Design, Fabrication, and Performance Evaluation of Tractor Drawn Multi-Row Garlic Planter

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Department of Mechanical Systems and Vehicle Engineering
School Of Mechanical, Chemical, and Materials Engineering

A Thesis Submitted in Partial Fulfillment of the Requirements For The Award of the Degree of Master of Science in Agricultural Machinery Engineering

Office of Graduate Studies
Adama Science and Technology University

November, 2021
Adama, Ethiopia

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CANDIDATE'S DECLARATION

I hereby declare that this Master Thesis entitled "**Design, Fabrication and Performance Evaluation of Tractor Drawn Multi-row Garlic Planter**" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Obsa Girma Yigezu	________________________	________________
Name of the student	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "**Design, Fabrication and Performance Evaluation of Tractor Drawn Multi-row Garlic Planter** " prepared under my guidance by Obsa Girma submitted in partial fulfilment of the requirements for the degree of Masters of Science in Agricultural Machinery Engineering. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Dr.Ing.Simie Tola	______________________	_______________
Major Advisor	Signature	Date

THESIS APPROVAL SHEET

I, the advisors of the thesis entitled "**Design, Fabrication and Performance Evaluation of Tractor Drawn Multi-row Garlic Planter**" and developed by Obsa Girma, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

______________________	____________________	______________
Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Obsa Girma have read and evaluated the thesis entitled "**Design, Fabrication and Performance Evaluation of Tractor Drawn Multi-row Garlic Planter** " and examined the candidate during open defence. This is, therefore, to certify that the thesis is accepted for partial fulfilment of the requirement of the degree of Master of Science in Agricultural Machinery Engineering.

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Jesus Christ is the way, the truth and the life, Thank you Lord!

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ACRONOMYS

AMARC	Awash Melkassa Agricultural Research Centre
ASABE	American Society of Agricultural and Biological Engineers
ASAJ	American Society of Agricultural Journal
ASTM	American Society for Testing and Materials
CSA	Central Statistical Agency
ETB	Ethiopian Birr
RCBD	Randomized Complete Block Design

ABSTRACT

Garlic (Allium sativum) belongs to the alliaceous family, in the same family as onions. Garlic is one of the most important crops widely cultivated throughout the world including Ethiopia. Garlic is widely used as a seed, for consumption and medicinal purposes. Despite wide use, many problems are not solved in the production system, among which planting technique seems the first. Due to the lack of a garlic planter system farmers still use traditional methods for planting garlic seeds, this traditional method is inefficient, tiresome, labour-intensive, and time-consuming. So by providing planting machines the above problems was eliminated and improve planting efficiency and garlic productivity. The main aim of this study was to design, fabricate, and evaluate the performance of a tractor-drawn garlic planter capable of planting garlic seed. The following method was used, studying physical properties of garlic seed, design all of component parts,fabrication, performance evaluation of garlic planter, data collection, data organizing and data analysis to draw meaning full conclusion. The developed tractor drawn garlic planter consists of hopper, feed cup, seed metering mechanism, furrow opener, ground wheel, three-point hitch and furrow covering device. The physical properties of two varieties of garlic were studied. The shape index of two varieties was 0.78 and 0.755. The angle of repose of two varieties was 26°and 25°. The performance of tractor drawn garlic planter were evaluated in the laboratory and field. Row to row spacing can be 30cm and average depth of seed placement was found 5.97 cm as per garlic agronomic requirement. The seed rate was calibrated and observed that 122.86 kg/ha which is laying in the acceptable range of 100 to 140 kg/ha. The field test conducted at tractor speed of 36 rpm show 135.33 kg/ha seed rate. The theoretical field capacity, effective field capacity and field efficiency of the machine were 0.38 ha/hr, 0.27 ha/hr and 72.52 % respectively. The average germination of the metered seed was observe 83.35% seeds. The tractor drawn garlic planter which is estimated to be 16100.815 Ethiopian birr, then by using garlic planter machine farmers can save time, reduce planting operation cost and prevent drudgery of labour. Making a good plat form to adopt the planter to the farmers to use garlic planter effectively and efficiently.

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

CHAPTER ONE

1. INTRODUCTION

1.1. Background and Justification

Garlic (*Allium sativum* L.) belongs to the alliaceous family (Allen, 2009). The origin of garlic is thought to be in Central Asia (India, Afghanistan, West China, Russia) and spread to other parts of the world through trade and colonization (Tindal, 1986). Garlic is the most important *Allium* crop and ranks second next to onion in the world (Voigt, 2004). For its production and economic value, garlic is one of the main *Allium* vegetable crops in the world and is used as a seasoning in many foods throughout the globe. The oil of garlic is volatile and has sulphur combining compounds which are responsible for the strong odour, its unique flavour, and pungency as well as for healthful benefits (Salomon, 2002). Garlic is a basic flavouring in many types of dishes ranging from vegetable soup, meat, salad, tomato combination, spaghetti, sausages, and pickles (Brewster, 1994). Garlic has also a medicinal value which is well recognized in the control and treatment of hypertension, worms, germs, bacterial and fungal diseases, diabetes, cancer, ulcer, rheumatism, etc. (Samavatean, 2011). Many people perceived and appreciated garlic for its many medicinal attributes (Rabinowitch, 2002).

The plant can perform best when planted on well-drained soils. It is better to plant on flatbeds; but on heavy soils, which are poorly drained during the rains; it is advisable to plant on the ridges. To obtain a good yield, producers should give attention to select land that has high fertility and apply considerable quantities of manure or fertilizers. Garlic production requires a growing period of 4.5-6 months and the amount of rainfall required ranges between 600 mm to 700 mm during its production season. The optimum temperature for garlic growing lies between 12 °C and 24 °C (Lemma and Herath, 1994). Garlic withstands moderate frost. Garlic is one of the most important vegetable crops in Ethiopia and is used as an ingredient of local stew ‘wot’ and has also a tremendous use in the formulation of local medicines. Garlic production spread throughout the country and has been cultivated under irrigated as well as rain-fed conditions, mainly in the mid and highlands of Ethiopia (Lemma and Herath, 1994).

In Ethiopia, a total of 15,381.01 ha of land was under garlic production during the 2016/17 main cropping season, taking up about 6.71% of land area covered by all root crops at the count level and yielding about 138664.30 tons of those cultivated by small scale farmers, contributing about 2.99% to the total country-level root crop production (CSA, 2017). In Oromia region, the crop covered 6,430 ha of land with a total production of 60,175.5 tons and productivity of 9.4 t/ha in 2016/17. Though acreage of garlic, production, and productivity are not indicated for Eastern Hararghe Zone, about 50,683 farmers produced garlic in the area (CSA, 2017). Adet, Ambo, Debre-Work, Sinana, Jimma, and many other areas of the Ethiopian highlands produce the bulk of garlic under the small-scale farmer's sector. Farmers produce garlic under rain-fed conditions during both winter (August-December) and summer (March-July) cropping seasons for consumption and commercial purpose (Getachew, 2000).

Garlic is one of the most important bulb crops produced by small and commercial growers for both local use and export (Shimelis, 1998). As a cash crop, it is used to earn foreign currency by exporting to Europe, the Middle East, Africa countries, and the USA (Kilgori, 2007). At off-season, the same quantity of garlic is usually sold at twice or three times the value of onion (Getachew, 2000). However, the absence of the garlic planter affect garlic production, because traditional methods for planting garlic seeds is inefficient, tiresome, labour-intensive, and time-consuming, serious backache for farmers, high production cost, and also manual planting cannot achieve the planting uniformity and result in non-uniformity of growth.

1.2. Statement of the Problem

In Ethiopia, garlic production and its area coverage increase due to the growing market demand for garlic. Garlic is getting more attention and its planting area is increasing every year. Garlic is planted in dry or wet fields, as a single or inter-cropped by manual planting method, which has some disadvantages. Manual method needs high labour requirements in a short period. Due to the lack of a garlic planter system in Ethiopia, Farmers face a series of challenges in garlic production costs. This traditional method is inefficient, tiresome, labour-intensive, and time-consuming, serious backache for farmers, high production cost, and also manual planting cannot achieve the planting uniformity and result in non-uniformity of growth. Therefore, production maximization and labor drudgery are attained based on the minimization of these problems

by using a garlic planter machine. To overcome this problem,it is important to design,construct a garlic planter that is feasible and simple to operate. In my project, I was decide to design,construct,and evaluate the performance of a garlic planter machine that is available to rural farmers who cultivate garlic.

1.3. Objectives

1.3.1. General objective

- The main objective of this study was the design, fabrication , and performance evaluation of four row tractor-drawn garlic planter.

1.3.2. Specific objectives

The specific objectives of the study are as follows:

- To find the physical properties of garlic cloves related to garlic planter.
- To design and fabricate tractor-drawn garlic planter.
- To conduct on station performance evaluation of garlic planter.

1.4. Significance of the Study

The importance of the design and development of garlic row planter is to increase the production of garlic through uniform planting of garlic seed in the field by reducing the drudgery of labor, requirement of labour, saving time, resources, and money per hectare.

1.5. Scope of the Study

This study is limited to design, fabrication and performance evaluation of tractor drawn garlic planter at a local workshop. It includes selecting,identifying and specifying the size, type and its different part of planter during design time. After design different parts of garlic planter and fabrication of the garlic planter machine by using the available local materials and the presence of experienced workshops and the performance of the garlic planter machine were evaluated.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Garlic Plantation

In the agricultural field, seed planting operation is very time-consuming in the farming process. Also, more labour is required for seed planting. Hence the total cost of the farming increases and manual planting also it's a series backache problem to the farmers. Therefore scientists must develop seed planting machines that appropriate to the field condition and reduce the drudgery of labour.

Manual garlic seed planting is the operations which is very time-consuming and more labour is required for this operation. But this method has drawbacks like low seed placement, variation in spacing, and serious backache for farmers.

The mechanical method of garlic planting is when planting operation is done by farm equipment usually towed behind a tractor, and that sows seed in rows throughout a field. It is connected to the tractor with a drawbar or a three-point hitch. Planters lay the seeds down in a precise manner along rows.

Figure 2. 1.Manual planting method of garlic seed in the furrow

Source (taken from Best Fit Practice Manual for Garlic in Tigray Region, Ethiopia by Girmay G/Samuel and Eyasu Elias)

ASAJ (2010), Garlic can either be planted by precision, drilling and broadcasting. There are two major garlic planting methods use for Garlic.

▪ Row planting: furrows are prepared with the use of drought animals or hand hoe and cloves are dropped into furrow by hand. Then they are lightly covered with loose soil.
▪Broadcasting: cloves are broadcasted in a well prepared levelled land and covered by harrowing. Spacing between rows depends on the method of planting.

Hassan (1991), described two methods of garlic planting in Egypt. In the first method, the garlic cloves are planted manually on both sides of the furrow (furrow width 50-60 cm). The cloves are placed between 5 to 7 cm and the field is then irrigated. In the second method, the garlic cloves are planted in rows spacing 30 cm on the flat soil divided into 3 x 3 m plot. This result shows that the first method is the prevailing garlic-planting practice in Egypt.

2.1.1. Garlic Spacing

(Worku and Azene, 2015), studied the effects of spacing on intensity and severity of garlic rust (Puccinia allii) on yield and yield components of garlic at research field of Haramaya University, Ethiopia. It was found that the spacing was varied significantly in disease incidence and severity and the aforementioned agronomic data. The maximum yield was observed from the plot planted with 10 cm intra row spacing where was the minimum value of yield was recorded at plot planted with 20 intra row spacing. They recommended that spacing 10cmx30cm is optimal for better production of garlic under disease conditions.

ASAJ (2010), Proper spacing of rows and plants allows the garlic to take up a sufficient amount of nutrients for optimal yield. Dig your rows at least 25 to 30 cm apart. When you plant garlic, the spacing between cloves depends on the type of garlic. Stiff neck types (Allium sativum ophioscorodon), need to be 7 to 15 cm apart. Soft neck types (A. sativum sativum), also known as artichoke garlic, need to be 15 to 20 cm apart. Elephant garlic cloves (Allium ampeloprasum), also known as great-headed garlic, need to be 20 to 25 cm apart.

2.1.2. Position of garlic during planting

Orlowski (1992), conducted a three-year experiment to investigate the effects of different clove sowing methods on garlic yield. Their treatments included: (1) bud pointed upward (conventional); (2) bud pointed downward; (3) bud pointed either side; and (4) bud at any random position (similar to machine sowing). The dependent variables measured were the number of plants that emerged, plant height, garlic yield, and quality. The results showed that (1) treatments 1 and 2 had the highest and lowest yield, respectively, (2) treatments 3 and 4 didn't show any significant difference in yield, and (3) treatment 4 had about 13.7-19.4% lower production cost than that of treatment 1 with no significant difference in quality. This result shows, planting garlic inside position do not affect the number of plants that emerged, plant height, garlic yield, and quality when compared with upward position planting.

2.1.3. Seed Rate and Planting Methods

ASAJ (2010), the planting material is prepared first by separating the clove from one another. The cloves from the outer parts of the bulb are the best planting material. When there is a shortage of planting materials, the inner cloves can be used also but these should be separated from the outer cloves. The recommended seed rate is 100 to 140 kg per hectare depending on the clove size and planting method.

2.2. Physical and Mechanical Properties of Garlic

Haciseferogullari (2005), Studied physical properties of garlic, They concluded that the diameter of whole garlic, geometric mean diameter, sphericity ,volume ,bulk density were 27.24 mm,46.51 mm , 15.15 mm ,0.559 cm^2 , 2245.64 mm^3 and 478.75 kg/m^3.

El-Gayar (2005), reported that, the mean values of sphericity and roundness of garlic cloves were 0.43 and 0.19 for the sidth-40 variety, while they were 0.62 and 0.40 for baladi variety. The mean weight of Sidth-40 and Baladi cloves were 2.46 and 1.90 g, respectively. The mean length, width and thickness of both varieties ranged from 22.9 to 28.7, 14.13 to 14.5, 9.0 to 13.13 mm. the surface area and bulk density values ranged from 186.27- 253.6 mm^2, and 0.92-0.99 $\frac{g}{cm^3}$, respectively, for both variety cloves.

H.Bahnasawy (2007), reported that, the garlic geometric and arithmetic mean diameters ranged from 2.53 to 4.93, and 2.53, to 5.02 cm, respectively according to the bulb size categories. The cloves length, width and thickness were 1.92 to 2.91, 0.78 to 1.32 and 0.69 to 0.99 cm, respectively .the surface areas ranged from 53.31 to 136.4cm^2.

Karababa (2006), reported that when bulk granular materials are poured onto a horizontal surface, a conical pile will form. The internal angle between the surface of the pile and the horizontal surface is known as the angle of repose and is related to the density, surface area, and coefficient of friction of the material. Material with a low angle of repose forms flatter piles than material with a high angle of repose. In other words, the angle of repose is the angle of a pile forms with the ground. This property is sometimes used in the design of equipment for the processing of particulate solids. For example, it may be used to design an appropriate hopper. The angle of repose of bulb garlic was measured in two ways: (1) the filling method, to determine the static angle of repose, and (2) the emptying method, to determine the dynamic angle of repose. For the filling method, the sample was poured onto the cell through a fixed hopper to foster a constant feeding rate, and thus the formation of a natural slope. The emptying method was determined by using an open-ended cylinder of 15 cm diameter and 50 cm height. The cylinder was placed at the centre of a circular plate having a diameter of 70 cm and filled with a bulb. The cylinder was raised slowly until it formed a cone on the circular plate.

2.3. Machine Components

2.3.1. Seed hopper

Klenin and Sakun (1985),stated that seed boxes, barrels, and hoppers not only serve as spaces to store seed material but form an integral part of the technological process setting up a flow of seed material through feed hole to 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.

Kual (1985), showed that the hopper in the seed drill may be trapezoidal, rectangular, or oval. The capacity of the hopper also varies, depending upon the size of the machine. Making the hopper trapezoidal in shape help to ensure a free flow of seed.

Bosai and Vernair (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. 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.

2.3.2. Seed metering mechanism

The metering mechanism is the heart of the planting machine and its function is to distribute seeds uniformly at the desired application rates and controls seed spacing in a row. Proper selection and design of metering devices is an essential element for the satisfactory performance of the seed planter (Ikechukwu, 2014).

Harb (1997), developed a metering belt system garlic planter to plant seeds at a 10 cm distance between cloves along the rows. The machine opens a furrow for irrigation and plants two rows of garlic on both sides of the furrow top. Field experiments showed that the machine plants garlic cloves more uniformly at low forward speeds. At high forward speeds above 3 km/h, the percentage of unsuccessful fed increased to more than 20 %.

2.3.3. Frame

Richy and Hall (1996), stated the importance of the frame design. The design of the frame was particularly important in the 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 a lightweight 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 (1997), had given some guidelines in the fabrication of the planter frame. The frame was usually made of mild steel angle, well braced and reinforced at the corners. The frame needed to be strong enough to prevent sagging and to hold the parts in alignment as all parts were connected to the frame.

2.3.4. Drive mechanism

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

2.3.5. Hitching

Srivastava (1990), stated that the method of hitching also affects the rate of sowing. Hitching too low resulted in 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 the correct depth but also prevented plugging of the furrow opener with grass, dust, and wearing of boots.

2.3.6. Furrow opener

A furrow opener cuts a furrow soil and allows the seeds or seedling 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 shoe openers.

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

2.3.7. 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 (Shaaban, 2009).

2.4. Design, development, and performance evaluation of different types of garlic planter

Rocha (1991), designed and developed a manually operated planter for garlic bulbs mounted on two bicycle wheels and equipped with a toothed belt distribution mechanism. The toothed rubber belt was equipped using the sponge teeth 25 x 47 mm and 25 mm high. In infield tests using the prototype equipment, bulbs were spaced at 5 bulbs/meter.

Harb (1997), developed a metering belt system garlic planter to plant seeds at a 10 cm distance between cloves along the rows. The machine opens a furrow for irrigation and plants two rows of garlic on both sides of the furrow top. Field experiments showed that the machine plants garlic cloves more uniformly at low forward speeds. At high forward speeds above 3 km/h, the percentage of unsuccessful fed increased to more than 20 %.

Jarudchai and Jiraporn (2002), designed and developed a garlic planter in Thailand. They constructed and tested two models with different metering devices which included (1) a vertical metering plate with triangular grooves and (2) a bucket type device. The bucket type metering device presented the most impressive results regarding uniformity of the metering system and low garlic clove damage 0.23%.

Garg (2003), designed and developed a single-row manually-operated planter in India, which was evaluated for sowing garlic (Allium sativum). The machine consists of a planting mechanism and hopper mounted over a wheel hand hoe. The planting mechanism consists of a vertical disc with spoons on its face. The weight of the machine is approximately 12.0 kg. The machine is operated by 2 persons and another person is required for supplying the seed. The capacity of the machine varies from 0.03-0.04 ha/h. The machine is quite simple in design and costs Rs.1200. It is highly labour-saving equipment as it requires only approximately 83 man-h/ha in comparison to approximately 520 man-h/ha. The cost of planting using this machine is only 15% of the cost of planting by the traditional method.

Bakhtiari (2009), designed, fabricated, tested a tractor mounted with ground-wheel drive, triple unit, and row crop precision planter capable of planting three rows of garlic cloves on each raised bed. The results showed that the new machine was capable of planting 220,000 plants/ha. Miss index, multiple indexes, and seed damage were measured as 12.23, 2.43, and 1.41 %, respectively.

2.5. Research gap

Based on reviews studied and a tractor-drawn garlic planter is important to our farmers that will fit our condition and the planter is modified with the following features; the spacing of row to row, four number of row, fed cup metering mechanism, furrow openers, furrow cover, hopper, and power transmission comprise of chain and sprocket. Besides this suitable hitching system, the frame stands for the various loads accruing during the operation of the planting.

CHAPTER THREE

3. MATERIAL AND METHODS

3.1. Description of Study Area

The design, fabrication and performance evaluation of the tractor-drawn multi-row garlic planter was conducted at Awash Melkassa Agricultural Research Center (AMARC) which is located at 117 Km from Addis Ababa city. The geographical location of the research centre is an altitude of 1466 m above sea level and lies on the geographical coordinates of 8° 24' 0" N, 39° 20' 0" E Latitude and Longitude point, respectively. The mean annual rainfall ranges between 500 mm to 800 mm and the average annual minimum and maximum temperatures are 12 ^{o}C and 36 ^{o}C, respectively.

