11.96	60
Average	12.30	60.36	12.20	60.7	12.056	60.5

Appendix - H

Determination of slippage of ground wheel

Wheel slippage (%) of power transmission wheel was computed by using the formula:

Wheel slippage = $\frac{M1-M2}{M1}$ X 100

Where: M1 = Under no load distance to be covered in10 revolutions of wheel in the field (m),

M2 = Under Load distance covered in10 revolutions of wheel (m).

Speed (km/hr)	Sr. No.	Distance covered in 10 revolution		Slip (%)	Avg. Slip (%)
		Under no load,m	Under Load,m		
	1	25.88	23.44	9.42	
3.0	2	25.9	23.51	9.22	9.18
	3	25.76	23.46	8.92	
	1	25.66	23.11	9.93	
3.5	2	25.61	22.91	10.54	10.18
	3	25.69	23.1	10.08	
4.0	1	25.5	22.6	11.37	
	2	25.4	22.4	11.81	11.58
	3	25.4	22.46	11.57	

Appendix – I

Draft and Power Measurement

Power = $\frac{\text{Draught (kg)x speed (km/hr)}}{270}$ (hp)

Operation Speed (km/h)	Draft (kg)			Power (hp)		
	load Condition	unload Condition	Net draft	load Condition	unload Condition	Net power
	498	194	304	5.53	2.15	3.38
3	495	198	297	5.50	2.20	3.30
	496	197	299	5.51	2.18	3.32
Mean	**496.33**	**196.33**	**300**	**5.51**	**2.18**	**3.33**
	507	199	308	6.57	2.58	4.14
3.5	508	202	306	6.58	2.62	4.00
	512	201	311	6.64	2.60	4.03
Mean	**507.33**	**200.66**	**308.33**	**6.60**	**2.6**	**4.05**
	522	208	314	7.73	3.08	4.65
4	519	205	314	7.68	3.03	4.65
	526	206	320	7.80	3.05	4.74
Mean	**519.33**	**208.33**	**316**	**7.73**	**3.05**	**4.68**

Appendix- J

Calibration Data Sheet

D = Diameter of ground wheel = 0.60 m

L = Length of strip covered by ground wheel in one rev. = π x 0.6 m = 1.884 m

n = number of furrow openers = 2

R = Recommended row to row spacing = 0.20 m - 30 m

Area covered in one rev. of ground wheel = 0.60 × 2 × 1.884 = 2.26 m^2

Area covered in 10 rev. of ground wheel = 2.26 × 10 = 22.6 m^2

Calculation required for number of rev. required at different speed and time for that revolution at different speed.

(a) Speed 3.0 km/h

$N_2 = \frac{3.0 \text{ x } 1000}{60 \text{ x } 0.6 \text{x } \pi} = 26.52$

(b) Speed 3.5 km/h

$N_2 = \frac{3.5 \text{ x } 1000}{60 \text{ x } 0.6 \text{ x } \pi} = 30.94$

(c) Speed 4.0 km/h

$N_2 = \frac{4.0 \text{ x } 1000}{60 \text{ x } 0.6 \text{ x } \pi} = 35.36$

Time allowed for N revolution at different speed, $T = \frac{60 \text{ x } N}{Nx}$

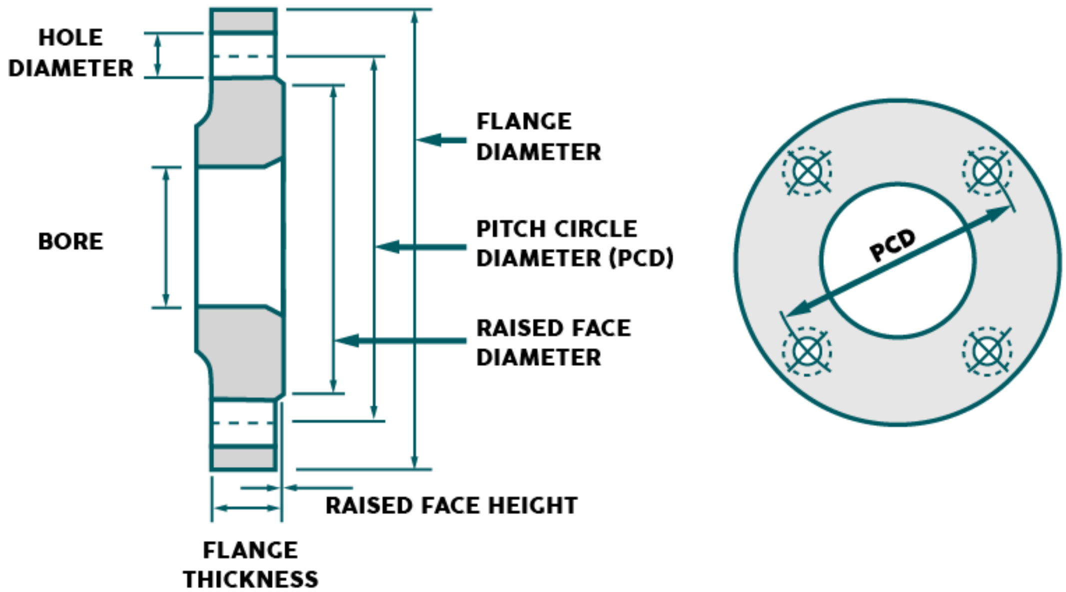
$T = \frac{60 \text{ x } 10}{26.56} = 22.59$ sec

$T = \frac{60 \text{ x } 10}{30.94} = 19.39$ sec

$T = \frac{60 \text{ x } 10}{35.36} = 16.96$ sec

Appendix- J

ASTM A182 Standard Steel Flange



ASTM specifications regulate approved raw materials for which flanges can be made and specifications

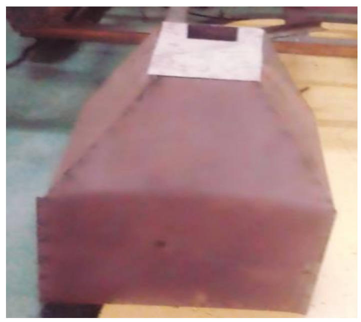
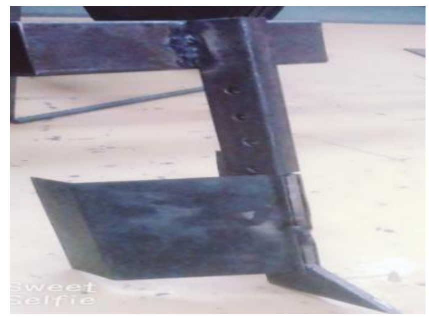
TYPE OF FLANGE	EN STANDARD	DIN STANDARD
Blind Flange	Type 5	DIN 2527
Threaded Flange	Type 12	DIN 2558, 2565 – 2569
Weld Neck Flange	Type 11	DIN 2627 – 2638
Flat Flange	Type 1	DIN 2573, 2578
Lapped Flange	Type 2, 4	DIN 2641, 2622, 2655, 2656

Appendix- L

Photo graphs of the planter and during manufacturing activities






Seed emergence stage

Seed cultivated stage