ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIALS ENGINEERING

MECHANICAL SYSTEMS AND VEHICLE ENGINEERING PROGRAM

DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF TWO-WHEEL TRACTOR DRAWN SIX ROW WHEAT SEED DRILL

Thesis Submitted to the Mechanical Systems and Vehicle Engineering Program for the Partial Fulfillment of the Requirements for the Award of Master of Science Degree in Agricultural Machinery Engineering

By

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CANDIDATE’S DECLEARTION

This is to certify that the thesis entitled “Design, Fabrication and Performance Evaluation of Two-wheel Tractor Drawn Six Row Wheat Seed Drill” for the partial fulfillment of the requirements for the award of the degree of Master of Science in Agricultural Machinery Engineering is a true record of my own work carried out from March, 2017 to August, 2017 under the supervision of Simie Tolla (Dr. Ing) and Fekadu Lemessa (Dr. Ing) Department of Mechanical Systems and Vehicle Engineering Program, Adama University, Ethiopia.

No part of the thesis has been submitted by me for the award of any other degree or diploma. All relevant resources of information used in this thesis have been dully acknowledged.

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ADVISORS DECLEARTION

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

Advisor: SimieTolla (Associate Professor) Signature_______ Date __________

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APPROVAL BY BOARD OF EXAMINERS

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DEDICATION

This work dedication goes to my parents for their consistent and unreserved help, support and prayers for my success and encouragement with selfless scarifies throughout my educational career.

LIST OF ABBREVIATIONS AND ACRONYMS

AAMI	Adama Agricultural Machinery Industry
ADWS	Animal Drawn Wheat Seeder
AIRIC	Agricultural Implement Research and Improvement Center
AR	Angle of Repose
CSA	Central Statistical Agency
EIAR	Ethiopian Institute of Agricultural Research
et. Al.	And Other
etc.	Etcetera
db	Dry Base
FAO	Food and Agriculture Organization
HRY	Head Rice Yield
KARC	Kulumsa Agricultural Research Center
MARC	Melkassa Agricultural Research Center
METEC	Metals and Engineering Corporation
TGW	Thousand Grain Mass
2WT	Two-wheel Tractor

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ABSTRACT

Wheat is one of the leading food crops in Ethiopia. In Ethiopia broadcasting system of sowing is prevalent up to date. Animal drawn seeders are developed for sowing wheat but proper seed rate is not maintained and uneven seed delivery was observed. The small power operated two-wheel tractors are being used by farmers for various farm operations. The objective of this study was to design, fabricate and performance evaluation of two-wheel tractor drawn wheat seed drill. In Ethiopia there is a limitation on tractor drawn planters attached with those two-wheel tractors. Therefore, this thesis work intended to avail a suitable low cost seed driller. The physical properties of five varieties of wheat were studied. The sphericity result was 61 % to 67 %. The angles of repose of all varieties were nearly equal to 26^0*. The developed two-wheel tractor drawn wheat drill machine consists of trapezoidal shape hopper, cup feed seed metering mechanism, shovel type furrow opener, ground wheel and furrow covering device. Row to row spacing can be 20 cm and depth also adjustable to 3 to 5 cm as per wheat agronomic requirement. The developed two-wheel tractor drawn wheat seed drill was tested in the laboratory and field. The seed rate was calibrated and observed that 112 kg/ha with a 4.5 mm cups depth adjustment which is laying in the acceptable range of 100 to 125 kg/ha. There was no visible damage observed. The preliminary test conducted at speed of 1.4, 2 and 2.5 km/h speed shows good seed rate but 2.5 km/h speed gave better operation result than other operating speeds. 350 to 372 plants population per 1.2* m^2 *area were observed during field germination count. The theoretical field capacity, effective field capacity and field efficiency of the machine were 0.30 ha/hr., 0.23 ha/hr. and 77.91 % respectively. The performance of two-wheel tractor drawn six row wheat drill was good for working in the well prepared seed bed for sowing.*

Key words: cup feed seed metering, design, seed drill, seed rate, two wheel-tractor ,wheat

CHAPTER 1

INTRODUCTION

1.1. Background and Justification

Ethiopia framing system is categorized as small land holdings, due to high population density with more than two-third of the population residing in rural areas. There are 111.5 million hectares of land in Ethiopia, 74.5 million hectares of which is suitable for agriculture, and 13.6 million hectares of which is currently under production. Farmers produce cereal crops like wheat, barley, and rice (CIMMYT, 2014).