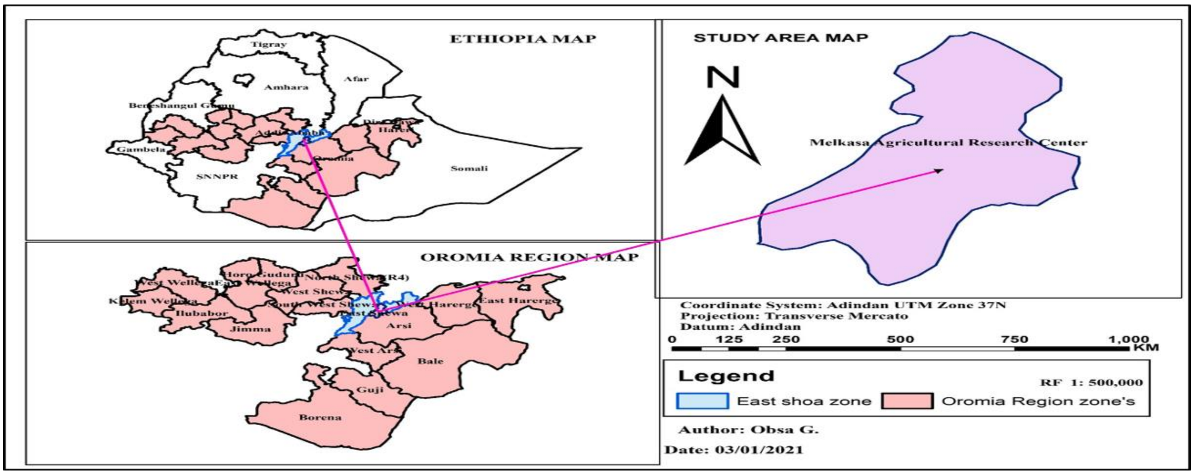


Figure 3.1.Study area description map

3.2. Design Requirement of Garlic Planter

The essential requirements of garlic planter are listed as follows:

1. Tractor drawn garlic planter was optimally perform its main function i.e.
   - ✓ plant garlic cloves or seed at required row to row and plant to plant spacing and at required depth.
   - ✓ Plant garlic seed with minimum percentage of damage, double and missing percentages.
2. Garlic planter was easy to repair at lower cost.
3. It was very reliable to use.
4. It was a durable one.
5. It was simple to use.

3.3. Components of Garlic planters

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

- Major Parts of garlic planters and material needed
- Frame
- Seed hopper
- Seed Metering Mechanism
- Drive Mechanism
- Furrow opener
- Seed covering devices
- Hitching

Table 3.1. Material used to construct prototype of garlic planter

S.No	Components	Specification	Material
1	Ground wheel	Wheel diameter 500 mm, width 100mm	Steel tire
2	Seed hopper	Trapezoidal shape with Top width, height and bottom width 513 x 400 x250mm	MS sheet 18 gauge
3	Seed metering mechanism	Cup metering mechanism, 16 cups around peripheral, distance between cups 100 mm.	MS sheet 18 gauges
4	Chain and sprockets	Sprockets 14 teeth and 14 teeth 50 mm diam. chain pitch 6.35 mm, total chain length 823mm.	Steel
5	Frame	Total length and width were 1250 mm and 1200 mm respectively.	MS square pipe 60 x 60 x 3mm
6	Tyne type of furrow opener	Adjustable row to row spacing and depth up to 70 mm, height of shank 48 mm, rake angle 120^o	Medium carbon steel

7	Seed tube	Diameter 60 mm, thickness 2 mm	MS sheet 18 gauges
8	Furrow covering	Adjustable row to row spacing and depth up to 50mm	Mild steel flat bar
9	Cups	Diameter 30 mm, thickness 2 mm	MS sheet metal
10	Three-point hitch system		Mild steel bar
11	Nuts and bolts		Low carbon steel
12	Ball bearing	Diameter 30mm	

During the field test 75 kg of Gojjam varieties of garlic seeds was used. During the laboratory experiments Gojjam and Minjar varieties of garlic seeds was used to study physical properties of potato.

Table 3. 2. Workshop machines used to construct prototype of garlic planter

S.No	Type of machine	Application
1	Welding machine	For welding part together
2	Grinder	To face the welding parts
3	Drilling machine	Making a hole in different parts
4	Lathe machine	For general purpose
5	Hack sow	For cutting parts
6	Bending machine	For twisting part
7	Steel scale	Measurement of linear distance
8	Steel tape	Measurement of linear distance
9	Centre punch	Hole marking
10	Hammer	To strike an object
11	Chisel	Cutting
12	Scissors	Cutting sheet metal
13	Wrench	Tightening nut and bolt
14	Screw driver	Tightening screw
15	Hand grinder	Grinding metal sheet
16	Flat file	Smooth rough edges
17	Plastic bag	To collect the seed

18	weight balance	To weight garlic
19	Stopwatch instrument	To record time taken during testing

3.4.Methods

The methods were the following procedures.

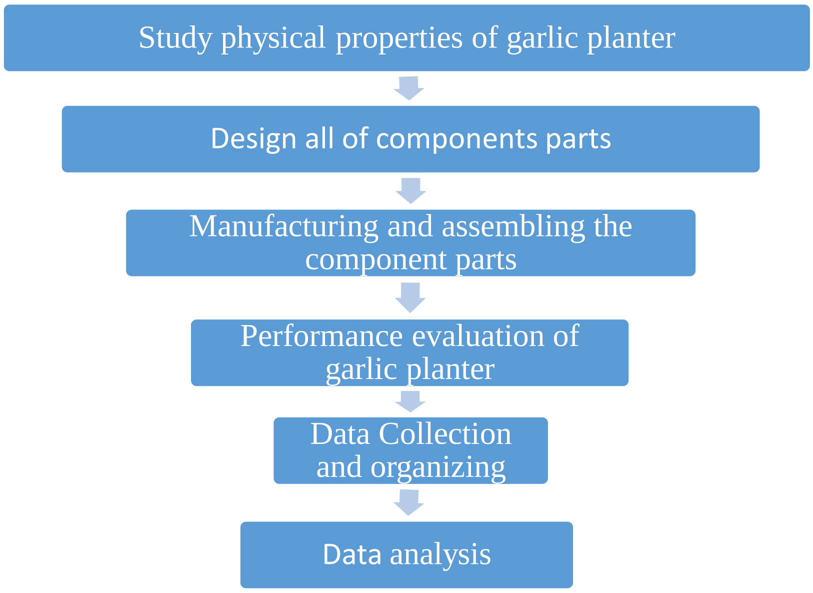


Figure 3.2. Procedures of method

3.5. Physical and Mechanical Properties of Garlic

The physical properties of garlic are an important factor for the design of garlic planter. The two garlic varieties was selected for the study. The physical properties of garlic namely: geometric mean diameter, surface area, Shape index, bulk density and angle of repose.

3.5.1. The geometric mean diameter

The geometric mean diameter (*Dg*) of the garlic cloves was calculated as follows (Garnayak, 2008).

Geometric mean diameter (Dg) $= \sqrt[3]{L\,WT}$, mm…………………………………….. (3.1)

Where: L = length, mm

W = width, mm

T = thickness, mm

3.5.2. The surface area

The surface area (*As*) of the cloves was calculated with a sphere of the same geometric mean diameter as follows (Bakhtiari , 2011).

$$As = \pi\ x\ Dg^2\ ,\ (mm^2)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3.2)$$

3.5.3. Shape index

Shape index is used to evaluate the shape of garlic bulbs and it is calculated according to the following equation (3.3) (Abd Alla, 1993).

$$\text{Shape Index} = \frac{W}{\sqrt{LT}}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3.3)$$

The garlic bulb is considered as oval if the shape index > 1.5, on the other hand, it is considered spherical if the shape index < 1.5.

3.5.4. The bulk density

The bulk density (*ρb*) of the cloves was determined using the standard test weight procedure by filling a container of 30 cm height and 10 cm diameter with the garlic cloves from a height of 15 cm from the top surface of the container at a constant rate and then weighing the cloves (Özguven, 2005).

$$\rho b = \frac{Ms}{Vc}\ ,(\frac{kg}{m^3})\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3.4)$$

Where: Ms = Total mass of cloves in the container, Kg

Vc = volume of the container, m^3

3.5.5. Angle of repose

The angle of repose of bulb garlic was measured by the emptying method, to determine the dynamic angle of repose by using an open-ended cylinder of 15 cm diameter and 50 cm height. The cylinder was placed at the centre of a circular plate having a diameter of 70 cm and filled with a bulb. The cylinder was raised slowly until it formed a cone on the circular plate. The angle of repose was calculated using equation (3.5) (Karababa, 2006):

$$\boldsymbol{\theta = tan^{-1}\frac{2H}{d}}\ ,\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \mathbf{(3.5)}$$

Where: θ = Angle of repose, empty or filling (deg.).

H = Height of the cone (cm).

D = Diameter of the cone (cm).

3.6. Design Consideration

The design factors considered to be important were function, maintenance, reliability, safety and cost (Norton, 2005). During the design of a garlic seed planter machine the machine specifications such capacity, efficiency, availability of manufacturing materials and spare parts were considered.

Assumption Made (data obtained from agronomic requirements of garlic (ASAJ, 2010).

1. Type of seed: Gojjam varieties of garlic seeds
2. Seed rate: 100 -140 kg/ha
3. Drawbar horse power (DBHP): 60 % of BHP of tractor
4. Speed of operation: 3rd gear of tractor

3.7. Description, design analysis and materials selection of major components of the prototype planter.

To design the planter first of all, working width of the implement was calculated. According to (Sharma, 2010).

Draw bar horse power. (DBHP)=60 % of BHP. The available horsepower of a 4WT is 25 hp

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

Therefore, DBHP = 25 hp × 0.6 = 15 hp

The tractor drawbar horse power (DBHP), draught available (Df) was calculated by equation (3.6) (Sharma, 2010)

$DBHP = \frac{Df\ x\ V}{270}$……………………………………………………………………..

(3.6)

Where: Df = draft force, (kg)

V = speed, ($\frac{km}{hr}$)

Generally the speed of garlic planting was done on the range 2 -5 km.hr^{-1} (ASABE, 2011).

Let the forward speed of planter be $3 km.hr^{-1}$.

Putting the values in the equation (3.6),

Draught available for planting= $\frac{15hp*270}{3\frac{km}{hr}}$ = 1350 kgf

Calculate actual draft on each furrow to get the width of garlic planter,

Take, g = 9.8 $\frac{m}{s^2}$

Soil and land characteristics,

Soil type = sandy loam

Slope of the land, i = 2%, ϴ = 1.718°

Furrow opener and furrow cover characteristics

Unit draft of soil, depend on the type of soil, k= $0.3\frac{kg}{cm^2}$

Total weight of the implement and seed, G = 1699.57 N

Draft on one furrow opener

Draft of one furrow opener was determined as follows (Tewari, 2018).

De= unit draft x cross sectional area of furrow opener…………………………… (3.7)

But to find the cross section area of furrow opener

$to = 2a + \tan\theta + Bo + \triangle t$ ……………………………………………………. (3.8)

Where: to = the distance between the furrow openers, (cm)

a = depth of furrow, (cm)

Bo = width of shank, (cm)

△t = clearance between two furrows, (cm)

$to = 2 \text{ x } 6 \text{ x } \tan 30° + 4 + 19.07$

$to =$30cm

Width of furrow opener = 2a max + Bo……………………………………………….. (3.9)

= 2 x 6 + 4 = 16cm

Then cross sectional area of furrow opener = $\frac{\text{depth x width}}{2}$…………………………. (3.10)

$= \frac{\text{6cm x 16cm}}{2} = 48\ cm^2$

Then, draft on one furrow opener was determined by equation (3.7) above.

Do= unit draft x cross sectional area of furrow opener

Do= $0.3\ \frac{kg}{cm^2}$ x 48 cm^2 x factor of safety = $0.3\ \frac{kg}{cm^2}$ x 48 cm^2 x *2 = 28.8 kg*

Number of furrow openers = $\frac{\text{Total draft}}{draft \;\; on\,one\,tine}$

$$= \frac{1350}{28.8} = 46.8$$

But designing of 46 furrow opener (46 rows) of garlic seed planter will have a buckling effect and will also create problem in transportation and handling. Therefore, it is better to design a garlic seed planter with 4 rows seed and 30cm spacing between furrow openers.

Working width of seed drill = 4 furrow opener x 30cm spacing

=120 cm

The prototype of designed machine has four row garlic planter with different components

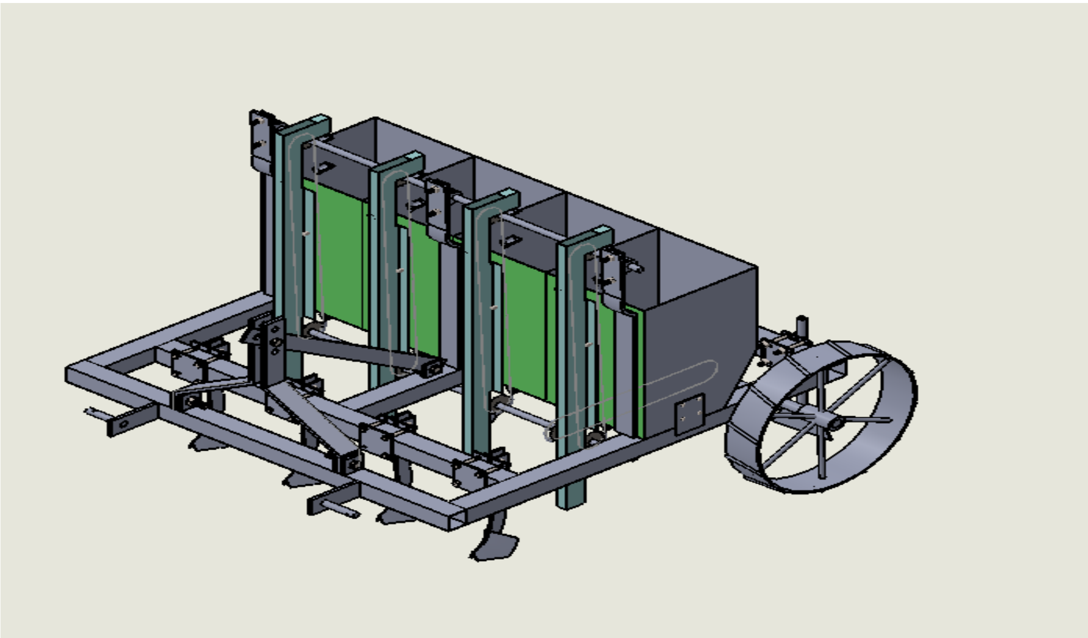


Figure 3.3.Three-D View of the prototype garlic planting machine

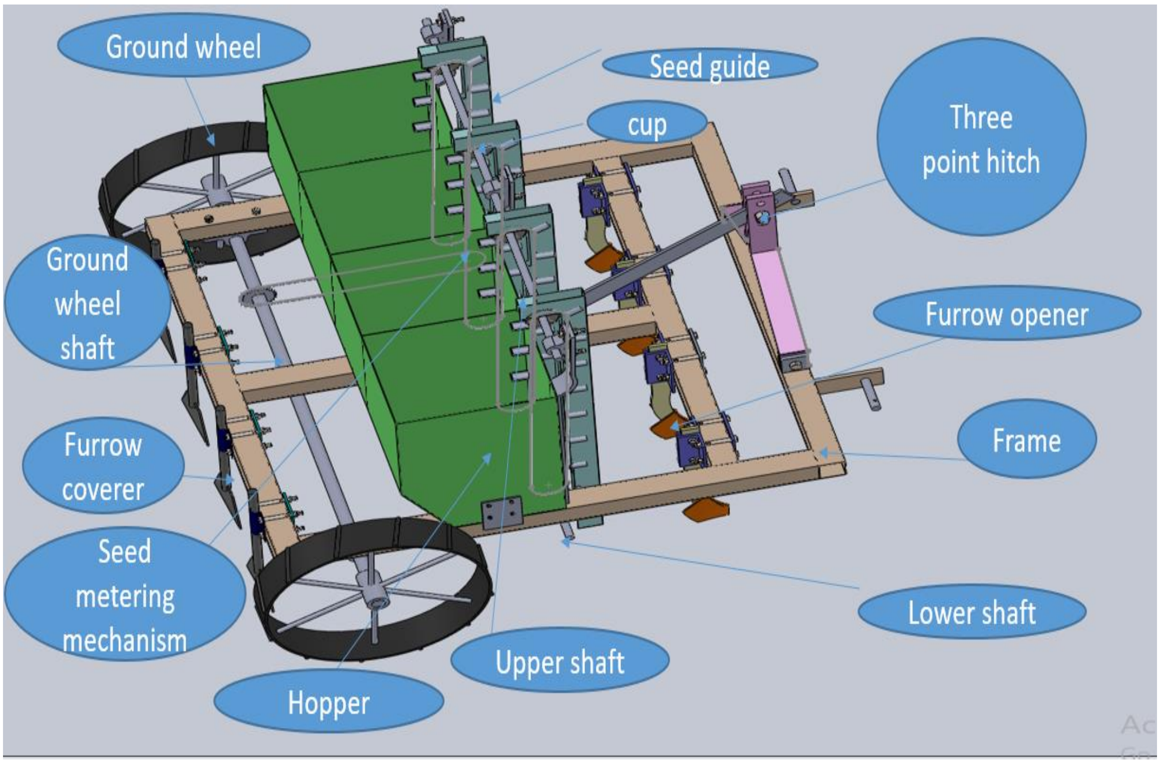


Figure 3.4. Diagram of the prototype of garlic planter machine

3.7. Description and Design of Garlic Planter Components

3.7.1. Main frame

The mainframe was constructed from mild steel square pipe. 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 is the skeletal structure of the planter which forms the platform on which other components are mounted. It was subjected to torsion and bending due to induced draft. Design was based on the stresses produced in the frame. The material of the main frame was selected based on achieving a reasonable weight and required strength. A square hollow pipe bar of 60 mm x 60 mm x 3mm mild steel was used to give the required strength and rigidity, so that it can withstand all types of load during operation. The frame and other component parts of the planter were connected using appropriate sizes of bolts, nuts and holes. Four furrow openers were fitted on the second front beam of the frame at the distance of 200mm from the both end of the front beam and four furrow coverer were fitted on the rear beam of the frame at the distance 214mm. The three-point linkage was welded at the centre of front beam of the frame.

The total draft was given by equation (3.11) (Bosai & Vernair, 1987).

Total draft = k x n x a x b …………………………………………………………… (3.11)

= (0.3 x 4x 6x 16) = 115.2

= 115.2 kg x factory of safety = 115.2 x 2 (factory of safety for M.S. =2) = 230.4 kg

Where: k= unit draft

n= number of furrow opener

a=depth of furrow, (cm)

b= width of furrow, (cm)

Torque produced on the square bar will be estimated by:

Torque on the square bar = draft x ground clearance

Ground clearance = 50cm

T = 230.4 kg x 50cm = 11520 kg-cm

In addition to the torque, the bending moment would also be produced. The bar was considered as a simply supported beam on the frame in between the furrow openers. To estimate the maximum bending moment will be given by equation (3.12) (Bosai & Vernair, 1987).

Mmax= WxL……………………………………………………………………….. (3.12)

Mmax= 230.4 x 150cm = 34560 kg-cm

Where: Mmax = maximum bending moment

W= Total draft (total weight on frame)

L= Total length of the frame

Equivalent torque due to torsion and bending moment is also estimated by equation (3.13) (Khurmi, 2003).

Te = $(\text{Mmax}^2 + T^2)^{1/2}$…………………………………………………………… (3.13)

Te = $(34560^2 + 11520^{\,2})^{\frac{1}{2}}$= 48875.22 kg-cm

Where: Te= Equivalent torque, (kg-cm)

T= Torque on the bar, (kg-cm)

Mmax = 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 (3.14 and 3.15) (Khurmi, 2003).

$\frac{1}{4}\frac{fs\,xR}{d} = \frac{Te}{I}$…………………………………………………………………… (3.14)

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

Assume that, maximum working stress of 1120 $\frac{\text{kg}}{cm^2}$ was occurred at the centre of the frame. For square section having each side measuring d.

I = Polar moment of inertia =$\frac{d^4}{9.6}$ …………………….. ……………….......................... (3.15)

The factor of safety was taken as 4, Fs is 1,120 kg/cm.

$$\frac{1}{4}\frac{1120\ x10}{d} = \frac{48875.22}{\frac{d^4}{9.6}} = \frac{11200}{d\ x\ 4} = \frac{48875.22\ x\ 9.6}{d^4}$$

$d^3 = \frac{1876808.448}{11200}$ = 5.5 cm = 6 cm = 60 mm

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

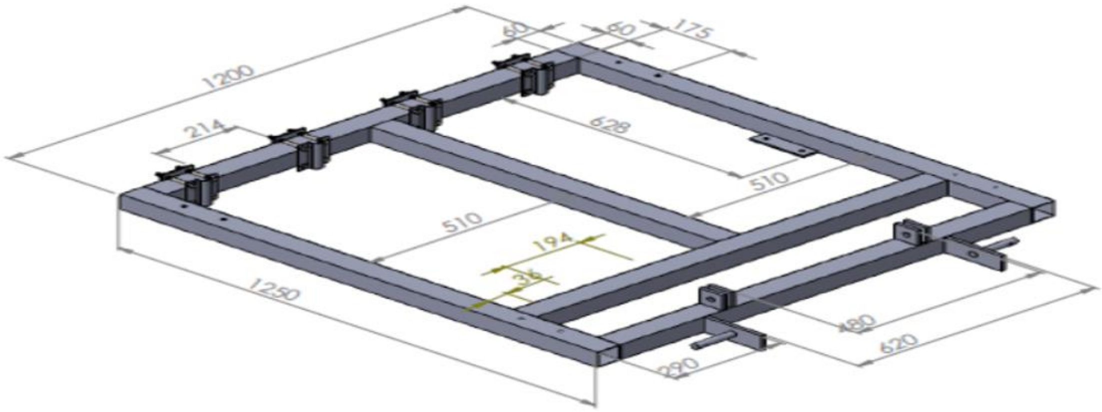


Figure 3.5.Frame sub assembly

3.7.2. Seed hopper

On the basis of reviews and studies of physical properties of garlic variety, the average bulk density of garlic seed was 535.7 $\frac{kg}{m^3}$ and the angle of repose was 26° had taken for designing the seed hopper. Trapezoidal shape of seed box is used in the machine for free flow of seed. The capacity of the hopper was determined by considering the following factors (Tewari, 2018).

Agronomic requirement garlic variety:

- Row to Row distance: 30 cm

- Seed rate (assumed): 100-140 kg/ha
- Bulk density of garlic: 535.7 $\frac{\text{kg}}{m^3}$

The working width of garlic planter

Ww = N x S…………………………………………………………………………. (3.16)

Where: Ww = working width of the planter, (m)

N = Number of furrow openers used

S = distance between two consecutive furrow opener, (m)

Ww = 4 x 30cm = 120cm = 1.2m

Then length of seed box (Lb) = Ww – 2b

Where: Lb = the length of seed box, (m)

Ww = working width of the planter, (m)

b = distance between the side box wall and ground wheel, (m)

Lb = 1.5 m – 2 x 0.15 = 1.5 – 0.3 = 1.2 m

Lb= 1.2 m

Let, take field efficiency of garlic planter = 75% = 0.75

The, actual field capacity of garlic planter.

AFC ($\frac{ha}{hr}$)=$\frac{speed\left(\frac{km}{hr}\right)x\ working\ width\ of\ planter(m)xfield\ efficiency\ \%}{10}$………………….. (3.17)

AFC =$\frac{3\,\frac{km}{hr}x\ 1.2\ m\ x0.75}{10}$ = $0.27\frac{ha}{hr}$

Seed weight = seed rate (kg/hr) x area covered (ha/hr) x time (hr)

Seed weight = 140 kg/hr x 0.27 ha/hr x 2 hr

Seed weight = 75.6 kg

Garlic seeds weight are 75.6 kg and the angle of repose of garlic seed was 25.5°, therefore the angle of the inclination of the side wall of a hopper should be more than the angle of repose of the seed for easy flowing of the seed 30°. The volume of hopper was calculated by equation (3.18) (Tewari, 2018).

$volume\ of\ hopper = \frac{weight\ of\ garlic}{bulk\ density\ of\ garlic}$………………………………………… (3.18)

Volume of hopper $= \frac{75.6kg}{535.7\frac{kg}{m^3}}$ = 0.14 m^3

Consider spillage losses of 10%. Therefore total volume of hopper.

Volume of hopper = 0.14 m^3+ 0.014= 0.154 m^3

$$Vh = \left(\frac{(a+b)}{2} x\ h\right) xlb \quad \text{...} (3.19)$$

Where: Vh = volume of the seed hopper having trapezoidal section (m^3)

a = bottom width of the hopper, (m)

b = top width of the hopper, (m)

h = height of seed hopper, (m)

Lb = length of the seed hopper or box, (m)

θ = angle inclination of hopper.

Let, take trapezoidal bottom width is = 25cm =0.25m

b = a + 2l

$$Vh = \left(\frac{a+a+2l}{2}\right) x\ h\ x\ Lb$$

But, $\frac{h}{l} = tan\theta$, l = hcotθ

$$Vh = \left(\frac{2a+2hcot\theta}{2}\right) x\ h\ x\ Lb$$

$$Vh = (a + h\cot\theta) x\ h\ x\ lb$$

0.154 m^3 = (0.25 m + h cot30) x h x 1.2m

0.154 m^3 = (0.25 m + 1.732h) x h x 1.2 m

0.154 m^3 = (0.3h + 2.078h^2)

h = 0.4m

Then, $Vh = \left(\frac{(a+b)}{2} x\ h\right) xlb$

0.154 m^3= ($\frac{(0.25\text{m} + \text{b})}{2}$ x 0.4) x 1.2m

0.154= (0.05 + 0.2b) x 1.2

0.154 = 0.06 + 0.24b

b = 0.513m

Specification of the hopper are:

Vh = volume of the seed hopper having trapezoidal section = 0.165m^3

a = bottom width of the hopper = 0.25 m

b = top width of the hopper = 0.513

h = height of seed hopper = 0.4m

Lb = length of the seed hopper or box = 1.2m

θ = angle inclination of hopper = 30° .

Thickness of seed hopper = for mild steel sheet 2 mm.

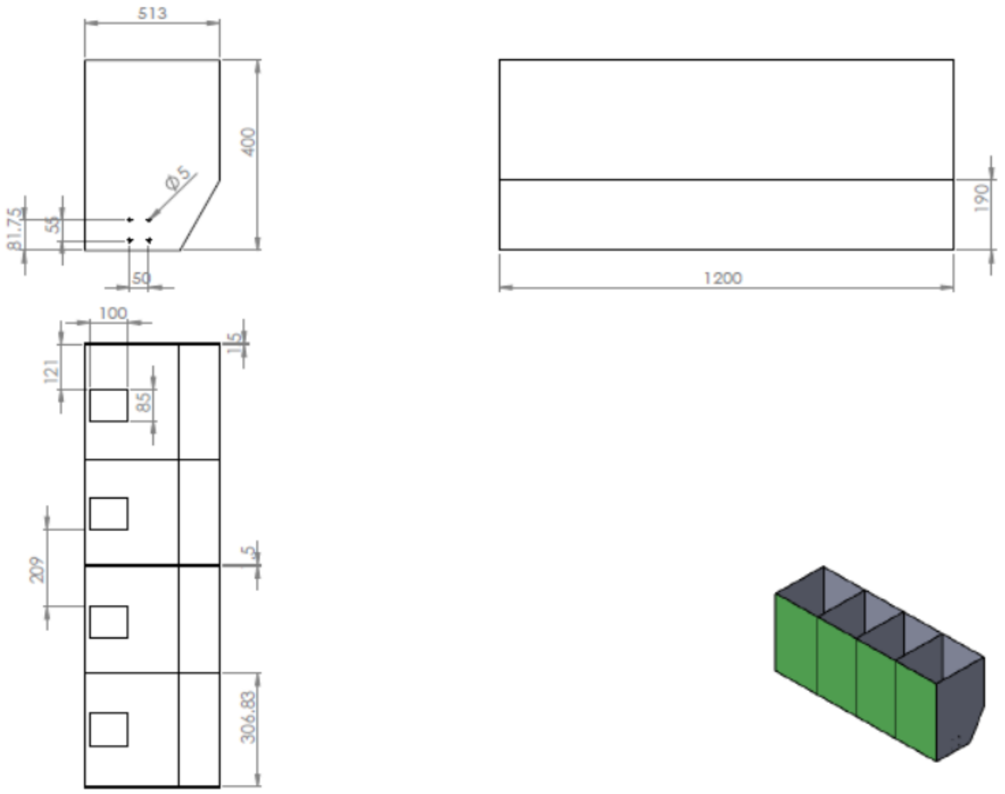


Figure 3.6.Seed Hopper

3.7.3. Design of furrow opener

To design the furrow opener available draft from the tractor that exerted on the tip of furrow openers on the length of furrow openers was determined by equation (3.20) (Bosai & Vernair, 1987).

Total draft= k x n x a x b…..……………………………………………………… (3.20)

Total draft = 0.3 x 4 x 6 x 16= 115.2 kg

$= \frac{115.2}{4}$ = 28.8 kg for each furrow opener

Bending moment = draft x length of the shank

= 115.2 kg x 50 cm = 5760 kg-cm

Bending stress was determined by equation (3.21) (Bosai & Vernair, 1987).

$\boldsymbol{f = \frac{M\ X\ C}{I}}$……………………………………………………………………… (3.21)

Where: f = bending stress, (kg.m^{-2})

I = moment of inertia, (m^4)

M = bending moment, (kg-cm)

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

The section modulus axis was computed by equation (3.22) (Bosai & Vernair, 1987).

$Z = \frac{M}{f}$.. (3.22)

Assuming bending stress is equal to 1120 $\frac{kg}{cm^2}$

$Z = \frac{\mathbf{5760}\boldsymbol{kg-cm}}{\mathbf{1120}\,\frac{\boldsymbol{kg}}{\boldsymbol{cm^2}}} = \mathbf{5.14}\boldsymbol{cm^3}$

Where: Z= section modulus of the furrow, (cm^3)

M= bending moment, (kg-cm)

F= bending stress, (kg.cm^{-2})

The width of the shank was determined by equation (3.23) (Bosai & Vernair, 1987).

$Z = \frac{bh^2}{6}$.................................... ....….... (3.23)

Where: Z= section modulus of the furrow, (m^3)

B = width of shank, (cm)

h = height of shank, (cm)

Width of shank was considered as 1:4, i.e. (h: 4b) (Bosai & Vernair, 1987).

$$Z = \frac{b(4b)^2}{6}$$

5.14 cm^3 = $\frac{16b^3}{6}$

b= 1.24cm = 12.44 mm

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

The thickness of shank furrow opener was selected = 8 mm

Therefore, the width of the shank = 12 mm

Height of shank = 4 x 12= 48 mm

Therefore, a Mild steel flat Tyne of 48 × 12 mm size was selected.

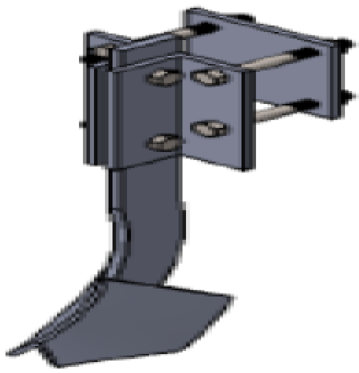


Figure 3.7. Furrow Opener sub assembly

3.7.4. Seed metering mechanism

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

The number of cups on the metering cup (n) was determined by equation (3.24) (Sharma, 2010)

$$n = \frac{\pi\ x\ D}{Nr\ x\ S} \qquad (3.24)$$

Where: n = number of cups on the metering chain

D = diameter of transmission wheel, (cm).

Nr = Speed ratio, transmission wheel to cup.

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

But, the speed ratio of ground wheel to metering mechanism is,

$$\text{Nr} = \frac{\pi D}{Ns\ x\ S} \qquad (3.25)$$

Take ground wheel diameter = 52 cm

Circumference of the ground wheel = πD$= \pi\ x\ 0.52m = 1.63m$

Number seed required in one revolution of ground wheel (Ns) = $\frac{\pi D}{S} = \frac{1.63m}{0.1\ m}$ = 16.3.7 = 16 seeds

Then, $Nr\ = \frac{\pi D}{Ns\ x\ S} = \ \frac{1.63m}{16\ x\ 0.1\ m} = \ \frac{1.63m}{1.6} = 1.0$

The speed ratio = 1

Then, number of cups will be $n = \frac{\pi\, x D}{Nr\, x\, S} = \frac{1.63m}{1\, x\, 0.1\, m} = \frac{1.63m}{0.1m}$ = 16.3= 16

Therefore, sixteen cups were provided on the periphery of each metering chain. The metering chain has 16 numbers of cups on its periphery.

The feed cup seed metering mechanism was selected for sowing garlic seeds. The diameter of seed metering was determined by equation (3.26) (Sharma, 2010)

$dr = \frac{Vr}{\pi Nr}$…………………………………………………………………...………. (3.26)

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

Vr = Peripheral velocity, (m/min)

Nr = rpm of metering mechanism

In one revolution = 1.63 meter is covered

The speed of tractor = 3 km/hr = 50 m/min = 0.833m/s

Then, $\frac{50\ m/min}{1.63\ m/revelotion}$ = 30.67 rpm = 30rpm

$dr = \frac{50m/min}{\pi\ x\ 30\frac{revelotion}{min}}$ = 0.5m = 0.5m

The spacing between consecutive cups was calculated by equation (3.27) (Sharma, 2010)

$t = \frac{\pi dr}{n}$…………………………………………………………………………… (3.27)

$t = \frac{\pi\ x\ 0.5}{16}$ = 0.1m

Spacing between consecutive cups is = 0.1m

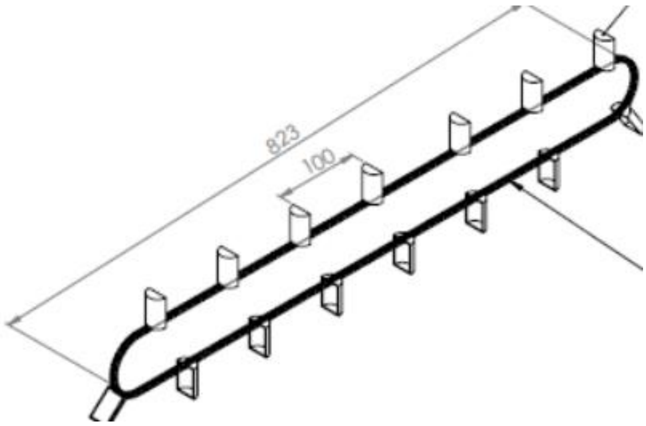


Figure 3.8.Seed metering mechanism

The gear ratio was determined using equation (3.28) (Sharma, 2010).

Gear ratio=$\frac{number\ of\ teeth\ on\ sprocketof\ seed\ metering\ shaft}{number\ of\ teeth\ on\ sprocket\ of\ ground\ wheel}$…………………………. (3.28)

$Gear\ ratio = \frac{14}{14}$ = 1:1

Based on (ASABE, 2011) recommendation operation speed of tractor drawn garlic planter was 2 up to 5 km / h.

- Speed selected for design 3 km/h.
- Number of teeth on sprocket of ground wheel was 14.
- Number of teeth on sprocket of seed metering shaft was 14.

3.7.5. Design of seed metering cups

The dimension of each feed cup will be decided by the average size of garlic seed from varieties that can be put in the feed cups considering the mean geometric diameter of garlic and the shaped cup will be determined based on the shape index of garlic seed. Diameter cup 44mm and thickness 3mm it made from galvanized metal sheet.

Figure 3.9. Seed metering cup

3.7.6. Weight determination of components of the planter

The weight of each part designs was calculated using Solid work 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 Solid work 2013 gave the output of the selected component area, volume and mass.

Table 3. 3. A solid work software weight determination analysis for garlic planter

Sr.No	components	Quantity	Area(m^2)	Volumem^3)	Density ($\frac{kg}{m^3}$)	Unit mass(kg)	Total mass
1	frame	1	0.291	0.00231927	7870	18.25	18.25
2	hopper	1	0.20225	0.00030375	8000	2.39	2.39

3	Three-point linkage	1	0.248	0.002976	7870	23.42	23.42
4	Main shaft	1	0.0007068	0.00092	7870	7.24	7.24
5	Metering shaft	2	0.0002545	0.00033	7870	5.2	5.2
6	Furrow opener	4	0.0248	0.000372	7870	11.71	11.71
7	Furrow coverer	4	0.0159	0.0002385	7870	7.5	7.5
8	Seed tube	4	0.028	0.000195	7870	1.53	1.53
9	Bearing	7	0.0194	0.00051	7870	4.01	4.01
10	Ground wheel	2	0.163	0.00163	7870	12.35	12.35
11	Metering device	4	0.0163	0.000272	7870	2.14	2.14
12	Total weight of component parts						95.74
13	Taking 2% margins for the weights of welding bolts, nuts, etc.						1.914
14	Total weight						97.65

Total mass of all components which lay on the wheel shaft was 97.65kg.

The weight of planter was calculated by using equation (3.29) (Sharma, 2010)

W = m x g ……………………………………………………………………….. (3.29)

Where: W= weight, (N)

m=total mass of the parts, (kg)

g= acceleration due to gravity, (9.81 m/s^2)

W = 97.65 x 9.81 = 957.94 N

Weight of Garlic Seed

The weight of the seed in the hoppers was estimated from the volume of the hopper Determined earlier above and the mass of seed was estimated using the following equations (3.30) (ITSI-SU, 2011);

$W_{seed} = M_{seed}\ x\ g$………………………………………………………...……...… (3.30)

$= 75.6$ kg x $9.81 {m}/{s^2}$ = 741.63 N

Total weight of a 4WT drawn garlic planter was becoming: WT = Weight of parts + weight of garlic

Total weight = 957.94 N + 741.63 N = 1699.57N

Total weight of the prototype planter

The total weight of the prototype planter including the weights of seed and seed hopper, frame, seed metering shaft, furrow opener, furrow coverer, seed tube, and three point linkage was estimated to 1699.57N.

5.7.7. Determination of force and torque required to drive the planter

3.7.7.1. Determination of force required to drive the planter

A rolling resistance force (F), which was assumed to act horizontally at the wheel and ground interface or ground and wheel contact patch, was estimated using the equation (3.31 and 3.32) (Reece, 2002)

F = $(C_R$ + i) x N……………………………………………………………………… (3.31)

F =$((\frac{Z}{d})^{1/2} + i)$ x N………………………………………….............................. (3.32)

But Z = on soft surface = 0.05d = 0.05 x 50 cm = 2.5cm

N= weight f planter on each wheel = $\frac{1699.57\ N}{2}$ = 849.78 N

i = gradient of the ground let, i= 5% = 0.05

F = $\left((\frac{2.5}{52})^{\frac{1}{2}} + 0.05\right) x$ 849.78N = 228.8N

F= 228.8N

Where: F= Rolling resistance force, (N)

CR= Coefficient of rolling resistance

d = wheel diameter, (cm)

Z = Maximum wheel sinkage depth, (cm)

N = Weight of planter on each wheel, (N)

i = Gradient of the ground

3.7.7.2. Determination of torque on the ground wheel

Torque on the ground wheel is estimated by using equation (3.33) (Sharma, 2010).

$T = F(\frac{d}{2})$………………………………………………………………………… (3.33)

T = 228.8N($\frac{0.5\text{m}}{2}$) = 57.2Nm

T= 57.2 Nm

Where: T = Torque on the ground wheel, (Nm)

F = Rolling resistance force, (N)

d = Diameter of the ground wheel. (m)

3.7.7.3. Determination of power requirement of the planter

The power requirement of the planter was determined by equation (3.34) (Sharma, 2010).

P = T x Nw………………………………………………………………………… (3.34)

Where: P = power requirement of the planter, (kW)

T = Torque, (Nm)

Nw = wheel revolution, (rpm)

P = 57.2x (30rpm x$\frac{2\pi}{60}$) = 179.69W = 0.17969KW

P = 0.17969 KW

3.7.8. Chain and sprocket

Locally available chain and sprocket was 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 garlic planter is very low, the smallest size available chain, i.e. motor bicycle chain was used for tractor drawn garlic planter. For power transmission, 14 teeth size sprocket was fitted on drive wheel. Another sprocket of 14 teeth size was used for driving shaft so that the transmission ratio of approximately 1:1 was maintained.

3.7.8.1. Calculation of chain length

The length of the chain was calculated by using equation (3.35, 3.36 and 3.37) (Sadhu, 1988).

L= m x p………………………………………………………………………………. (3.35)

Where: L= length of chain, (cm)

m = number of chain links

P = chain pitch, (mm)

But, the number of chain links

$M=2Cd + \frac{N1+N2}{2} + (\frac{N1-N2}{2\pi Cd})^2$…………………………………………………………. (3.36)

$Cd = \frac{cc}{p}$……………………………………………………….………………,…......... (3.37)

Where: Cd = Centre distance chain, (mm)

P = Commercial available chain pitch, 6.35mm

N1= Number of teeth of the pinion, 14

N2 = Number of teeth of the sprocket, 14

Cc = Approximate centre to centre distance between sprockets, 540mm

Solving for Cd

$Cd = \frac{cc}{p} = \frac{540\text{mm}}{6.35mm} = 85.039\text{mm}$

Solving for M

$M = 2 \times 85.039 + \frac{14+14}{2} + (\frac{14-14}{2\pi Cd})^2 = 184.07$

M = 184 pitches

Solving for L

L = M x P

= 184X 6.35 = 1168.4 mm

L=1.168m

Now, since the chain length in pitches is changed from 184.07 to 184 pitches, the exact centre to centre distance of the sprockets has to be corrected. (Sadhu, 1988).