In Ethiopia, wheat is one of the major food crops. It is the second important cereal crop with annual production of about 3.43 million tons cultivated on area of 1.63 million hectares (CSA, 2013). Based on CSA (2013) data, wheat occupied about 17% of the total cereal area with average national yield of 2.11 t/ ha. This is low compared to the world average of 4 t/ha (FAO, 2009). The demand for wheat has been increasing due to growing population, urbanization and the expansion of food processing industries in the country. In 2013/14, 4.7 million farmers produced 39 million quintals of wheat across 1.6 million hectares of land, making it the third most important cereal crop in the country. Between 2007/8 and 2013/14, yield and total production of wheat grew annually by an average of 8.4% and 11.6%, respectively (EATA, 2014).

Agricultural mechanization has a significant contribution to agricultural development and its purposes are increasing land and labor efficiency by reducing the difficulty in farming operation, bringing more lands under cultivation, save energy and resources. To enhance wheat production and productivity in the country, the farmers should use different agricultural machineries in addition to other inputs. The quality and precision of the operation are equally significant for realizing higher yields. The various agricultural operations need a high degree of precision to increase the efficiency of the inputs. However, when such operations are performed through indigenous method their efficiency is reduced. So as to ensure timeliness of various operations, it is quite better to use such power driven seeders which have higher output these has helped in increasing area cultivated and increase in cropping intensity.

The relatively slow growth in mean national yield for bread wheat (*Triticum aestivum* L.) from 1.46 t/ha in 2004/2005 CSA (2005) to 2.01 t/ha CSA (2011) is due to several constraining factors, such as poor crop management that include the prevalence of poor weed control, aggravated by the limited availability of herbicides in the market and its improper use, depleted soil fertility and lack of small scale agricultural machineries like seeder.

Agricultural productivity in Ethiopia is improving, there are still major gaps in productivity when compared with the rest of Africa in some crop areas, and almost universally, when compared with the global output level (FAO, 2014). For example, the African average production of wheat is approximately 10% more per hectare, and the global average is about 50% higher than Ethiopia. Even with significant improvement in productivity in recent years, Ethiopia is still a net wheat importer (CIMMYT, 2014). According to Asfaw *et al*. (2012) the gradually rising incomes and urbanization have contributed to the shift in dietary preferences from other grains to wheat and rice in Ethiopia.

Similarly, Nicole et al. (2012) results suggested that rising incomes, growing populations, women's participation in the labor force increasing at a faster rate than men's, and wheat food aid are the key drivers for rising wheat consumption. In consideration of wheat importance for food security in Africa, Kamruzzaman and Mohammad (2008) recommended the need of increasing area under wheat production to bridge the gap between wheat demand and supply in the region.

Sowing is a critical field operation that makes the prospects of a crop. Farmers still follow traditional methods of manually sowing as broadcasting or dibbling. These methods result in lower yield due to uneven distribution of seed, low germination and excessive weed growth. Availability of farm power is a pre-requisite for timely field operations that are essential for optimum productivity in agriculture.

Two-wheel tractors are sources of power designed to perform most field operations. Due to the size of such tractors, they become an economic alternative for small farming. In addition, two-wheel tractors are much more productive than animal traction and they require less time for attendance and preparation, giving the individual farmer more independence and contact with modern technology (Bill, 1999).