C = (e + $(e^2 - 8m)^{\frac{1}{2}}$)$x\ \frac{p}{4}$.. (3.38)

But, e and m are determined by equations (3.39 and 3.40) (Sadhu, 1988).

e = LP- $(\frac{N1+N2}{2})$.. (3.39)

e = 184 -$\left(\frac{14+14}{2}\right) = 170$

m = $\left(\frac{N2-N1}{2\pi}\right)^2$ .... (3.40)

m = $(\frac{14-14}{2\pi})^2$ = 0

Therefore, the corrected centre to centre distance between the sprockets is

C = (170+ $(170^2 - 8\ x0)^{1/2}$) x $\frac{6.35}{4}$

C = 539.75 mm

3.7.8.2. Chain velocity determination

Average chain velocity was estimated by equation (3.41) (Sadhu, 1988))

Vav =$\frac{n\ x\ p\ x\ rpm}{376}$.. (3.41)

Vav = $\frac{14\ x\ 0.375\ x\ 30}{376}$ = 0.418 $\frac{m}{s}$

= 0.418 $\frac{m}{s}$

Where: Vav = Average chain velocity, (m.s^{-1}).

n = the driven sprocket no. of teeth

rpm = Maximum revolution of the driving sprocket, 30rpm

P = Chain pitch, 6.35mm = 0.375 inch

3.7.8.3. Determination of chain force

The total load (force) on the driving side of the chain was calculated by using equation (3.42, 3.43, 3.44 and 3.45) (Sharma, 2010).

FT = F + Fc + Ff.. (3.42)

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)

$F = \frac{P}{Vav}$ ………………………………………………………………………. (3.43)

$= \frac{185.29}{0.418}$ = 429.88 N

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

P = power at garlic planter wheel or power to be transmitted, (Watt)

Vav = average chain velocity, (m.s^{-1}).

$Fc = \frac{W\ x\ \mathrm{Vav}^2}{g}$…………………………………………………………………. (3.44)

$= \frac{1.5x\ 0.418\ ^2}{9.81}$ = 0.0267 N

= 0.0267 N

Where: Fc = Centrifugal force on the chain, (N)

W = weight per meter of the chain (1.5N/m)

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

Ff = W x Kf x Cc……………………………………………………………….… (3.45)

= 1.5x 4 x 0.54 = 3.24 N

= 3.24 N

Where: Ff = frictional force, (N)

Cc = Nominal centre to centre distance between the sprockets, (0.54 m)

Kf = friction factor = 4 for horizontal drive, 2 for inclined drive and 1 for vertical drive (Norton, 2005).

Then, FT = 429.88 + 0.0267 + 3.24

= 433.147 N

According to ANSI standard, the minimum tensile strength of the chain was 3470 N. To avoid breakage and failure of the chain, the safety factor should be more than one. Checking safety factor, Sf calculated by using equation (3.46) (Sharma, 2010).

$Sf = \frac{Tensile\ strength}{FT}$……………………………………………………………….. (3.46)

Sf $= \frac{3470}{433.147}$ = 8, the value is greater than unity.

Therefore, we can conclude that the chain is safe from breakage.

Where: Sf = safety factor

FT = Total force on driving chain, (N)

3.7.9. Design of ground wheel shaft

Design of ground wheel Shaft was made of mild steel rod. The length of the bar was kept as 1500 mm to facilitate the hub on the both ends and sprocket at the one end of shaft. The shaft was rested on two hubs which was fitted on the frame.

Figure 3.10.Ground wheel 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 (3.47), (ASME, 1995) given as:

$$d^3 = \frac{16}{\pi \; x \; Ss}\sqrt{(Kb \; xMb)^2 + (Kt \;\; x \; Mt)^{\,2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.47)$$

Where: d = 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, (MN.m^{-2})

For rotating shafts, when a load was suddenly applied with minor shock (Khurmi, 2003)(recommended that values of Kb = 1.2 to 2.0 and Kt = 1.0 to 1.5 to be used. Furthermore, it was noted that for shaft without a keyway, the allowable stress (Ss) must be 55 MN.M^{-2}, and for shaft with key way, the allowable stress (Ss) should not exceed 40 MN.M^{-2}.

A) Determination of vertical forces acting on the ground wheel shaft

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

Figure 3.11. Vertical force distribution on the shaft

Where: RA = Vertical reaction at wheel A

RB = Vertical reaction at wheel B

Wc = Half of the total weight acting at bearing C, (849.78N)

Wd = Half of the total weight acting at bearing D, (849.78N)

Ff = Vertical chain force, (446.5367 N)

Total weight of the potato planter which lay on the shaft was 1699.57 N refer above section.

WC=Wd = 849.78 N ……………. are half of total weights

To know the unknown force of RA and RB, use equilibrium equation method.

$\sum MA=0$

RB x 1.4m + Ff x 1.207m –Wc x 0.0965m – Wd x 1.3035m =0

RB x 1.4m + 433.147N x1.207 m – 849.78N x 0.0965m – 849.78N x 1.3035m = 0

RB x 1.4m + 522.8Nm – 82 Nm – 1107.68Nm = 0

RB = 476.34N

The summation of all force gave RA

RA + RB + Ff – Wc – Wd =0

RA + 476.34 N + 433.147N – 849.78N – 849.78N = 0

RA = 790.07 N

B) Vertical Shear Force and Bending Moment Diagram

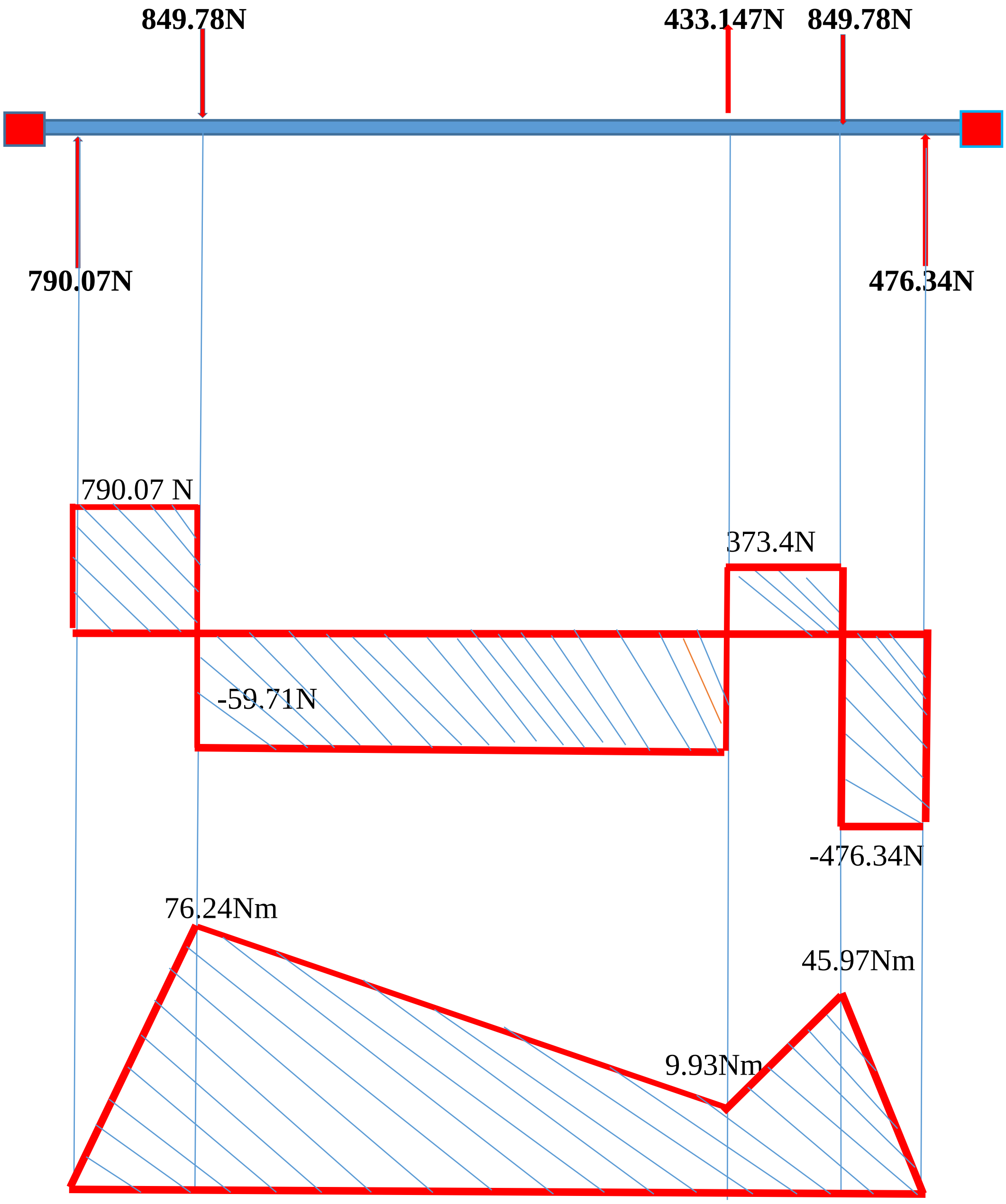


Figure 3.12.Shear force and bending moment diagram representation

C) Determination of Horizontal Force Acting on the Ground Wheel Shaft.

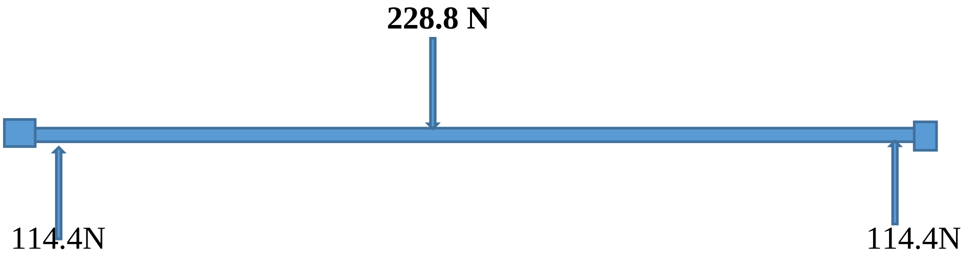


Figure 3.13.Horizontal force distribution on the shaft

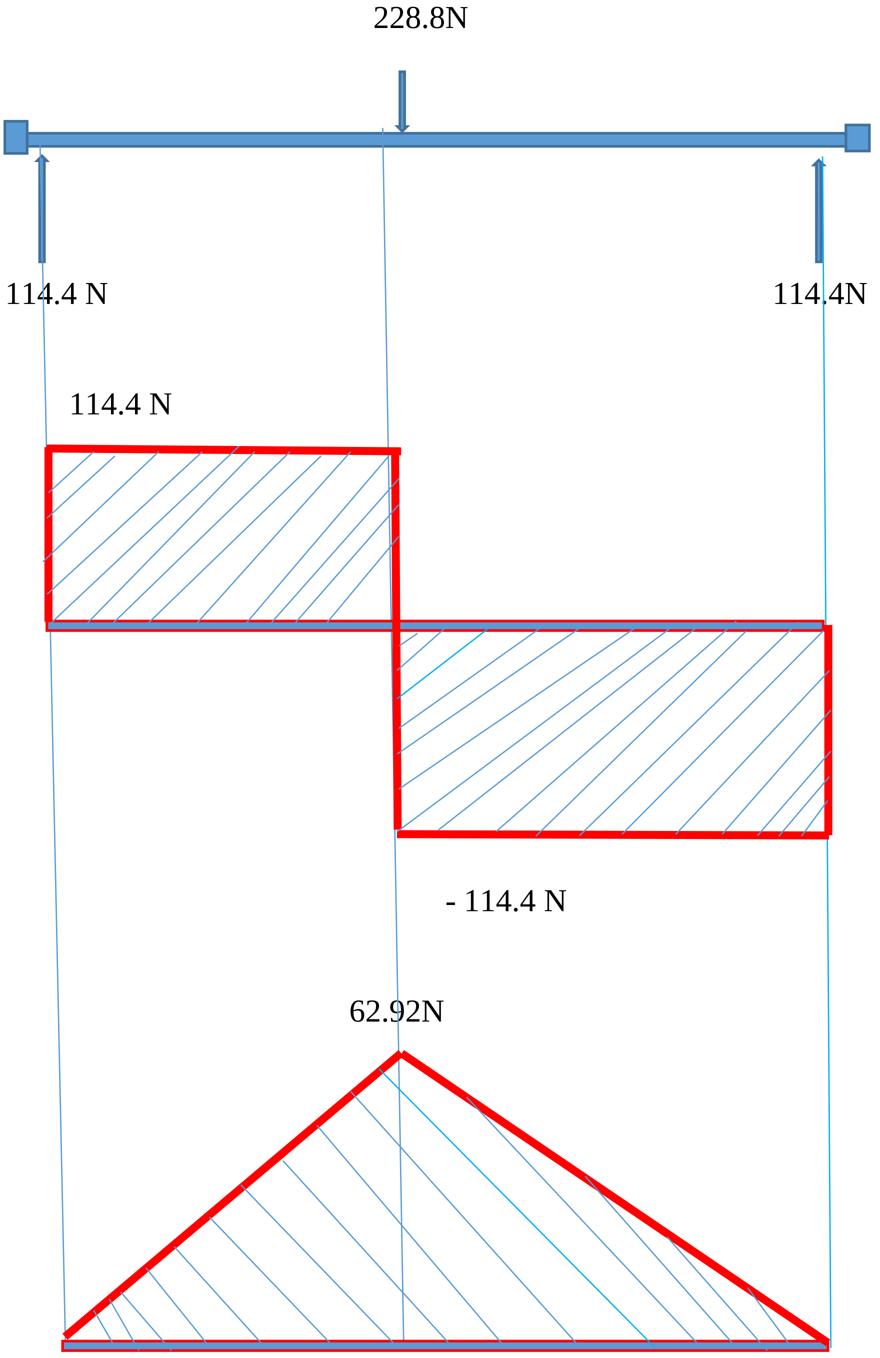


Figure 3.14.Horizontal shear force and bending moment diagram representation

The forward driving force is 228.8 N and applied horizontally at point A and B.

RAH + RBH = 228.8N

RAH = RBH = $\frac{228.8\text{N}}{2}$ = 114.4 N

Where: RAH = Horizontal reaction at wheel A

RBH = Horizontal reactions at wheel B

FH = Horizontal force

Torsional moment (Mt) on the shaft were calculated using equation (3.48 and 3.49) (Ryder, 1989)

$Mt = \frac{P\ x\ 60}{2\pi\ x\ N}$…………………………………………………………………… (3.48)

P = F x V……………………………………………………………………………… (3.49)

= 228.8N x 0.833 m/s =190.59 W

= 190.59W

$$Mt = \frac{P\ x\ 60}{2\pi\ x\ N}$$

= $\frac{190.59\ x\ 60}{2\pi\ x\ 30}$ = 60.66Nm

Where: Mt = torsional moment, (Nm)

P = power required to drive the machine, (kW)

N = speed of the shaft, (rpm)

P = power required to drive the machine, (kW)

V= Forward speed (m.s^{-1})

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

The maximum bending moment on the shaft was determined from the following expressions given by equation (3.50) (Richard, 2011).

$Mb = \sqrt{(Mv)^2 + (Mh)^2}$…………………………………………………………..… (3.50)

= $\sqrt{(76.24)^2 + (62.92)^2}$

= 98.85 Nm

Where: Mb = Maximum bending moment, (Nm)

Mv = Vertical bending momentum= 76.24Nm from bending moment diagram

Mh = Horizontal bending momentum = 62.92 Nm from bending moment diagram

Using Equation 3.47 above

$$d^3 = \frac{16}{\pi\ x\ Ss}\sqrt{(Kb\ xMb)^2 + (Kt\ \ x\ Mt)^{\ 2}}$$

$$= \frac{16}{\pi\, x 55 x\, 10^6} \sqrt{(2\, x\, 98.85)^2 + (1.5\, x\, 60.66)^2}$$

d = 27.2 mm

Therefore, the standard size of 30 mm shaft diameter has been used.

3.7.10. Design of seed metering Shafts

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

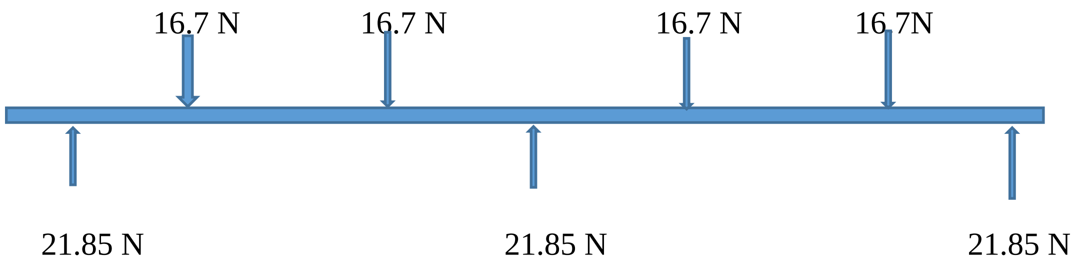


Figure 3.15. Force distribution on the metering shaft

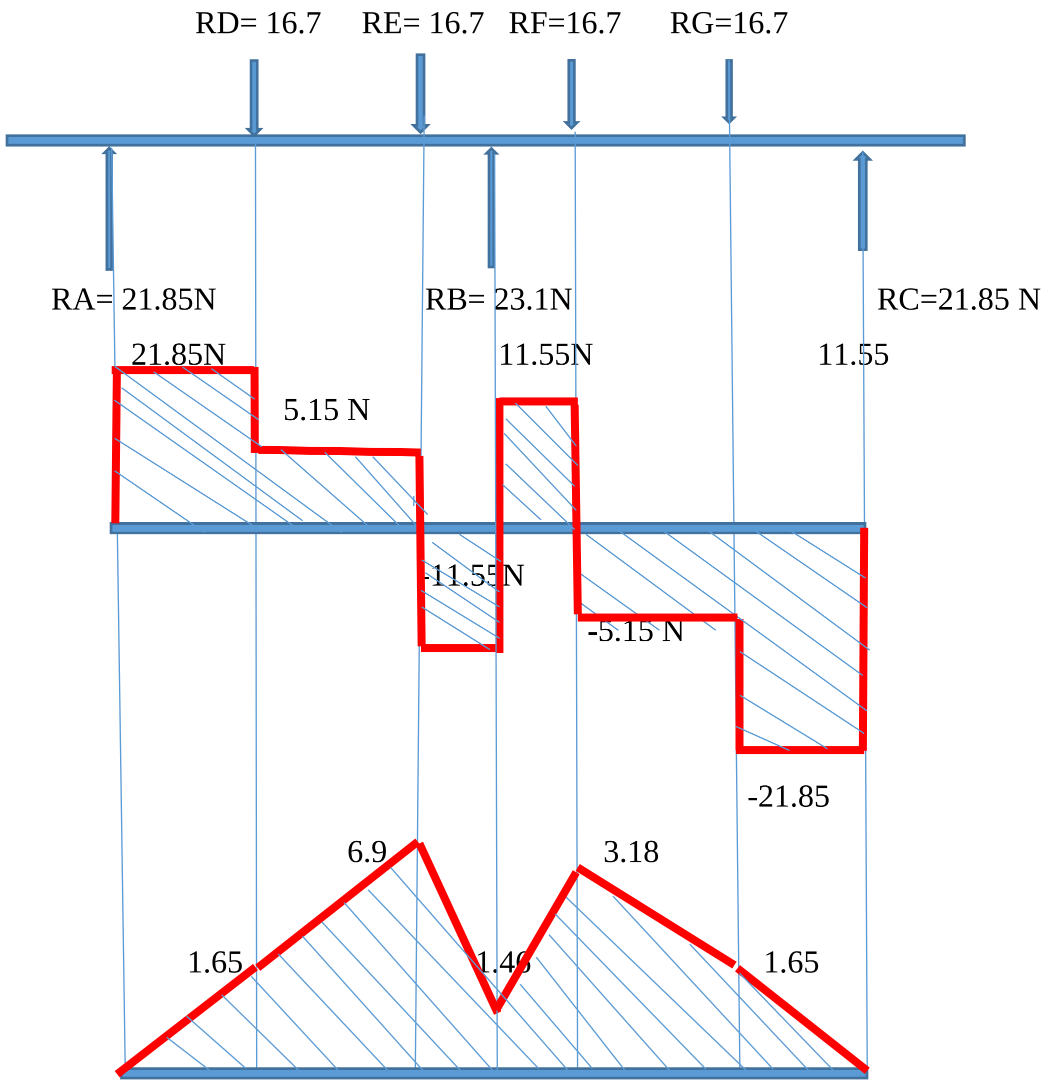


Figure 3.16.Metering shaft shear force and bending moment diagram representation

Weight of seeds on 16 cups + weight of chain + weight of 16 cups

Weight = 0.0024kg + 1.5kg + 0.2kg = 1.7024kg x 9.81$^{m}/_{s^2}$ =16.7 N

Let RA, RB and RC = Reactions at A, B and C respectively

∴ RA + RB + RC = Total load acting downwards at C, D, E and F

= 16.7 N + 16.7 N + 16.7 N + 16.7 N = 66.8 N

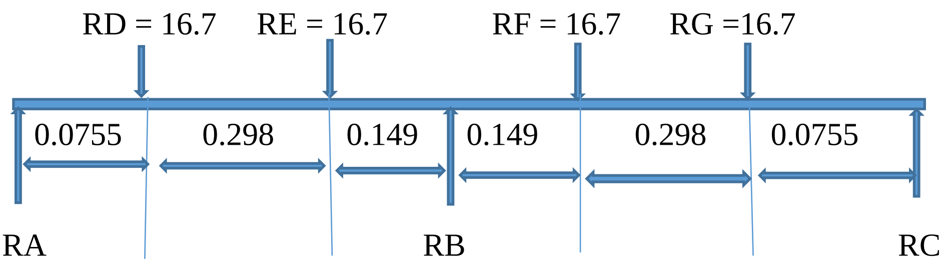


Figure 3.17. Force distribution on the two span of metering shaft

Considering each span simply supported.

Free bending moment,

For span AB, bending moment at D = $\frac{Wxax\ b}{L} = \frac{16.7\ X\ 0.0755\ X\ 0.447}{0.5225}$ = 1.078Nm

Where: w = weight of chain, seeds and cups at the point D

a= distance of point D from reaction A (RA).

b= distance of point D from reaction B (RB).

L= distance of span AB or distance reaction A to reaction B.

For span AB, bending moment at E = $\frac{Wxax\ b}{L} = \frac{16.7\ x\ 0.3735x\ 0.149}{0.5225}$ = 1.778 Nm

Where: w = weight of chain, seeds and cups at the point E

a= distance of point E from reaction A (RA).

b= distance of point E from reaction B (RB).

L= distance of span AB or distance of reaction A to reaction B.

For span BC, bending moment at F =$\frac{Wxax\ b}{L} = \frac{16.7\ x\ 0.149x\ 0.3735}{0.5225}$ = 1.778 Nm

Where: w = weight of chain, seeds and cups at the point F

a= distance of point F from reaction B (RB).

b= distance of point F from reaction C (RC).

L= distance of span BC or distance of reaction B to reaction C.

For span BC, bending moment at G = $\frac{Wxax\ b}{L} = \frac{16.7x\ 0.447x\ 0.0755}{0.5225}$ = 1.078Nm

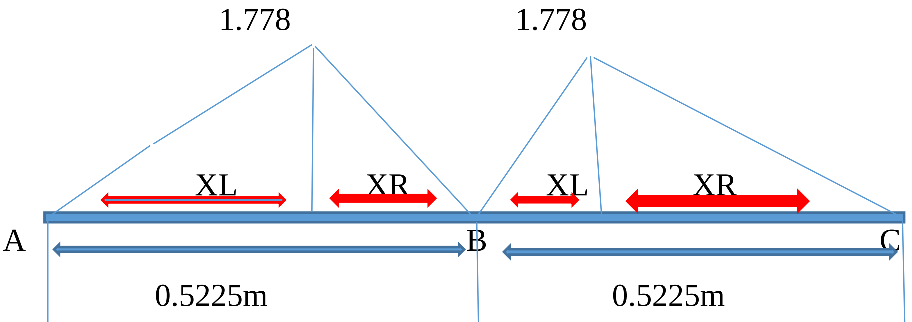
Where: w = weight of chain, seeds and cups at the point G

a = distance of point G from reaction B (RB).

b= distance of point G from reaction C (RC).

L= distance of span BC or distance of reaction B to reaction C.

Free bending moment diagram for span AB and BC, then calculating the area for span AB and BC.



$A_{BC} = \frac{1}{2} x\ bx\ h$ $\quad$ $A_{BC} = \frac{1}{2} x\ bx\ h$

$A_{BC} = \frac{1}{2} x\ 0.5225 x\ 1.778$ $\quad$ $A_{BC} = \frac{1}{2} x\ 0.5225 x\ 1.778$

A_{BC} = 0.4645 $\quad$ A_{BC} = 0.4645

X1= XL = $\frac{a+L}{3}$= $\frac{0.3735+0.5225}{3}$ = 0.299 $\quad$ X1= XL = $\frac{a+L}{3}$ = $\frac{0.149+0.5225}{3}$ = 0.2238

X2 = XR = $\frac{b+L}{3}$= $\frac{0.149+0.5225}{3}$ = 0.2238 $\quad$ X2 = XR = $\frac{b+L}{3}$= $\frac{0.3735+0.5225}{3}$ = 0.299

By Applying three moment theorem for A-B-C,

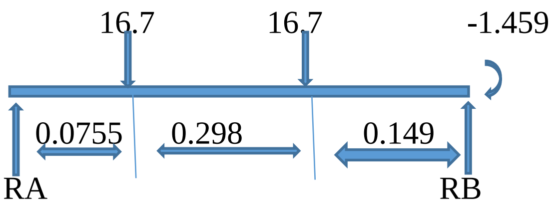
MA (L1) + MB (L1+L2) + MC ((L2) + $\frac{6\ A1\ X1}{L1}$ +$\frac{6\ A2\ X2}{L2}$ = 0

MA (L1) + 2MB (0.5225+0.5225) + MC ((L2) + $\frac{6\ x\ 0.4645 x\ 0.299}{0.5225}$ +$\frac{6\ x\ 0.4645\ x\ 0.299}{0.5225}$ = 0

MB = -1.459

Know reaction force at RA, RB and RC can be calculated,

For span AB



∑MA=0 (+ve)

16.7 X 0.0755 + 16.7 x 0.3735- RB x 0.5225 – 1.459 = 0

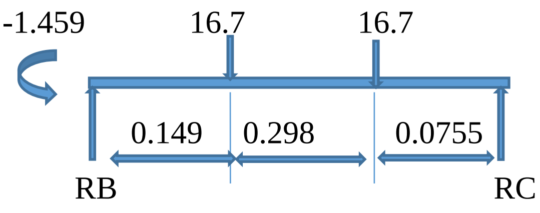
RB = 11.55 N

∑FY=0 (+ve)

RA + RB -16.7-16.7 = 0

RA = 21.85 N

For span BC



∑MA=0 (+ve)

16.7 x 0.149 + 16.7 x 0.447 – RC x0.5225 + 1.459 = 0

RC = 21.85

∑FY=0 ($\uparrow$ +ve)

RB + RC -16.7-16.7 = 0

RB = 11.55

RB = 11.55 +11.5 = 23.1, from both span

Torsional moment (Mt) on the shaft was calculated using equation (3.51 and 3.52) (Ryder, 1989)

$$Mt = \frac{P\ x\ 60}{2\pi\ x\ N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.51)$$

P = F x V…………………………………………………………………………… (3.52)

= 16.7 N x 0.833m/s = 13.91W

Then, $Mt = \frac{13.91\ x\ 60}{2\pi\ x\ 30}$ = 4.43 Nm

The equivalent twisting moment on the shaft was determined from the following expressions given by equation (3.53) (Khurmi, 2003)

$$Te = \sqrt{(Km\ x\ M)^2 + (Kt\ x\ Mt)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.53)$$

$$Te = \sqrt{(1.5\ x\ 6.9)^2 + (1.2\ x\ 4.43)^2}$$

Te = 11.635 Nm

Where: M = maximum bending moment, 6.9 Nm from bending moment diagram (Nm)

Mt =torsional moment moment, (Nm)

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

From above section using equation 3.47.

$$d^3 = \frac{16}{\pi\ x\ Ss}\sqrt{(Kb\ xMb)^2 + (Kt\ \ x\ Mt)^{\ 2}}$$

$$= \frac{16}{\pi\ x\ 55\ x\ \ 10^6}\sqrt{(2\ x3.69)^2 + (1.5\ \ x\ 11.635)^{\ 2}}$$

d = 11.9 mm

Therefore, the standard size of 18 mm seed metering shafts diameter has been used.

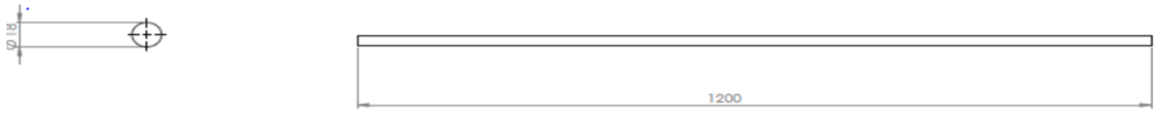


Figure 3.18.Metering shaft

3.7.11. Design of ground wheel drive

Two ground engaging wheels, with external diameters of 50 cm, were designed as an integral part of the seed metering mechanism. They are connected to the seed metering device through chain and sprocket where produces the necessary force to drive the metering cup. The rim of wheel was made from mild steel flat iron 6 mm thick and 100 mm wide. Each wheel had six spokes made from mild steel rods with diameter of 12 mm and length of 225mm, and were welded to the rim and hub at the centre of the wheel that served as bushing or shaft bearing, at equal interval

Estimation of the force required to drive the planter using equation (3.54) (Sharma, 2010).

$$Ff = \left(\sqrt{\frac{Z}{Wd}} + i\right) x \; Mwe \ldots\ldots \quad (3.54)$$

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

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

Wd = Wheel diameter, (50cm)

Mwe = Machine weight on each wheel, (849.78N)

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

Ff = $\left(\sqrt{\frac{3cm}{50cm}} + 0.05\right) x \; 849.78N$ = 250.64 N

Ff = 250.64 N

The torque of the ground wheel was determined by equation (3.55) (Sharma, 2010).

$$T = Ff \; x(\frac{Wd}{2}) \ldots\ldots \quad (3.55)$$

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

Ff = Force required to drive the planter, (261.55N)

Wd = Wheel diameter, (50cm)

$T = 250.64 \; x(\frac{0.5}{2})$ = 62.66N

T = 62.66N

Shear stress on the ground wheel was determined by equation (3.56) (Sharma, 2010).

$\tau = \frac{T}{2\ x\ Am\ x\ tw}$………………………………………………………………… (3.56)

Where: τ = shear stress on the ground wheel, (kPa)

T= torque produced by the ground wheel, (Nm)

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

tw = thickness of the wheel wall, (0.006m)

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

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

The area of the ground wheel was determined by equation (3.57) (Sharma, 2010).

$Am = \pi\ x(rm)^2 = \pi(0.25 - 0.5\ x\ tw)^2$……………………………………………… (3.57)

$Am = \pi(0.3 - 0.5\ x\ 0.006)^2$ = 0.19m^2

Then, $\tau = \frac{62.66}{2\ x\ 0.19\ x\ 0.006} = \frac{62.66}{0.002299}$ = 27.48 KPa

Comparing this shear stress with the maximum allowable shear stress of the mild steel sheet metal << max, 80 MPa, which tells us the wheel was safe for operation.

The angle of twist can be estimated using the equation (3.58) (Richard , 2011).

$\theta = \theta_1 x\ L$……………………………………………………………………….. (3.58)

$\theta = \left(\frac{TL_m}{4GA_m{}^2 x\ tw}\right) x\ L = \left(\frac{62.66X\ 2\pi(0.5-0.5X\ 0.006)}{4\ X\ 80X10^9\ X\ 0.19^2 x\ 0.006}\right) x\ 0.1$ = 0.0000000102degree

θ = 0.0000000102 degree (negligible)

Where: L= length or width of the wheel, 0.1m

T= torque produced by the wheel, 62.66 Nm

Lm=the length of the median line of the wheel

θ1=the angle of twist

G= modulus of rigidity, 80GPa for stainless steel

The angle of twist produced by the wheel is negligible since the torque is small.

3.7.11.1. Design of hub

The hub of a wheel is one of the most important components of rigid wheel. It gives support to the spokes and the shaft. The diameter of the hub is calculated using following formula. The outside of the hub is given by (Richard, 2011).

D =1.50d + 25.00 mm, D= 1.50 x 30mm +25mm

D = 70 mm

Where: D = outside diameter of hub, mm

d = diameter of shaft, mm

Considering the availability of material 50 mm diameter of hub is used

The length, L, of hub is given by (Richard, 2011).

$$L = \frac{\pi\ X\ d}{2} \qquad (3.59)$$

$$L = \frac{\pi\ x\ 30}{2} = 47.1 \text{ mm}$$

The inner diameter of hub was taken equal to the diameter of the shaft i.e. 30mm.

3.7.11.2. Wheel width

When two cylindrical objects of length L and diameters d_1 and d_2 contact, a narrow rectangle of width 2b and length L is created.

The contact stress between two cylinders expressed by (Hertz, 1881)

$$b = \sqrt{(\frac{2F}{\pi L})x(\frac{(1-(V1)^2)}{E1} + \frac{(1-(V1)^2)}{E2} / (\frac{1}{d1} + \frac{1}{d2})} \qquad (3.60)$$

$$Pmax = \frac{2F}{\pi bL} \qquad (3.61)$$

The stress created has an elliptical distribution across the contact zone fig (3.19).

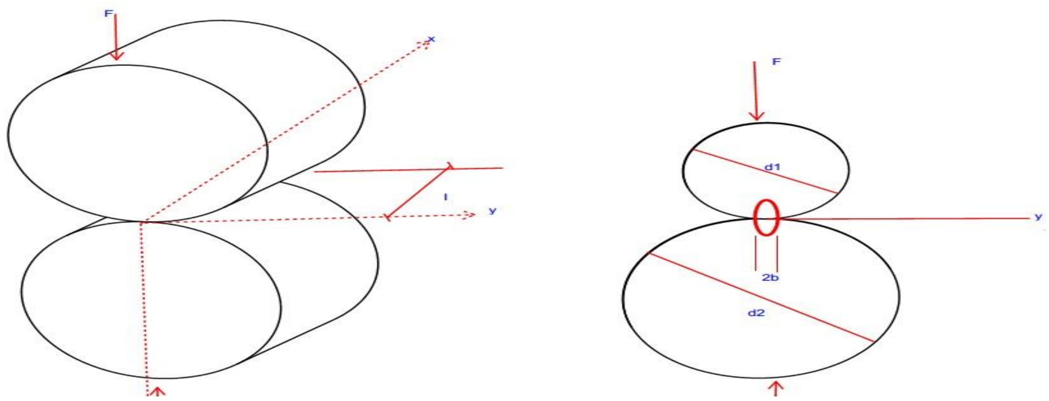


Figure 3.19. The contact stress between two cylinders

The above equations apply to a cylinder and a plane surface (d= ∞) contact (Richard, 2011).

Poisson's ratio is a measure of the Poisson effect, the phenomenon in which a material tends to expand in directions perpendicular to the direction of compression. Conversely, if the material is stretched rather than compressed, it usually tends to contract in the directions transverse to the direction of stretching. It is a common observation when a rubber band is stretched, it becomes noticeably thinner. Again, the Poisson ratio will be the ratio of relative contraction to relative expansion and will have the same value as above.

Where: d_1= Diameter of the wheel, 0.50m

d_2= Diameter of the contacting surface, ∞

F = the force exerted by the wheel, 849.78 N

L = Contact length/width of the wheel with the ground, 0.1m

P_{min} = the minimum penetration resistance/pressure of the ground (at 0-10cm depth) at optimum moisture content, cone, 550KPa (Ashebir, 2015).

v_1= Poisson ratio of steel, 0.3 (Norton, 2005).

v_2= Poisson ratio of sandy loam soil, 0.25-0.4 (Norton, 2005).

E_1 = Young's modulus of elasticity of steel, 200GPa (Norton, 2005).

E_2=Young's modulus of elasticity of sandy loam soil, 10-50MPa (Norton, 2005).

Four-wheel tractor drawn planter wheel width in the design was 10 cm and this had to be checked whether the width selected would allow the wheels to rotate on the surface of the ground without sinkage or not. If Pmax<Pmin, it is assumed that the width of the wheel is safe. If not, the width of the wheel has to be increased to some level to avoid wheel sinkage in operation. Calculating width (b),

$$b = \sqrt{(\frac{2x849.78N}{\pi x\ 0.10m})\text{x}(\frac{(1-(0.3)^2\ )}{200\ x10^9 pa} + \frac{(1-(0.4)^2)}{50\ x\ 10^6 pa}\ /(\frac{1}{0.5m} + \frac{1}{\infty}\ )}$$

b = $52\text{x}10^{-3}$

Calculating maximum pressure (Pmax),

$$Pmax = \frac{2\ x\ 849.78N}{\pi b\ x\ 0.1} = 104.035\text{x}10^3$$

Pmax = 104.035KP$_a$<<<<<<<< P_{min} =550kpa,

Pmax<Pmin,

Therefore, the size of the width of the garlic planter wheels is adequate and the wheel would rotate on the surface of the ground without sinking into the soil.

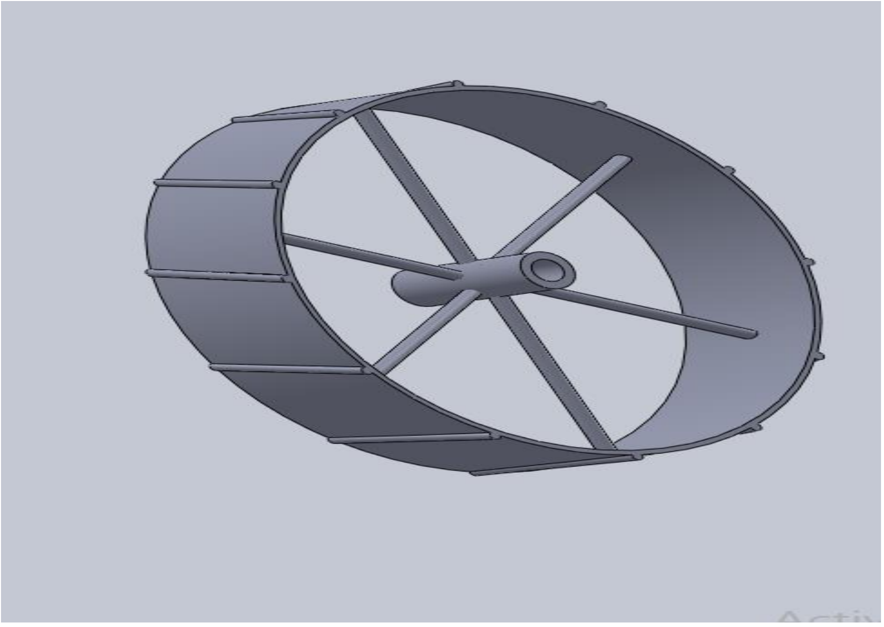


Figure 3.20.Ground wheel

3.7.12. 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 connect the feed cup outlet to the furrow opener. The seed tube carries the garlic 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 100 mm was selected. The length of seed tube was kept 974 mm.

3.7.13. Furrow coverer

The furrow coverer was one of the important parts of the planter, it covers the garlic seed for proper growth of crop.

3.8. Bearing selection

The optimal bearing was 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 consideration of the design life, precision, rigidity, and critical speed, etc. of the bearing. For shaft diameters from 15 to 100mm, the housing has a bearing block of two drilled holes for attachment bolts (ASTM, 2014).

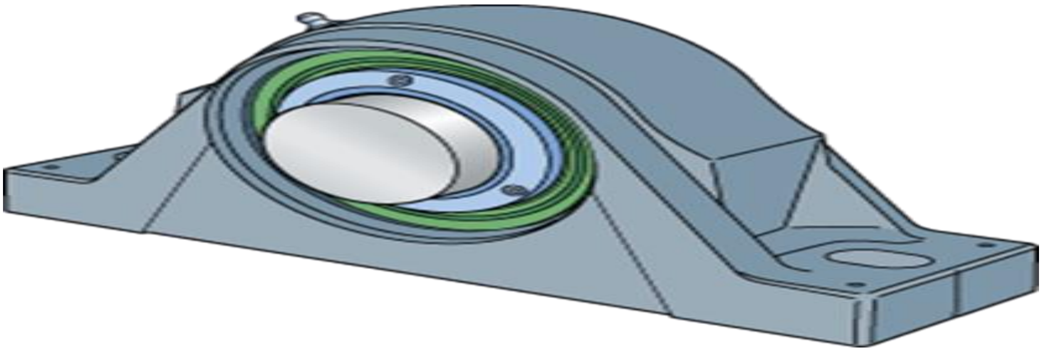


Figure 3.21.ASTM Standard selection of bearing

3.9. Three Point Linkage

Three-point linkages were provided to connect the frame of garlic 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.