The developed two-wheel tractor drawn wheat seed drill could have components of cup feed metering mechanism, seed hopper, ground wheel, furrow opener, soil covering device and two-wheel tractor itself for power source. The seed drill could get the power for ground wheel for picking and delivering the wheat seeds. Theoretically two-wheel tractor drawn seed drill could maintain the seed uniformity between rows. A uniform distribution of seed with 20 cm spacing along the row planting is desirable. The cup metering mechanism required to hold the seed in each cup should be between 12 to 15 seeds based on the physical property carried out to maintain the seed rate of 100 to 125 kg/ha and the required plant population should be 377 plants/m^2. The developed seed drill could place the seed 3 to 5 cm below the ground surface.

The animal-drawn and four-wheel tractor drawn seed drills were available in the country are not suitable for fragmented plot of the farmers' land. The animal population in Ethiopia is decreasing and a small farmer does not have pair of oxen. Currently, small power two-wheel tractors are being popular and used by farmers for various farm operations. It shows the increasing demand of two-wheel tractors availability in Ethiopia. Two-wheel tractors are suitable for use on small or medium farms while four wheel tractors are either difficult or uneconomical to use on fragmented land. It is known that Ethiopian farmers have small land holding capacity, low animal population. Animal also requires food stuff, shelter for living, care and maintenance. The cost of animals for operation is higher as compare to other source of power. The power tiller can be operated at 1.5-2 km/h speed for sowing (Anonymous, 2013).

Therefore, if the country is to feed the rapidly growing population and meet the high demand, it needs to increase the production and productivity of wheat through efficient production and adoption of seed drill machines like two-wheel tractors seed drills. Because Ethiopia's farmers have about 14.7 million households (CSA, 2012) of which about 60%, which operate on less than 1 hectare of ground while only about 1% of farmers, operate on land greater than 4 hectares. To overcome the drawbacks of various sowing systems to get desired performance and to fulfill agronomic requirement it should be necessary to develop two-wheel tractor drawn wheat seed drill and required to identify economically and technically feasible two-wheel six row seed drill for smallholder farmers.

1.2. Statement of Problems

Recently the governments of Ethiopia adopt and assemble two-wheel tractors at METC in Adama agricultural machinery industry. The industry has tried to disseminate it to the farmers with a long term payment. In 2014/15, the industry and the private importers sold the two-wheel tractor with a moldboard attachment at a price of about 55,000 to 69,000 Birr. However, there is no two-wheel tractor drawn sowing machine in Ethiopia. Sowing wheat crops using manual and animal drawn wheat row seeder is tedious and time consuming and results a lower rate of production and productivity.

The main problem observed in case of animal drawn seeders is that the proper seed rate was not maintained and also uneven seed delivery was observed. Many seeds are dropped when the operator stops and then no seeds are dropped until the seeder has moved forward for a small distance. This uneven seeding leads to an uneven plant population and results seed lose and germination problems. In case of manual and animal drawn planting, labors can suffer from back pain, difficult to get enough labor at peak periods to plant on time, difficult to maintain optimum spacing and uniform plant density have been happened. Because there is reduction in farm labor due to migration to urban areas and the labors are costly and scares.

Additional problems were:

- Lack of locally made two-wheel tractor drawn drill machine which can fulfill the needs of the farmers.
- Lack of draught oxen due to beef fattening and meat export competition.
- Animal drawn seeders need animal training for months`. This activity was tedious and risky for the operator.

Two-wheel tractor drawn seed drill machine alleviated the sowing operation problems. Therefore, the developed 2WT drawn seed drill alleviates draught oxen availability problems. Hence, two-wheel tractor drawn row seed drill technology needed for sowing operation. Besides, for small land holder farmers, using two-wheel tractors are suitable in terms of ease of operation in different land size and topography and also for multiple task operation.

1.3. Objective of the Study

1.3.1. General Objective

The main objective of this study is to design, fabricate and performance evaluation of two-wheel tractor drawn wheat seed six row seed drill machine.

1.3.2. Specific Objectives

i. To study the physical properties of selected varieties of wheat.
ii. To design and fabricate two-wheel tractors drawn wheat row seeder.
iii. To evaluate the performance of two-wheel tractor drawn wheat row seeder.