Table 3.4.Three-point hitch specification

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

Source: American Society of Agricultural Engineers (ASAE, 2001)

3.10. Performance Evaluation of Garlic Planter

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

Figure 3.22.Fabricated picture of tractor drawn garlic planter

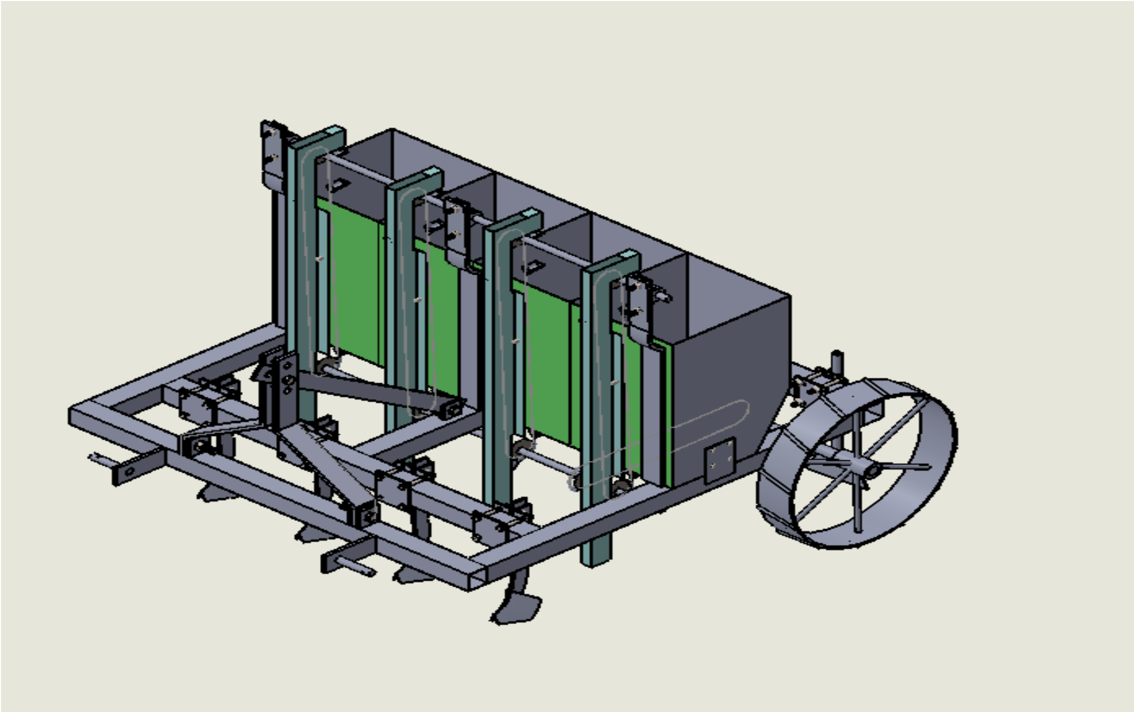


Figure 3.23.Isometric drawing of tractor drawn garlic planter

3.11. Working Principle of Garlic Planter

For operating the garlic planter in the field, a three-point linkage of the planter was attached to the tractor with the help of a pin. Seed hopper filled with good quality of garlic seed. The whole unit was taken to the field having a well-prepared seedbed. The garlic planter was operated by a tractor. The garlic planter consists of a chain and cup type seed metering mechanism, which gets drive from the ground wheel. As the planter moves forward, the chain and cup 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. At the same time, the furrow opener opens up a furrow in which the seeds are planted. As the planter moves further, the covering device attachment then covers the seeds.

3.12. Laboratory Test

3.12.1. Calibration of the 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-E)

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 plastic bag were placed under the furrow openers.
5. The quantity of seeds dropped from furrow openers for 10 revolution were collected and weighed.
6. The quantity of seeds dropped was converted on hectare basis i.e.kg/ha
7. Three replications were taken for 2 km/hr, 2.5 km/hr and 3 km/hr speed for garlic seeds were observed (Appendix-D).

3.12.2. Cloves damage test

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

$$Damage\ percentage = \frac{weight\ of\ damaged\ seed}{total\ weight\ of\ sample} x\ 100 \quad (3.62)$$

3.12.3. Seed germination test

Garlic seed samples (100) seeds was taken randomly and kept in the seed germinator and water was sprinkled at optimum water requirement of garlic seed. The temperature of the seed germinator was maintained at optimum. The sprouts of seeds was observed after seventh-day and number of sprouts was count daily. The counting of sprouts was stopped when the number remains constant. Since the sample is 100 seeds, therefore, the number of sprouts straight away gave the germination percentage of seeds. The germination percentage of garlic seeds were determined before and after the laboratory test of metering systems (Belcher ., 2013)

3.12.4. Soil moisture content

The sample were collected from five randomly selected sites across the field. The moisture content was determined in the laboratory by the oven-dry method. The moisture content (dry basis) was determined by equation (3.63) (Belcher et al ., 2013).

$$W = \frac{Ww-Wd}{Wd} \text{X}\ 100\% \quad (3.63)$$

Where: W= Moisture content, (% db.)

Ww= Wet mass of soil, g

Wd = Dry mass of soil, g

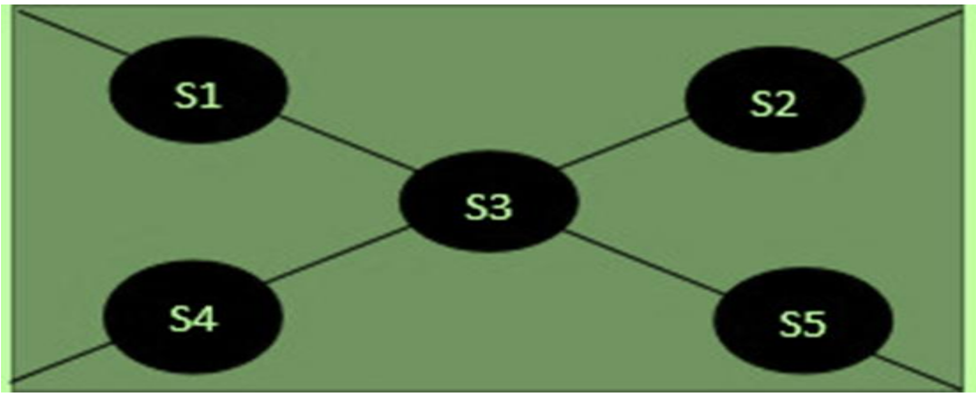


Figure 3.24.Soil sample taking method on the field

3.12.5. Bulk density of soil

The bulk density of the soil was determined by the core cutter method. The core sampler of the soil of known volume was collected and weighed. The ratio of the dry weight of soil to the volume gives the bulk density. The soil bulk density was determined by using equation (3.64) (Rangapara, 2014).

$$\text{Bulk density of soil}(\text{g}.cm^{-3}) = \frac{weight\ of\ dry\ soil\ sample\ (g)}{volume\ of core\ sampler\ (cm^3)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.64)$$

3.13. Field Test

3.13.1. Field description

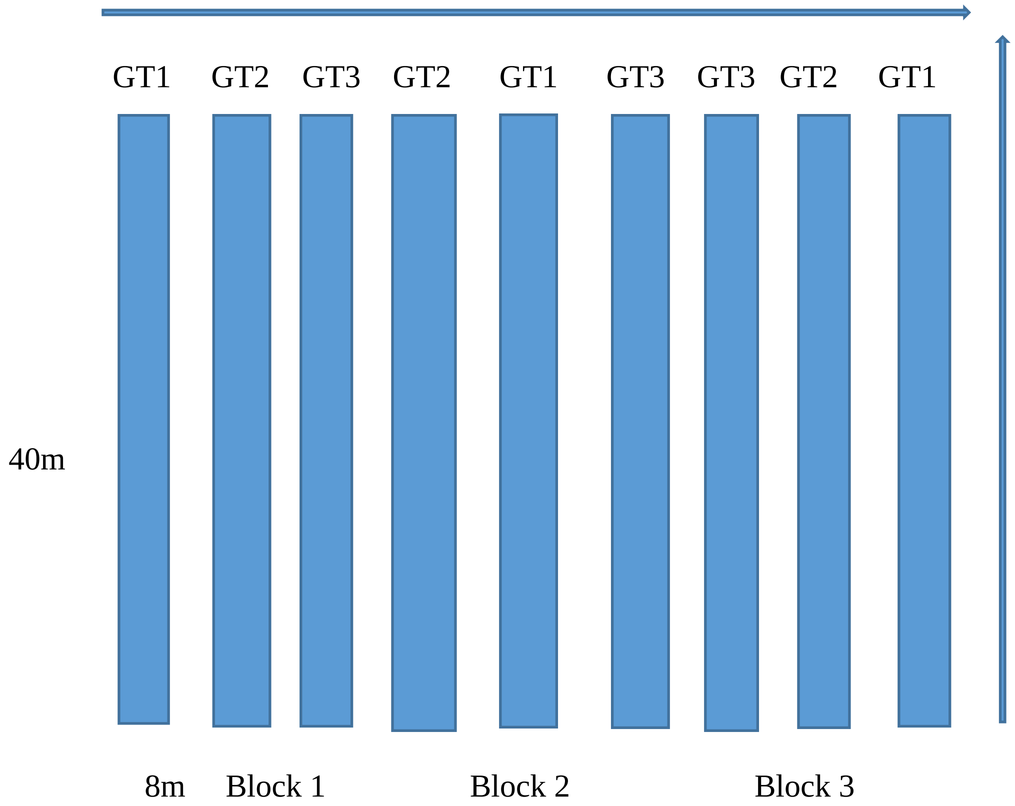
Field condition is important for sowing operation. The following parameters were determined before sowing.

- Type soil
- Depth of seedbed
- Method of sowing
- Size of the plot
- Soil moisture content in percent
- Bulk density

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 garlic planter in the field.

3.13.2 Experimental design

The experiment were conducted in the field with Gojjam garlic variety (G) and three forward speed of tractor 2km/hr,2.5km/hr and 3km/hr with forming three treatments. Each treatment replicated three times with Randomized Complete Block Design (RCBD).



Where: G = Garlic

T = Treatment with index number 1, 2, 3

Figure 3.25. RCBD plot size sample representation

The well-prepared experimental field was divided in to 9 plots each having an area of $320m^2$ (i.e. 40 m x8m net size of each plot). After preparing the field plot, the garlic planter was prepared and adjusted for sowing operation. The tractor drawn garlic planter was adjusted at throttle position and sowing operation was carried out for each randomly selected plot samples by taking a performance evaluation data.

3.13.3. Seed distribution test

This test were 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 three times with garlic seed.

3.13.4. Percentage of missing

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

3.13.5. Percentage of double

If the distance between two seeds was found less than 5cm at the time of measuring distance between two seeds, this was considered as some double. The observations are tabulated in Appendix-D.

3.13.6. Placement of seed

The planter was operated in the field under good seedbed conditions. Then the soil was removed carefully without disturbing the seed at several plots in each row. The depth of the seed below the soil surface was measured. The observation are tabulated in Appendix-D.

3.13.7. Draft requirement test

The 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 which was in neutral gear but with the implement in the operating position. The draft was recorded in the measured distance of 20m. On the same field, the implement was lifted off the ground, and the draft record. The difference between the two readings, give the draft of the implement. This procedure was repeated for all the speed selected in the study. The observation are tabulated in Appendix-D.

3.13.8. Wheel slippage

A mark was made on the tractor drive wheel with coloured tapes and the distance the tractor moves forward at every 10 revolutions under the no-load condition and the same revolution with a load on the same surface was measured. Wheel slip for any given load was determined by equation (3.65) (Rangapara, 2014). The observation are tabulated in Appendix-D.

$$wheel\ slippage = \frac{M1-M2}{M1} X100 \ldots\ldots (3.65)$$

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

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

3.13.9. Fuel consumption

The fuel consumption was measured as per the standard method. The fuel tank of tractor was filled up to its top level before field testing. After planting, the tractor engine was stopped and the fuel tank was refilled up to the same level with the graduate cylinder to determine the quantity of diesel fuel needed to refill the tractor tank up to the same level. The amount of fuel refilled after planting is considered as fuel consumption tractor during planting.

3.13.10. Determination of theoretical field capacity,effective field capacity and field efficiency

The theoretical field capacity and effective field capacity was computed by using the following equation (3.66 and 3.67). (Hancock et al., 1999).

$$\text{Theoretical field capacity}(\text{ha}.hr^{-1}) = \frac{\text{W x S}}{10} \ldots\ldots (3.66)$$

Where: W= width of planter, (m)

S= speed of operation, (km.hr^{-1})

10 = conversion factor

$$Effective\ field\ capacity\ (\text{ha}.hr^{-1}) = \frac{Area\ of\ plot(ha)}{Time\ taken\ (hr)} \ldots\ldots (3.67)$$

Field efficiency is the ratio of the effective field capacity to theoretical field capacity determined by using equation (3.68) (Hancock et al., 1999).

$$Ef = \frac{FCe}{FCt}\ x\ 100 \ldots\ldots (3.68)$$

Where: Ef = field efficiency (%)

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

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

3.14. Operational Cost of the Machine

The cost of operation for the machine was worked out by calculating the fabrication, fixed, and variable costs as presented in Appendix-F. Estimation of hourly operational costs of the planter was based on the capital cost of the planter, interest on capital, cost of repairs and spare parts, labour cost, and depreciation. The operation cost of components of the prototype planter was estimated in Birr (ETB) by using equation (3.69) (Geonse, 1995).

$$Dp = \frac{CC-SVC}{EL}, (ETB.hr^{-1}) \quad \text{……………………………………………………….. (3.69)}$$

Where: DP = Depreciation cost, $(ETB.hr^{-1})$

CC = Capital cost, (ETB)

SVC = salvage value cost, (ETB)

EL= Estimating life, (hr)

Interest on capital was calculated by using equation (3.70) (ASABE, 2011)

$$IC = \left(\frac{CC+SVC}{2}\right) x \left(\frac{1\%}{NAOHP}\right) \text{…………………………………………………………. (3.70)}$$

Where: IC = Interest on capital, (ETB.hr^{-1})

CC = Capital cost, (ETB)

SVC= selvage value cost, (ETB)

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

Labor wage (LW) was calculated by equation (3.71) (ASABE, 2011)

$$LW = \frac{DLW}{DWH} \text{……………………………………………………………………… (3.71)}$$

Where: LW = Labour wages, (ETB.hr^{-1})

DLW = Daily labour wage, (ETB)

DWH = daily working hours, (hr)

Cost of repairs and spares (CRS),) and hourly operational cost was calculated by using equation (3.72) (Geonse, 1995)

$$CRS = \frac{CC\ x\ 6\%}{AWHP} \text{………………………………………………………….….. (3.72)}$$

Where: CRS = cost of repairs and spares (ETB.hr^{-1})

CC = Capital cost, (ETB)

AWHP = Annual working hours of the planter, (hr^{-1})

The wage of the tractor (WT) was calculated by using equation (3.73) (Geonse, 1995)

$$WT = \frac{DTW}{DWH} \text{…………………………………………………………………….…… (3.73)}$$

Where: WT = Wage of the tractor, (ETB)

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

DWH = daily working hours, (hr)

The hourly operational cost was calculated by using equation (3.74) (Geonse, 1995)

$$Hourly\ operational\ costs = (Dp + IC + LW + CRS + WT) \text{…………………..… (3.74)}$$

Where: DP = Depreciation cost, $(ETB.hr^{-1})$

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

LW = Labour wages, (ETB.hr^{-1})

CRS = cost of repairs and spares (ETB.hr^{-1})

WT = Wage of tractor, (ETB)

3.15. Data Analysis

The data obtained from the laboratory experiment and field test was analysed, into tables and graphs by using the software Microsoft Excel 2013 version.

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

A tractor drawn garlic planter was designed and fabricated. The physical properties of garlic 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 analysed and results are discussed in this chapter.

4.1. Laboratory Test Result

4.1.1. Physical properties of the seeds

In order to get some of physical properties of the garlic seed, 40 sample seeds were randomly taken from two different variety of garlic and their length, width and thickness were measured using Vernier calliper. The geometrical dimension of the principal axes (L is length, D is the width and T is the thickness) of randomly selected garlic seeds were measured using Vernier calliper. The mean length (L), width (W), thickness (T), geometric mean diameter, surface area and shape index of two different garlic was found in the ranges from 28.55 to 29.33mm,13.17 to 13.23mm, 10.44 to 10.57 mm, 15.53 to 15.89 mm,769.18 to 807.88mm^2 and 0.755 to 0.78 respectively. Angle of repose garlic was maximum 26°, minimum 25° and average is about 25.5°.

The average values obtained for geometric mean diameter ,surface araea and shape index of the selected garlic seed was became 15.71mm,788.53mm^2 and 0.767mm respectively. The result obtained in table 4.1. that garlic seed had more or less sherical shape(= 0.767). Hence, metering devices with circular shaped cups were used to accommodate it.

Table 4. 1. Physical properties of two different garlic varieties

Physical properties	Units	Two different varieties of garlic seed		
		Gojjam	Minjar	Average
Mean Length	mm	28.55	29.33	28.94
Mean Width	mm	13.17	13.23	13.2
Meant thickness	mm	10.44	10.57	10.5

Mean geometric diameter	mm	15.53	15.89	15.71
Mean Surface area	mm^2	769.18	807.88	788.53
Mean Shape index		0.78	0.755	0.767
Angle of repose	°	26	25	25.5

The obtained shape index was compared with the recommended limits and classified into different classes (The garlic bulb is considered as oval if the shape index > 1.5, on the other hand, it is considered spherical if the shape index < 1.5.) Shape index of garlic bulbs was calculated by equation above equation (3.3) (Abd Alla, 1993).

$$\text{Shape Index} = \frac{W}{\sqrt{\text{LT}}} \quad \ldots\ldots (3.3)$$

Gojjam, shape index = 0.78 spherical

Minjar, shape index = 0.755 spherical

4.1.2. Laboratory performance of garlic planter

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

Figure 4.1.Calibration of garlic planter

4.1.2.1. Operating speed effect on seed damage at different hopper fill

Three replication is carried out for calibrating the garlic planter in the laboratory. Table 4.2, indicates the effect of three different speed at three hopper level on seed damage for different observation varied with operating speed 2km/hr, 2.5km/hr and 3km/hr at complete hopper fill, ½ hopper fill and ¼ hopper fill. The percent of external damage of the seeds were tested at three operating speed for different hopper level.

Table 4. 2. Average effect of operating speed on seed damage at different hopper fill level

Operating speed (km/hr)	Complete hopper fill	½ hopper fill	¼ hopper fill
	% damage	% damage	% damage
2	0.373	0.28	0.18
2.5	0.83	0.75	0.63
3	2.17	1.82	1.48
mean	1.124	0.91	0.803

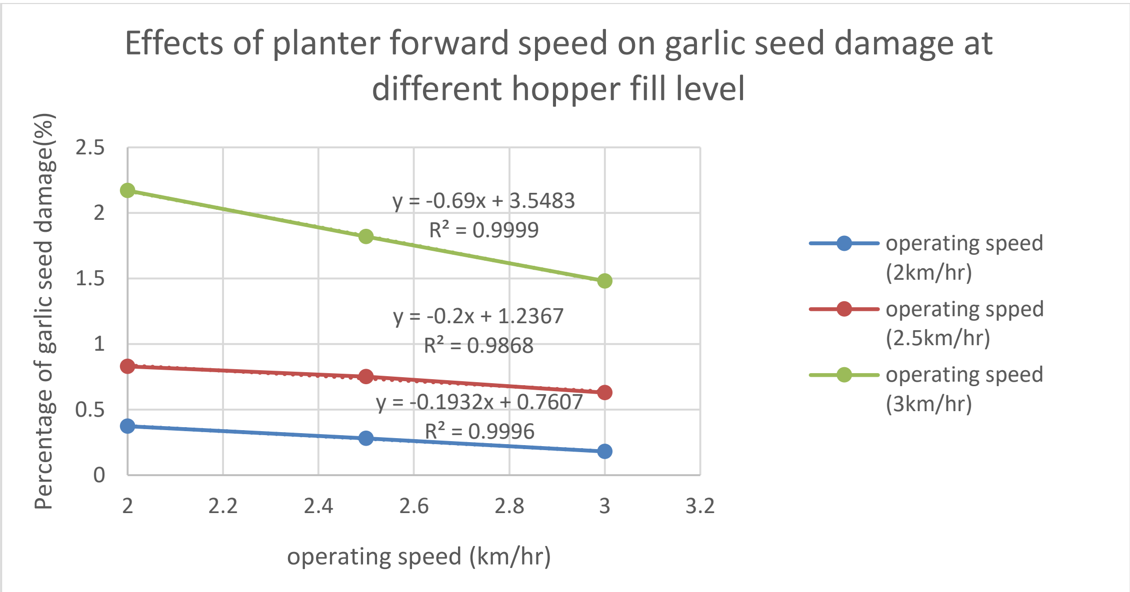


Figure 4.2.Effects of planter forward speed on garlic seed damage at different hopper fill level

From table 4.2, it is show that as the speed increase the mechanical damage of garlic seed increase. The mechanical damage of seed was due to higher rotational speed of metering mechanism 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 operating speed and level of hopper fill was showed in fig 4.2. The data obtained from the testing were analysed, linear regression showed good correlation between seed damage and operating speed in all trials, high coefficient of determination ($R^2 = 0.9996, R^2 = 0.9868\ and\ R^2 = 0.9999$) were observed with complete hopper fill, ½ hopper fill and ¼ hopper fill respectively.