1.4. Significance of the study

It is known that our farmers are using animals for their agricultural operations. The cost of animals for operation is becoming higher as compare to other source of power. Therefore, there is good potential once they own the two-wheel tractor for their use for other agricultural operation like seed bed preparation, fertilizer application, intercultural in widely spaced row crops, harvesting of cereal crops under upland conditions, irrigation purpose, transport of farm produce and stationary farm operations.

The main benefit of using two-wheel tractor draw seeder is to give better yield of crop and saving of time. Wheat row seeder technology has a significant contribution to the development of wheat production by increase timeliness and better quality of work, hence putting more land into production; reduce drudgery in farming activities, thereby enhancing lifestyles; improve the timeliness and efficiency of farm operations, improve the quality and value of work, produce and processed products, provide employment (entrepreneurship) and sustainable rural livelihoods.

Considering small and fragmented plots of land availability and the shortage of draught oxen in the country today, it is necessary to shift and adopts appropriate engine powered wheat row seeder drawn to conduct on the technical and economical suitability for small and medium scale wheat growing areas farmer.

CHAPTER 2

LITERATURE REVIEW

The design and development of wheat seeder has been the subject of interest for many researchers from the beginning of the twentieth century for various seed crops. Most Ethiopian farmers have been using the method of broadcasting seeds and fertilizers and covering by maresha for a long time. Broadcasting is not suitable method of planting for different kinds of crops as it does not ensure desired plant population. The spacing will not be uniform and hinders intercultural practices, which contribute to lower yield.

In 1995, engineers from MARC designed the first row planter as an attachment to the indigenous maresha plow to enable farmers to plow and plant crops in rows (as opposed to broadcasting). The original row planter was first brought to the field in 1996 after a farmer from the Wolencheti Peasant Association had expressed interest in testing the technology after he had visited MARC to observe the new technologies being developed (Abera Adamo, 2001).

In the country there are federal and regional agricultural mechanization research centers. These centers have tried to work on the different agricultural operations by developing tools and implements which improve the farming practices. Melkassa Agricultural Research Center has an Agricultural Mechanization Research Process in its compound. This sector worked on different agricultural machinery operation. For several years, the center attempts to develop various types of animal and manual driven wheat row planter. Recently the center developed and popularized a six row animal drawn wheat planter. This planter designed to plant wheat at a seed rate of 125 kg/ha up to 150 kg/ha. It has 1.2 m width coverage within one pass. The application rate of this planter was about 6 hr/ha (Friew Kelemu et al., 2016).

Behera et al. (1995) expressed that Naveen seed cum fertilizer drill gave the best performance in terms of seed distribution efficiency of 91.38 per cent compared to five other seed cum fertilizer drills tested. The overall performance index was highest (0.88) in case of Naveen seed cum fertilizer drill. They recommended that Naveen seed cum fertilizer drill might be used for sowing of wheat, by changing the exposed length of the fluted roller with minor adjustments.

2.1. Physical Properties of Seeds

Mohsenin (1986) discussed on the physical properties of grains, fruits, seeds and vegetables might be considered either in bulk or individual units of material. It is important to have an accurate estimate of shapes, size, bulk density, angle of repose and other physical characteristics, which may be considered as engineering parameters for the design and development of the sewing machine. Determination of these properties is also essential for the development of optimum seed metering device in pneumatic planter and precision sowing machine to suit the grains.

Patil (2011) conducted the physical properties of various rice varieties. The sizes (mm) of the varieties of rice were 3.93, 3.45, 4.30, 3.48 3.08, 3.72 and 3.27 mm respectively. The surface areas of these varieties of rice were 58.98, 44.48, 66.79, 46.09, 37.02, 55.18 and 41.13 mm^2 respectively. Thousand grain mass (gm) of these varieties were 31.66, 23.57, 27.61, 22.71, 22.26, 21.55 and 21.45 gm respectively. The angle of repose (degree) of these varieties was 33.3, 27.3, 29.1, 32.5, 28.2, 30 and 33.3^0 respectively.

Dhiman et al. (1985) studied the advantages of a seed-cum-fertilizer drill over the traditional wheat sowing method infield experiments. These advantages included: uniform seed and fertilizer distribution in the field, quantities of seed and fertilizer and distance between rows could be adjusted, seed and fertilizer could be placed at the required depth with fertilizer below or beside the seed. Field capacity of 1 and 4 ha/day could be achieved by bullock and tractor power, respectively. The drill gave a 17 % increase in wheat yield for normal sowing times.

2.2. Design and Development of Seeders Review

Dhruw (2003) designed and fabricated two row bullocks drawn multi seed cum fertilizer drill machine. The machine has components of frame, ground wheel, power transmission unit, seed and fertilizer metering devices. The seed rate of wheat during laboratory testing was found to be 98.16 kg/ha. The effective field capacity of machine was found to be 0.052 ha/h and field efficiency was 75.36 %. The speed of operation was 1.72 km/h & the average draught required to pull the zero till seed drill was 62.51 kgf.

Anonymous (1997) considered and fabricated animal drawn seed cum fertilizer drill and three row bullock drawn equipment. The machine encountered 66 % labour and time saving and resulted 60

% economical in operation. The seed drill machine has a shoes type furrows opener and a fluted roller seed metering mechanism. It also increases 8 % yield as compared to the conventional method of sowing.

The manually-operated single row precision Wheat-Cum-Fertilizer planter was found to be important in affecting the mean seed spacing, mean emergence time, and the percentage of emergence ($p < 0.05$). The analysis of factors affecting seed spacing uniformity indicated that 81% which the best seed spacing uniformity results were obtained in the laboratory test. The field efficiency of 82 % was encountered which is close to the minimum requirements (Ashenafi Tariku, 2015).

Bansal et al. (1989) designed and fabricated the roller-type positive feed wheat seed metering mechanism seed drill consists of two rollers with 45˚ inclined ends assembled on a hexagonal shaft such that the gap width between the rollers can be adjusted. The rollers rotate inside a circular tube fitted below the hopper. The performance study of the seeder mechanism result showed between the rollers and the speed of their rotation had a good seeding rate for wheat.

Varshney et al. (1991) developed and fabricated two-wheel tractor operated seed cum fertilizer drill. The height of unit should not cause any inconvenience to the operator in using the controls and the seed cum fertilizer dill should be easily maneuverable. The hitching arrangement consists of power tiller hitch point, swivel pin and seed drill hitch bracket. Swivel action of hitch facilitate easy turning. The clearance is provided between the power tiller hitch point and hitch bracket take care of vertical misalignment of seed drill with the power tiller.

Ali et al. (1993) designed a drop type two to six row tractor drawn semi-automatic some seed drill with an adjustable row spacing of 30 to 90 cm has been developed and fabricated for rain feed farm operation. The seed drill opens the furrow, places seeds, fertilizer and cover them. A tractor operated and one person is required for its efficient and smooth operation. Its effective field capacity is 1.41 acre/h and it has a forward speed of 2 to 3 km/h depending upon soil type and seedbed preparation.

Pradhan and Ghosal. (2012) designed the design of cup in a cup feed metering mechanism. Cup feed metering mechanism is very important to enhance the performance of seed drill. Due to vibration and shock, the seed retention and release for these cups were poor. So the cups were modified to be cylindrical at the top and conical at the bottom giving the better performance.

Unadi and Gupta (1994) designed and fabricated seven row seed cum fertilizer drill with working width of 1.75 m. For each seed drill row, there was a seed hopper, a six fluted seed metering roller, a double disc furrow opener and also for each rows have fertilizer metering mechanism. The fertilizer furrow opener frame was fixed to the seed furrow opener frame to place the fertilizer 2 cm below the seed level and 5 cm to the side of the seed. The capacity of machine was about 0.3 ha/h at a forward speed 0.7 m/s and field efficiency of 72.2 percent. Damage due to metering mechanism was nil for dry Paddy and 0.6 per cent for soaked Paddy.