4.1.2.2. Hopper filling effect on the seed rate

Table 4.3 indicates the effect of hopper filling on seed rate (kg/hr) of garlic 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 for three different operating speed.

Table 4.3. Hopper filling level effect on the seed rate at different operating speed

Operating speed (km/hr)	Trials No	Complete hopper fill	½ hopper fill	¼hopper fill
		Seed rate(kg/ha)	Seed rate(kg/ha)	Seed rate(kg/ha)
2	3	137.46	128.07	121.5
2.5	3	120.6	115.36	111.56
3	3	110.53	104.6	100.63
mean	3	122.86	116.01	111.23
SD		13.61	11.75	10.44
CV		11.07	10.13	9.38

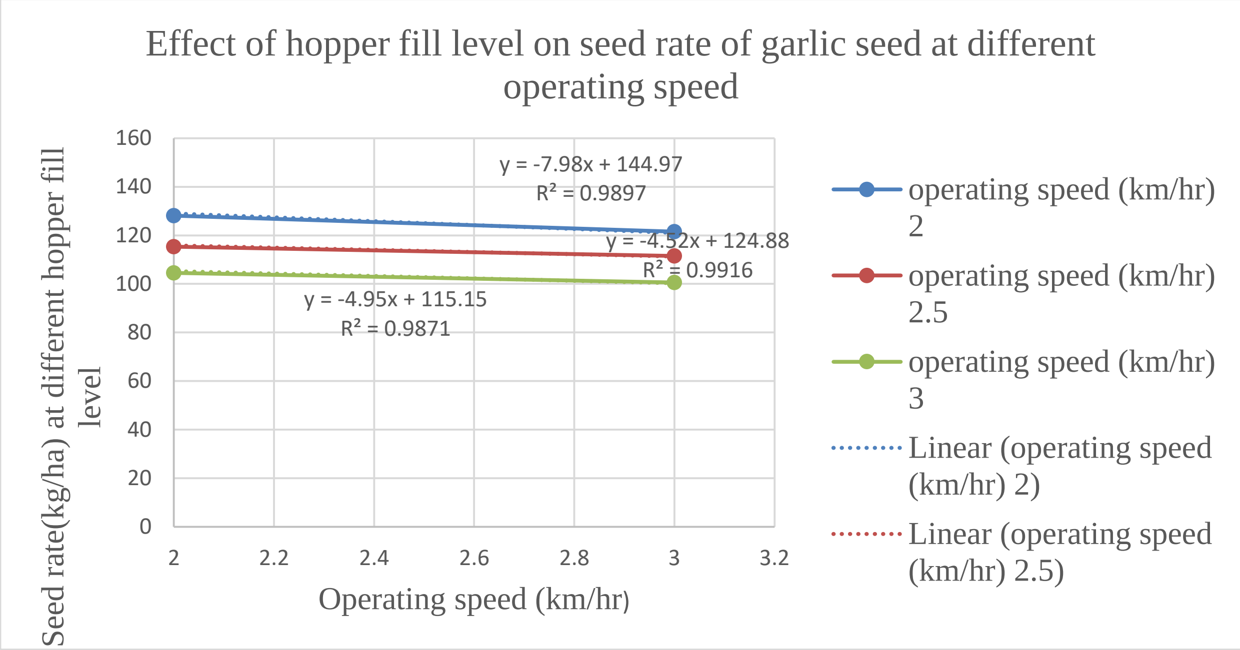


Figure 4.3. Effect of hopper fill level on seed rate of garlic seed at different operating speed

Seed rate increased with the increase in hopper fill and operating speed decrease as shown in table4.3. The increase in seed rate with the increase in hopper fill and decrease in operating speed might be due to decrease in exposure time to pick the seed and due to decrease slip of seed from the cup due to lower speed of metering device.

This may be due to the variability of garlic seed in size and shape, vibration of metering chain when hopper fill level is low and the friction between the metering chain and garlic seed at the picking zone due operating speed.

The correlation between seed rate at different level of hopper fill and operating speed was showed in fig 4.3. The data obtained from the testing were analysed, linear regression showed good correlation between seed rate and hopper fill level (complete hopper fill, ½ hopper fill and ¼ hopper) in all trials, high coefficient of determination ($R^2 = 0.989, R^2 = 0.991$ and $R^2 = 0.987$) were observed with 2km/hr,2.5km/hr and 3km/hr respectively.

4.1.3. The physical properties of the Soil

4.1.3.1. 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 sand–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 5cm diameter and 5cm height.

The mean data on soil moisture content after tillage operations at 0 to15 cm are recorded and presented. Average value of moisture content (Dry basis) and bulk density of experimented plot was found 11.78% and 3.224 gm/cm^3 respectively.

Table 4.4.Moisture content and bulk density of soil

Sample No	Weight of soil(gm)	Weight of soil after oven dried(gm)	Soil moisture content (Db) (%)	Volume of core sampler (cm^3)	Bulk density(gm/cm^3)
1	358.86	321.86	11.49	98.17	3.278
2	341.3	303.33	12.51	98.17	3.089
3	351.13	316.8	10.83	98.17	3.22
4	364.06	322.23	12.98	98.17	3.28
5	355.16	319.66	11.1	98.17	3.256
Average	347.13	316.77	11.78	98.17	3.224

4.2. Field Performance of Garlic Planter

4.2.1. Description of field evaluation

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

- Type of soil – sandy loam soil
- Soil moisture content in percent – 11.78%
- Bulk density – 3.224 gm/cm^3
- Depth of seed bed – 15 cm
- Size of each plot- 40m x 8m =320m^2

Figure 4.4.Garlic planter under operation

4.2.2. Placement of seed

Placement of seeds in all the furrows opened by the planter shown in appendix-D. The average depth of seed was 5.97cm 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 and the distance between rows was 29.96 to 30.1 cm and average distance was 30 cm.

Table 4.5.Average Depth of seed placement and row to row distance under different treatments

Operating speed (km/hr)	Depth (cm)	Row to row distance (cm)
2	5.983	30.1
2.5	5.94	29.95
3	6	29.96

4.2.3. Percentage of missing and percentage of double

Percentage of missing and percentage of double for the planter shown in appendix-D. Percentage of missing slightly increased as operating speed increased showed in table 4.6. The seed missing and percentage of double were depending on hopper fill level and forward speed of operation.

Table 4.6. Average of Number of Missing and Number of Double

Speed (km/hr)	Spacing between two consecutive seeds(cm)	Number of missing	% of missing	Number of double	% of double

2	11.13	1	8.98	2	17.96
2.5	11.85	2	16.84	1	8.43
3	11.53	2	17.34	1	8.67

Percentage of double slightly decreases with speed increase. It is mainly affected by the hopper fill level and forward speed of operation.

4.2.4. Draft and power requirement of planter

The data recorded the effect of different speed on the draft (kg) and power (hp) are in Appendix-D. Draft increased with the increase in operating speed as shown in table 4.9 and fig 4.5. The net draft observed were 229.66, 238, 243.66(kg) at forward speed of 2, 2.5 and 3(km/hr) 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 in to draft value. The tractor requires more at higher speed due to overcome more resistance developed at tractor and at working place.

Table 4.7. Average Draft and Power Measurement

Operation Speed (km. hr−1)	Trials number	Draft (kg)			Power (hp)		
		load Condition	unload Condition	Net draft	load Condition	unload Condition	Net power
2	3	337.33	107.67	229.66	2.49	0.79	1.7
2.5	3	349.33	111.33	238	3.23	1.03	2.2
3	3	361	117.33	243.66	4.01	1.3	2.7
	Mean	349.22	152.77	237.1	3.24	1.04	2.2
	SD	11.83	66.65	7.042	0.76	0.25	0.5
	CV	3.389	43.63	2.97	23.43	24.53	22.72

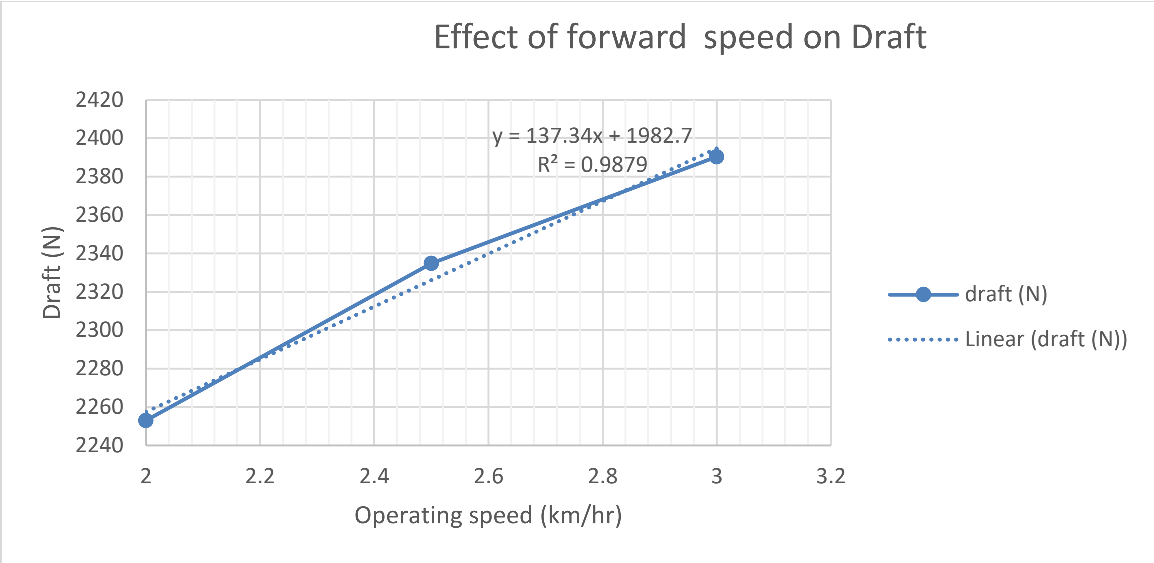


Figure 4.5.Effect of forward speed on Draft

The data showed in fig good correlation between draft and operating speed in all trials, with a high coefficient of determination ($R^2 = 0.989$).

4.2.5. Wheel slip

The data concerning the effect of different speed on the wheel slippage are presented in appendix-D. 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. 2.5 km/hr is Optimum speed for the operation.

Table 4.8. Average slippage

Speed (km/hr)	Tr.No	Distance covered in 10 revolution		Slip (%)
		Under no load ,m	Under load,m	
2	3	17.96	17.17	4.39
2.5	3	17.82	16.84	5.49
3	3	17.56	16.21	7.68
mean		17.78	16.74	5.85
SD		0.20	0.49	1.67
CV		1.14	2.91	28.61

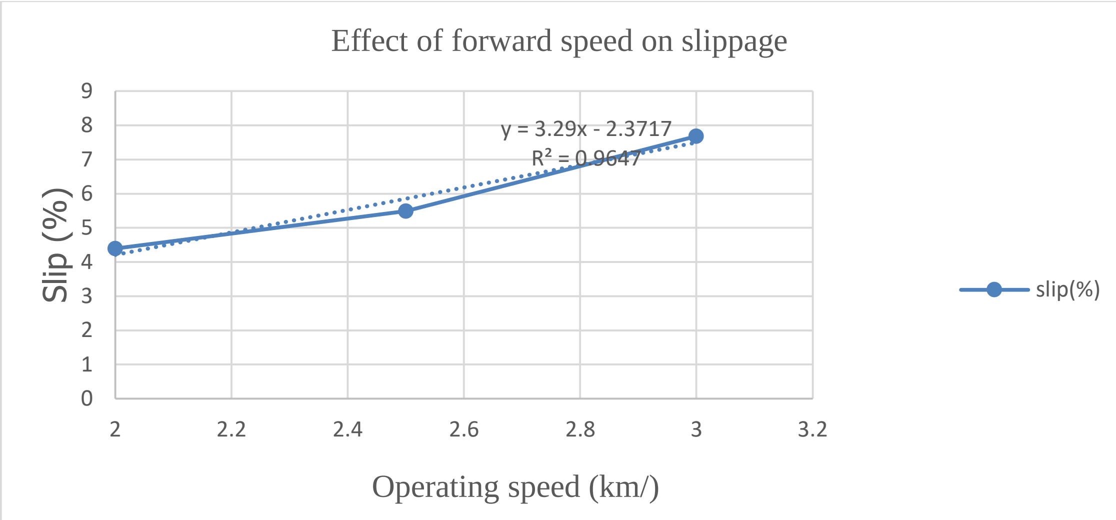


Figure 4.6. Effect of forward speed on slippage

The data showed in Fig 4.6 good correlation between wheel slippage and operating speed in all trials ,with positive and high coefficient of determination(($R^2 = 0.967$).

4.2.6. 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 320 m^2 and are presented in Table 4.9. From field data collected fuel consumption was 0.277 lit for each plot.

Table 4.9. Fuel Consumption

Speed (km/hr)	Tr.No	fuel consumption to cover m2 (lit)	fuel consumption (lit/ha)
2	3	0.245	7.66
2.5	3	0.157	4.92
3	3	0.43	4.475
mean		0.277	5.685
SD		0.139	1.4
CV		50.24	24.77

Fuel consumed by planter per unit area (lit/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 fuel consumption per unit area decreased.

4.2.7. Time and labor requirement

The data concerning the effect of different speed on the time to cover 1ha area are presented in Table 4.10. 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 4.10.Time and Labour Requirement

Speed (km/hr)	Time to cover 320 m^2(sec)	Time to cover 1 ha (hr)	No of labour
2	476	4.12	2
2.5	424.33	3.68	2
3	397	3.44	2
mean	432.44	3.75	2
SD	40.12	0.34	0
CV	9.28	9.17	0

The garlic planter was required two persons for manipulation and operation of sowing activity of garlic on the well prepared land. The first person was required for to perform a sowing operation i.e. one skilled labour for operating the tractor and the second one required for refilling of the seeds. It is clear that as speed increase time decrease to cover 1 ha area.

4.2.8. Determination of theoretical field capacity, effective field capacity and field efficiency

The data concerning the effect of different speed on the theoretical field capacity, effective field capacity and field efficiency to cover 1 ha area are presented in appendix-D

The data of average effect of different speed on the theoretical field capacity, effective field capacity and field efficiency to cover 1 ha area are presented in Table 4.11.

Size of plot = 40 x 8 = 320m^2

Width of planter = 1.5 m

Table 4.11. Theoretical Field Capacity, Effective Field Capacity and Field Efficiency

Speed (km/hr)	Tr.No	Total time required to cover 320m^2		Total time to cover 1 ha	Theoretical field capacity(ha/h)	Effective Field Capacity (ha/h)	Field Efficiency (%)
		In (sec)	In (hr)				
2	3	476	0.131	4.121	0.3	0.242	80.77
2.5	3	424.33	0.12	3.68	0.375	0.271	72.35
3	3	397	0.11	3.44	0.45	0.293	64.45
Mean		432.44	0.12	3.75	0.38	0.27	72.52
SD		40.12	0.01	0.34	0.07	0.03	8.16
CV		9.28	8.80	9.18	20.00	9.52	11.25

4.2.8.1. Theoretical and effective field capacity

Theoretical field capacity and effective field capacity mean values were obtained at different operating speeds shown in Table 4.11. The minimum value of theoretical field capacity observed at 2 km/hr speed was 0.3 ha/hr and maximum values at 3 km/hr speed was 0.45 ha/h. The values of effective field capacity on 2, 2.5 and 3 km/hr were 0.242, 0.271 and 0.293 ha/h respectively. The Fig: 4.7 shows that theoretical and effective field capacity increased with increase in speed.

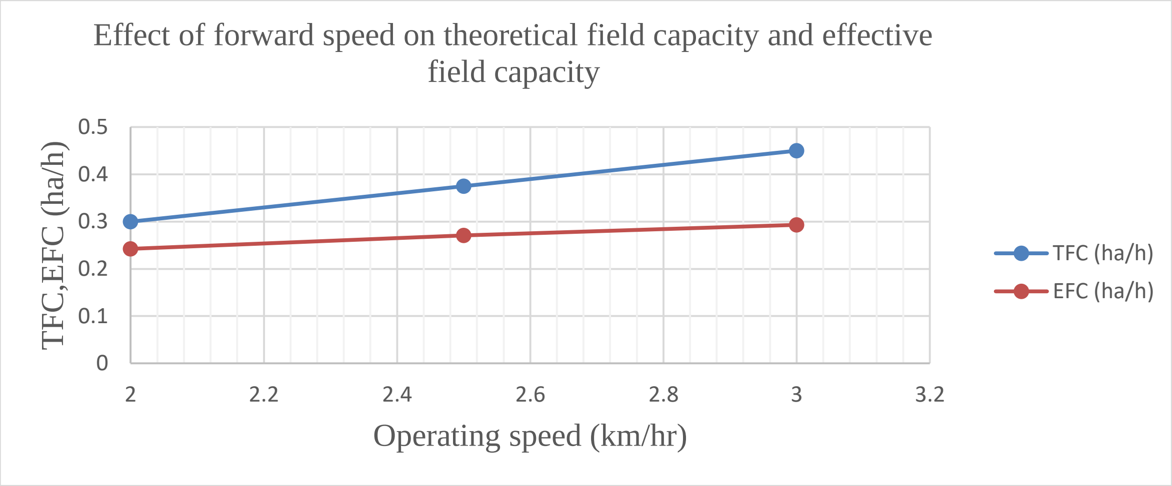


Figure 4.7.Effect of forward speed on theoretical field capacity and effective field capacity

4.2.8.2. Field efficiency

The field efficiency mean values obtained were listed above in Table 4.11. The minimum field efficiency occurred at 3 km/hr operating speed was 64.45 % and the maximum field efficiency noticed that at a speed of 2 km/hr was 80.77 %.

The Fig: 4.8 shows that field efficiency decreased with increased in operating speed. (Rangapara, 2014) Suggested that the field size was decreased; number of passes of the planter increased too, which leads to increase in time losses and gave lower values of field efficiency. The highest 80.77% field efficiency was observed at lower speed. The major reason for the reduction in the field efficiency by increasing forward speed was due to the less theoretical time consumed in comparison with the other test plots.

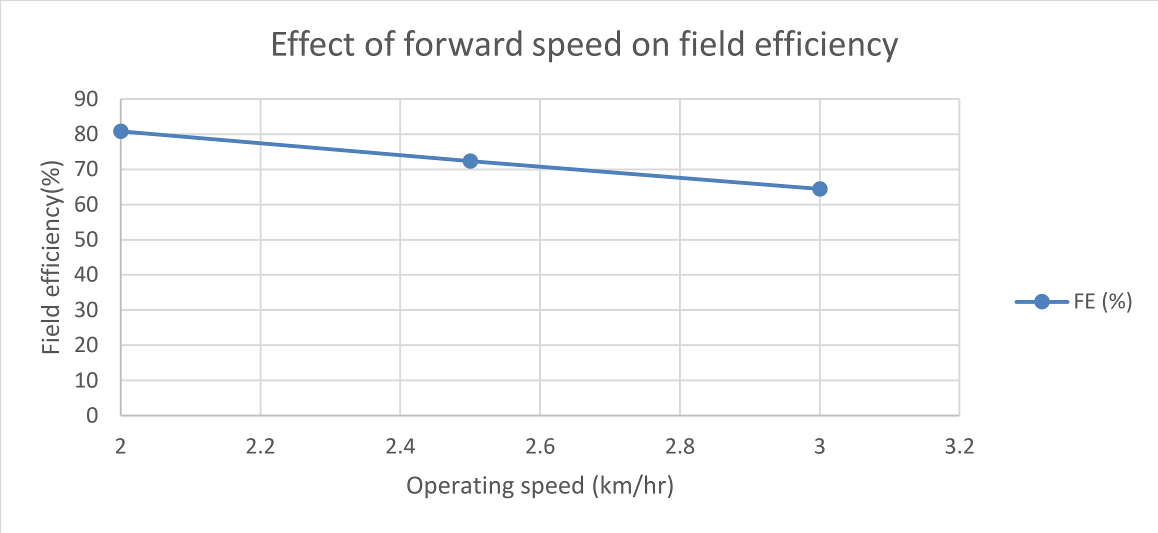


Figure 4.8.Effect of forward speed on field efficiency

4.2.9. Plant population test in field

The plant population test was presented in Table 4.12. The seed germination percentage was varied from 81.5% to 85.06 % at the three plots which each plot area was $320m^2$.

Table 4.12. Seed Germination Test in the Field

3rd gear speed	No of seed planted	No of seed germinated	%.+. of germination
1	395	336	85.06 %
2	388	324	83.5 %
3	391	319	81.5 %
cv	0.007	0.022	0.0175
mean	391.3	326.33	83.35
Sd	2.87	7.13	1.459

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 or metering of the seeds. The lower the CV, the higher the precision of the experiment for a determined parameter.