Gupta et al. (2004) developed and tested the seed cum fertilizer drilling attachment to the tractor driven cultivator. The field observations such as depth of seed and fertilizer placement, vertical distance between seed and fertilizer, effective field capacity, field efficiency, etc. were recorded. It was observed that the use of machine resulted in 20 to 30 per cent saving of seed and fertilizer.

Singh and Vatsa (2007) developed and evaluated a light weight power tiller operated seed drill for sowing wheat in hilly terraces where vertical interval between terraces was high. Field trials were conducted at the university farm and at the farmers' field to determine the performance of the seed drill in comparison to the traditional method of sowing. The machine was efficient and economical by the net saving of 78 % labour and 62 % cost of sowing over the traditional method.

Endrerud (1999) determined that the kinetic energy of seeds sliding and falling down a seed tube was influenced by tube diameter, inclination of the tube and radius of coulter bend in a simulation of a tube and coulter system. The kinetic coefficient of friction found by elevating the tube until the seed velocity was constant was only valid for tube inclinations up to 25˚. At higher tube inclinations, the coefficient of kinetic friction had to be replaced with a new apparent coefficient of friction with a higher value. Ideally, the delivery tube leading to the bend should be inclined at 60˚ to the horizontal plane.

The seed and fertilizer box was made trapezoidal for free flow of seeds and fertilizer without bridging. The cup feed mechanism was selected for metering Paddy seeds to avoid seed damage and hence does not affect germination (Patil, 2011)

2.3. Performance Evaluation

Khan et al. (1990) considered the importance of mechanization and sowing operation. There should be provision of changing seed rate from 6 to 300 kg/ha. Metering of the required seeding and fertilizer application rate should be reliable and early to adjust. There should be provision of changing row spacing between seeds and fertilizer deposition. Seeds should not be damaged by the seed metering and placement device. The inverted 'T' furrow openers are best suited for better seed germination. This drill can be used in both tilled and no-tilled filed conditions and for direct seeding of wheat on rice stubble fields.

Varshney et al. (1991) developed and tested a power tiller drawn seed-cum fertilizer drill in in the laboratory and in the field. In the field, the drill performance in sowing wheat was tested and compared with a 3 row animal-drawn seed-cum-fertilizer drill. Field capacity, plant emergence and yield were determined with respect with this drill. The capacity of the drill was 5.5 % higher than the animal drawn seed drill.

Kumar et al. (1986) reported performance of the seeding device for attachment with a three–tyne or a five-tyne animal drawn cultivator. It was provided with a manually operated single-fluted feed roller and a seed distributor for equal distribution of seeds in furrows. The machine was tested and found that the performance was good for wheat.

Gupta et al. (1999) designed a single row, multi-crop planter for use in hilly areas. It could sow a number of crops, such as maize and wheat. Field trials were conducted to determine performance. The effective field capacity of the machine was regarded as 0.064 ha/h with average field efficiency about 76%. The machine was efficient and economical compared with traditional sowing methods.

Varma and Tiwari (2001) designed and developed a power tiller operated till plant machine for enhanced wheat production. The unit contained a six-row seed drill, rotavator, fertilizer application unit and a seed covering cylindrical roller. Field performance of this machine was reported to be very good for seeding of wheat after rice in silt loam soil. Its average capacity was to the tune of 0.15 hectare per hour. The power tiller till plant machine gave about 23 per cent higher grain yield as compared to the conventional tractor farming system.

Jagvir et al. (2004) evaluated and compared the effect of using a no-till seed cum fertilizer drill on wheat crop yield, energy input, soil health and cost of operation in comparison with the conventional seed drill. The no-till seed drill resulted in a 17.09 % increase in yield, 83.22 % savings in energy and 80.34 % savings in the cost of production. Seeding with the help of seed drill is undoubtedly advantageous in wheat sowing.