4.3. Manual Method Garlic Planting

According to capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia (CASCAPE, 2017) project demonstration manual planting results, row spacing of 30 cm was found to be optimum for were garlic production which resulted in 9657.6 kg /ha. The garlic seed row to row spacing should be 30 cm, while plant to plant space of garlic seed should be 7-15 cm.

Table 4.13. Performance of garlic planter compared with conventional practice

Sr.No	Parameter	Units	Tractor drawn garlic planter	Manual planting
1	Row to row spacing	mm	300	300
2	Plant to plant spacing	mm	100	70-150
3	Effective working wide	mm	Four rows	One row
4	Field efficiency	%	72.52	-
5	Depth of planting	cm	6	5-7
6	Travel speed	Km/hr	2- 5	-
7	Germination count	%	81.5-85.06	70-95
8	Seed rate	Kg/ha	137	100-140

4.4. Economical Evaluation

In the planting operation using the four row tractor drawn garlic planter, two persons were required one person to refill the seed to the hopper and the other to operate the machine. However, time required for manual planting of garlic seed for one hectare of land which was 384 hours (forty eight persons per day) of human power. While Two person are needed to plant garlic seed by tractor drawn garlic planter within 3.75 hr/ha to do the same work. Hence 380.25 reduce the time requirement per hectare in hour and also, labour requirement reduced when the tractor drawn garlic planter was used. However, tractor drawn garlic planter which is estimated to be 16100.815 Ethiopian Birr to be high for a single farmer to own the machine but by renting farmers can save time, reduce production cost (planting operation cost) and prevent drudgery of labour.

4.5. Fabrication Cost Estimation of Tractor Drawn Garlic Planter

The unit cost of a tractor drawn garlic planter was determined by calculating the cost of different components and their fabrication cost as given in Appendix-F.

Table 4.14.Cost summary

No	Cost variables	Summary
A	Raw material cost	7882 ETB
B	Material wastage 2.5%	197.05ETB
C	Machine cost	3440ETB
D	Labour cost	987.5 ETB
E	Overhead cost 5% (C+D)	221.375 ETB
F	Profit 10% (A+B+C+D+E)	1272.79ETB
G	Sells tax 15%(A+B+C+D+E+F)	2100.1 ETB
H	Selling price	16100.815 ETB

The result showed that the developed tractor worked satisfactory functionally and therefore proposed its use for the planting of the garlic using 25 hp tractor.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

A prototype of tractor drawn garlic planter was developed for sowing operation suitable for medium farmers and its performance was evaluated. The machine was powered by 25hp Captain seventh generation 4WD tractor. The planter consists of seed metering mechanism, seed tube or seed guide, furrow openers, drive wheel and power transmission. The field testing of tractor drawn garlic planter was carried out at the field of AMARC(Awash Melkassa Agricultural Research Centre).The field was well prepared at 15 cm depth, firm, fine structure, smooth and level, relatively free of surface trash. In field test tractor drawn garlic planter was operated 3rd gear speed at 2 km/hr, 2.5km/hr and 3 km/hr.

The following conclusions could be made from the study of tractor drawn garlic planter.

- Tractor drawn garlic planter works with better efficiency in the fields as compared with manual planting method.
- The tractor drawn garlic planter which is estimated to be 16100.815 Ethiopian birr to be high for a single farmer to own the machine but by renting farmers can save time, reduce planting operation cost and prevent drudgery of labour.
- The prototype of the tractor drawn garlic planter works satisfactory and saves time.

5.2. Recommendation

The performance evaluation made revealed that garlic planter can be used on the farms, but the following issue must be addressed to promote planter to the farmers.

- Promotion and dissemination of the technologies has to be done to end users.
- Making a good plat form to adopt the planter to the farmers to use garlic planter effectively and efficiently.

Suggestion for future work

The following suggestions may be exploring to improve the performance of tractor drawn garlic planter.

- Increasing number of rows to improve field capacity and field efficiency of tractor drawn garlic planter.
- Making a sit chair at the back of garlic planter for labourer to put seed on the cup when cup misses garlic seed and drop-off seed when seed cup care two number seed from the seed box to eliminate missing percentage, double percentage.
- The planter may be tested for different other related crops and feedback received may be used for further design refinements, if any.

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APPENDICES

Appendix- A

Table A.1.Specification of tractor drawn garlic planter

Sr.No		Parameter	Specification
1		Power source	25 HP tractor
2		Overall dimensions	
	A	Length, mm	1500
	B	Width, mm	1250
	C	Height, mm	1114
	D	Weight, kg	97.65
3		Furrow openers	Shovel type
4		Furrow coverer	Flat type
5		Garlic seed metering mechanism	
		Type	Cup on chain
		Number of cups on each roller chain	16
6		Drive system	Chain and sprocket
7		Transmission ratio (Ground wheel shaft to metering shaft	1:1
8		Garlic hopper capacity(kg)	75.6
9		Number of rows	Four
10		Row to row space(mm)	300
11		plant to plant space (mm)	100
12		Ground wheel	Steel tire
13		Machine cost	16100.815 ETB

Appendix-B

Table B.1.Physical properties of Gojjam garlic seed variety

Sr.N	Length	width	thickness	Geometric mean diameter	Surface AREA	Shape Index
1	29	14	11	16.46	851.07	0.78
2	31	11	9	14.53	663.12	0.65
3	29	11	10	14.72	680.44	0.64
4	22	14	7	12.91	524.03	1.12
5	35	12	12	17.14	923.03	0.5
6	24	12	11	14.68	677.30	0.73
7	30	15	12	17.54	677.30	0.79
8	30	12	12	16.28	832.88	0.63
9	29	12	9	14.63	672.16	0.74
10	32	11	10	15.21	726.59	0.61
11	28	12	11	15.46	750.61	0.68
12	27	16	11	16.81	887.52	0.92
13	31	24	16	22.83	1637.03	1.07
14	27	12	12	15.72	776.39	0.66
15	22	13	12	15.08	714.43	0.80
16	32	23	8	18.05	1023.86	1.43
17	29	13	8	14.44	655.46	0.85
18	30	13	12	16.72	878.53	0.68
19	27	11	6	12.12	461.53	0.86
20	29	11	9	14.21	634.28	0.68
21	32	10	7	13.08	537.56	0.66
22	27	11	9	13.87	604.77	0.70
23	31	15	12	17.73	987.83	0.77
24	27	12	7	13.13	542.03	0.87
25	26	15	28	22.18	1545.53	0.55
26	31	16	11	17.60	973.14	0.86
27	23	11	6	11.49	414.74	0.93
28	28	10	8	13.08	537.56	0.66
29	30	10	7	12.80	514.92	0.69
30	29	11	8	13.66	586.07	15.23
Mean	28.56667	13.1	10.36667	15.47	763.06	1.26
max	35	24	28	22.83	1637.03	15.23
min	22	10	6	11.49	414.74	0.55

Table B.2. Physical properties of Minjar garlic seed variety

Sr.No	Length	Width	Thickness	Geometric Mean diameter	surface Area	Shape index
1	35	15	11	17.94	1010.71	0.76
2	32	17	10	17.58	971.23	0.95
3	30	16	10	16.86	893.48	0.92
4	29	14	12	16.95	902.39	0.75
5	35	14	9	16.39	844.40	0.78
6	32	14	10	16.48	853.32	0.78
7	31	18	16	20.74	1351.33	0.80
8	39	17	12	19.96	1251.38	0.78
9	30	13	11	16.24	829.02	0.71
10	28	15	11	16.65	871.00	0.85
11	31	13	8	14.77	685.26	0.82
12	33	12	10	15.82	785.94	0.66
13	25	12	9	13.92	608.84	0.87
14	27	13	13	16.58	863.82	0.69
15	37	12	9	15.86	790.69	0.65
16	25	15	12	16.50	855.85	0.86
17	27	12	14	16.55	860.41	0.61
18	33	12	8	14.68	677.30	0.73
19	27	10	9	13.44	567.54	0.64
20	25	13	13	16.16	820.62	0.72
21	22	10	10	13.00	531.14	0.67
22	24	10	10	13.38	562.86	0.64
23	25	16	11	16.38	843.13	0.96
24	29	10	7	12.66	503.41	0.70
25	28	12	8	13.90	607.03	0.80
26	24	10	10	13.38	562.86	0.64
27	22	11	11	13.85	603.11	0.70
28	27	8	8	11.99	452.15	0.54
29	37	14	13	18.88	1119.71	0.63
30	31	19	12	19.19	1156.44	0.98
Mean	29.33333	13.23333	10.56667	15.89	807.88	0.75
Max	39	19	16	20.74	1351.33	0.98
Min	22	8	7	11.99	452.15	0.54

Appendix-C

Laboratory test

Table C.1.Calibration of planter test in laboratory

Speed	Seed Variety	Seed rate (kg/ha)			average
		1	2	3	
	Gojjam	138	135	133	135.33
36 rpm	Gojjam	126	129	131	128.66
	Gojjam	118	115	116	116.33

Damage percentage = Weight of damaged seed/ total weight of seed collected x 100

Table C.2. Effect of hopper filling level on seed damage of garlic seeds

Operating speed (km/hr)	Trials No	Complete hopper fill	½ hopper fill	¼hopper fill
		% damage	% damage	% damage
	1	0.45	0.26	0.21
2	2	0.34	0.29	0.16
	3	0.33	0.3	0.17
	Average	0.373	0.28	0.18
	1	0.89	0.77	0.59
2.5	2	0.77	0.73	0.68
	3	0.84	0.75	0.62
	Average	0.83	0.75	0.63
	1	2	1.72	1.53
3	2	2.21	1.91	1.48
	3	2.3	1.85	1.44
	Average	2.17	1.82	1.48

Table C.3.Effect of hopper filling level on seed rate of garlic seed

Operating speed (km/hr)	Trials No	Complete hopper fill	½ hopper fill	¼hopper fill
		Seed rate kg/ha	Seed rate kg/ha	Seed rate kg/ha
	1	137.7	128.13	121.57
2	2	137.3	128.06	121.42
	3	137.4	128.02	121.53
	Average	137.46	128.07	121.50
	1	120.2	115.4	111.8
2.5	2	119.8	115.6	111.3
	3	121.8	115.1	111.6
	Average	120.6	115.36	111.56
	1	110.6	104.8	100.9
3	2	110.2	104.6	100.7
	3	110.8	104.4	100.3
	Average	110.53	104.6	100.63

Appendix-D

Field test

Determination of number of missing and number of doubles

Name and Variety of Seeds = garlic seeds and Gojjam and Length of Furrow = m

Table D.1. Number of missing and number of double

Speed (km/hr)	trials	Spacing between two consecutive seeds(cm)	Number of missing	% of missing	Number of double	% of double
2	R1	11.1	1	9	2	18
	R2	10.8	1	9.25	2	18.5
	R3	11.5	1	8.69	2	17.39
	Av	11.13	1	8.98	2	17.96
2.5	R1	11.7	2	17	1	8.54
	R2	11.9	2	16.8	1	8.4
	R3	11.95	2	16.74	1	8.36
	Av	11.85	2	16.84	1	8.43
3	R1	11.6	2	17.24	1	8.62
	R2	11.2	2	17.85	1	8.93
	R3	11.8	2	16.94	1	8.47
	Av	11.53	2	17.34	1	8.67

Table D.2.Depth of seed placement and row to row distance under different treatment

	Speed km/hr					
	2		2.5		3	
Sr.No	Depth, cm	Spacing,cm	Depth,cm	Spacing,cm	Depth,cm	Spacing,cm
1	5.8	30.4	6	30.2	5.8	30
2	6.1	30	5.9	30	6.2	30.1

3	6.15	29.8	6.1	29.8	6	29.9
4	5.9	30	5.8	29.9	5.9	30
5	6	30	6	30	6	29.8
6	5.95	30.5	5.85	29.8	6.1	30
Ave	5.983	30.1	5.94	29.95	6	29.96

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).

Table D.3.Determination of slippage of ground wheel

Speed (km/hr)	Tr.No	Distance covered in 10 revolution		Slip (%)	Avg. Slip (%)
		Under no load ,m	Under load,m		
	1	18.02	17.21	4.49	
2	2	17.96	17.19	4.28	4.39
	3	17.92	17.13	4.4	
	Average	17.96	17.17	4.39	
	1	17.85	16.91	5.26	
2,5	2	17.82	16.84	5.49	5.49
	3	17.79	16.77	5.73	
	Average	17.82	16.84	5.49	
	1	17.62	16.29	7.54	
3	2	17.56	16.21	7.68	7.68
	3	17.51	16.14	7.82	
	Average	17.56	16.21	7.68	

$$power = \frac{Draft\ (kg) x\ speed\ (\frac{km}{hr})}{270}$$

Table.D.4.Draft and power measurement

Operation Speed (km. hr^{-1})	Trials number	Draft (kg)			Power (hp)		
		load Condition	unload Condition	Net draft	load Condition	unload Condition	Net power
2	1	339	106	233	2.51	0.78	1.72

	2	336	109	227	2.48	0.807	1.68
	3	337	108	229	2.49	0.8	1.69
	Average	337.33	229.66	229.66	2.49	0.79	1.7
	1	348	110	238	3.22	1.01	2.20
2.5	2	349	113	236	3.23	1.04	2.18
	3	351	111	240	3.25	1.02	2.22
	Average	349.33	111.33	238	3.23	1.03	2.2
3	1	361	119	242	4.01	1.32	2.68
	2	359	116	243	3.98	1.28	2.7
	3	363	117	246	4.03	1.3	2.73
	Average	361	117.33	243.66	4.01	1.3	2.7

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

Size of plot = 40x8 = 320 m^2

Width of Planter = 1.5 m

Table D.5.Theoretical field capacity, effective field capacity and field efficiency

Speed (km/hr)	Tr.No	Total time required to cover 320 m^2		Total time to cover 1 ha	Theoretical field capacity(ha/h)	Effective Field Capacity (ha/h)	Field Efficiency (%)
		In (sec)	In (hr)				
2	R1	476	0.132	4.125	0.3	0.242	80.66
	R2	474	0.131	4.093	0.3	0.244	81.33
	R3	478	0.132	4.146	0.3	0.241	80.33
	Ave	476	0.131	4.1213	0.3	0.242	80.77
2.5	R1	426	0.118	3.696	0.375	0.27	72
	R2	422	0.117	3.66	0.375	0.273	72.8
	R3	425	0.118	3.689	0.375	0.271	72.26
	Ave	424.33	0.1176	3.68	0.375	0.271	72.35
3	R1	397	0.1102	3.44	0.45	0.2903	64.51
	R2	396	0.11	3.437	0.45	0.2909	64.64
	R3	398	0.1105	3.453	0.45	0.289	64.22
	Ave	397	0.11023	3.443	0.45	0.293	64.45

Appendix –E

Calibration Data Sheet

D = Diameter of ground wheel = 0.52 m

L = Length of strip covered by ground wheel in one revolution = $\pi\ x\ 0.52\ m$ =1.633

N = Number of furrow openers = 4

R = Row to row spacing = 30 cm

W = Effective Width =1.2m

Effective width of coverage = n x R = 4 x 30 = 120cm = 1.2m

Area covered in one revolution of ground wheel = 0.52 m x 4 x 1.633m = 3.39m^2.

Area covered in 10 revolution of ground wheel =3.39 x 10 = 33.9 m^2

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

A) For speed = 2km/hr

$N_1 = \frac{2\ \text{x}1000}{0.52\ x\ \pi\ x60}$ = 20.4

B) For speed = 2.5 km/hr

$N_1 = \frac{2.5\ \text{x}1000}{0.52\ x\ \pi\ x60}$ = 25.5

C) For speed = 3km/hr

$N_1 = \frac{3\ \text{x}1000}{0.52\ x\ \pi\ x60}$ = 30.6

Time allowed for N = 10 revolution at different speed, T = $\frac{60\ XN}{N_1}$

T = $\frac{60\ X10}{20.4}$ = 29.41 sec

T = $\frac{60\ X10}{25.5}$ = 23.53 sec

T = $\frac{60\ X10}{30.6}$ = 19.6 sec

Appendix- F

Table F.1.Materials for construction of the planter and its cost

Sr.No	Type of material	Specification	Material used	Cost (Birr)
1	Hollow square pipe	60x60x3mm	6m	960 Birr
2	Sheet metal	3x 1000x3000m	4m	400 Birr
3	Galvanized metal sheet	2x1000x2000	2m	360
4	Angel iron	5x40x40	3	340
5	Round bar	Ø20x6000 mm	2.4m	280
6	Round bar	Ø30x6000 mm	1.5m	270
7	Metal bolt and nut	M-6 x60	8 pcs	40
8	Metal bolt and nut	M-8 X50	10 pcs	70
9	Metal bolt and nut	M-10 X100	16 pcs	160
10	Metal bolt and nut	M-10 X120	32 pcs	352
11	Motor cycle Chain	6.35 mm pitch	6pcs	1680
12	sprockets	14 Number of teeth	9 pcs	450
13	bearing	P206	2 pcs	600
14	bearing	P203	4 pcs	1200
15	Flat iron	10 x60 x6000	6m	270
16	electrode	Ø 2.5	2 pack	300

17	paint	2 litre	2 litre	150
Total cost(Birr)		7882 birr		

Table F.2.Machine and labour cost

	Type of machine	Machine cost/hr	Working hour	cost	Labour cost/hr	Working hour	Total price
	Universal metal cutting	80	10	800	12.5	10	125
	Welding machine	30	8	240	12.5	12	150
	Power hack saw	20	2	40	12.5	3	37.5
	Lath machine	150	12	1800	12.5	12	150
	Rolling machine manual	20	5	100	12.5	8	100
	Radial drill machine	50	4	200	12.5	20	250
	Grinding machine	40	5	200	12.5	10	125
	Bending machine	30	2	60	12.5	4	50
Sub total				3440			987.5

- **Total fabrication cost of garlic planter**

Table F.3. Cost Summary

No	Cost variables	summary
A	Raw material cost	7882 ETB
B	Material wastage2.5%	197.05ETB
C	Machine cost	3440ETB
D	Labour cost	987.5 ETB
E	Overhead cost 5%(C+D)	221.375 ETB
F	Profit 10%(A+B+C+D+E)	1272.79ETB

G	Sells tax 15%(A+B+C+D+E+F)	2100.1 ETB
H	Selling price	16100.815 ETB

The result showed that the developed tractor worked satisfactory functionally and therefore proposed its use for the planting of the garlic using 25 hp tractor.

- **Calculation of operational cost of tractor drawn garlic planter**

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

Assumptions: Yearly working hour (NAOHP) Number of the annual operational hours of the planter (hr) = 200

Rate of interest, I = 8%

Operational cost of the planter

I. Fixed cost of planter

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

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

Capital cost, CC = 16100.815 ETB

Salvage cost, SVC = 10 % x 16100.815 (considering 10 % of Capital cost)

SVC = 1610.0815 ETB

Assume, Economic Life, EL = 10 years.

$$Dp = \frac{16100.815 - 1610.0815}{200\ x\ 10}$$

Dp = 7.24 ETB/hr

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

$$IC = \frac{CC + SVC}{2}\ X\ \frac{I\%}{NAOHP}$$

$$IC = \left(\frac{16100.815 + 1610.0815}{2}\right)\ X\ \left(\frac{8\%}{200hr}\right)$$

IC = 3.54 ETB/hr

Total fixed cost = DP + IC

Total fixed cost = 7.24ETB/hr + 3.54 ETB/hr

Total fixed cost = 10.78 ETB/hr

II) Variable cost of planter

A) <u>Labor wages (LW), was calculated as follows:</u>

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

$$LW = \frac{80\ ETB}{8hr}$$

LW = 10 ETB /hr

B) <u>Cost of repairs and spares (CRS) was calculated as follows:</u>

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

$$CSR = \frac{16100.815X\ 6\%}{200}$$

CSR = 4.83 ETB/hr

<u>C). Wage of Tractor (WT), was calculated as follows:</u>

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

$$WT = \frac{2000\ ETB}{8\ hr}$$

WT = 250 ETB /hr

DTW - Daily Tractor wage (ETB)

DWH - Daily working hours (hr)

Total Variable cost = LW + CRS +WT

Total Variable cost = 10 ETB/hr + 4.83 ETB/ hr + 250 ETB/ hr

Total Variable cost = 264.83 ETB / hr

Total operational cost = Fixed cost + Variable cost

Total operational cost = 10.78 ETB /hr + 264.83 ETB /hr

Total operational cost = 275.61 ETB /hr

Appendix- G

Pictures showing fabrication tractor drawn garlic planter


Figure G.1.Picture showing fabrication of tractor drawn garlic planter

Pictures showing procedure for performance evaluation of tractor drawn garlic planter machine

Figure G.2.Picture showing grading of garlic seed

Figure G.3.Picture showing measuring of garlic seed physical properties

Figure.G.4.Picture showing taking of soil sample to measure soil moisture content and bulk density

Figure G.5.Picture shows data taking during Performance evaluation of tractor drawn garlic planter

Figure G.6.Picture shows seed emergency stage

Figure G.7. Picture shows seed cultivation stage