Two-wheel tractors and their equipment can be owned by the farmers due to lower prices, and can be driven by any family member as they are simple and easy to handle. Therefore, small-scale farmers can shift from animal-powered farming to engine powered farming. Although the labor productivity of two-wheel tractors is lower than that of four-wheel tractors, it will be higher than that of animal-powered farming, and the farmer can enjoy speedy and timely completion of farm work with less labor. Farmers also may be assured that almost all farm work done by animal power can be carried out by two-wheel tractors, still making use of their technical knowledge of conventional animal-powered farming. Thus, two-wheel-tractors are useful mainly to small scale farms.

Two-wheel tractors are sources of power designed to perform most field operations. Due to the size of such tractors, they become an economic alternative for scale farming. In addition, two-wheel tractors are much more productive than animal traction and they require less time for attendance and preparation, giving the individual farmer more independence and contact with modern technology.

The yield of wheat was significantly higher than with seed drills and planters compared to the traditional method. Due to more fatigue, it was suggested that power operated equipment was better than manual operated method for sowing. Gogoi and Kalita (1995) conducted a field experiment of wheat crop was significantly higher with drilling in lines 0.92 t/ha than broadcasting 0.81 t/ha.

The performance of a seed drill depends upon uniformity of seed distribution in furrows planting operation. The fluted-roller seed meter is capable of metering seed uniformly and is commonly used as metering device for drilling of wheat but is negatively impacted by sudden release of seed batches (Maleki et al., 2006). Fluted meters have a cup on a rotating shaft and an opening gate. The result shows that changing the shaft speed, forward speed, or gate opening greatly hinder the accuracy of population and spacing of the seed. With the increase in seed size the variability was even greater. The popular and widely used horizontal seed metering is having several problems, including higher seed damage, missing and multiple drops (Singh, Singh and Saraswat, 2005).

Cup feed, inclined and vertical plate planters were developed and used further to reduce these losses. Furthermore, the research on these above mentioned aspects led to the development of the pneumatic seed-metering device (Shafii and Holmes, 1990; Guarella, Pellerano and Pascuzzi, 1996). This mechanism has several advantages over the previous mentioned metering system including metering irregular shaped seeds, preventing seed damage, efficient and cost effective besides spherical seeds.

CHAPTER 3

MATERIALS AND METHODS

3.1. Description of the Study Site

The study site was located 17 km away south of Adama at Melkassa Agricultural Research Center (MARC). It's found at an elevation of 1560 m above sea level with point locations of $8^0$24’ N latitude and $39^0$21’ E longitude. The average annual rainfall in the area is 768 mm, which is erratic and uneven in distribution. The site has a mean maximum temperature of 30.5^0C and mean minimum temperature of 12. 6^0C.Clay loam and sandy loam soil textures are the dominant soils of the area.

Fig: 3.1(a). Map of study site

Fabrication and testing of the prototype was carried out at Melkassa Agricultural Research Center (MARC) in agricultural mechanization research process workshop. Testing of the seeder was carried out at Melkassa research trial filed. The site has a suitable land and an irrigation system. The center has well-organized laboratory, technician and labor access for the fabrication and testing of the prototype.

3.2. Material Selection

Selection of proper materials for manufacturing various components of seed drill is very important. The farm machinery has to work under severe hazardous and heterogeneous environmental conditions. It should be adequately strong, stiff, and wear resistant and serves the purpose and operating requirements of the seed drill parts. It should be readily shaped, welded and easily machine able. The materials for construction of different components should be easily and locally available. Use of standard sizes of bearing with house, fasteners and chains would help in easy inter -changeability and replacement. It can be fabricated & repair by village artisans. The structure of power unit should be simple and this makes the operation, maintenance and repair easy. Before starting the construction of seed drills, the following factors are considered for appropriate selection of materials. Selection of metal must be such that it can be formed into desired shape. It is based on ductility characteristics of the metal. The materials for fabrication of various components were selected considering their function and strength requirements as given in Table: 3.1. The economic consideration and ease availability of materials also taken into account.

Table: 3.1. Materials used for fabrication of seed drill

No.	Parts	Material Used	Specification
1	Seed Hopper	Galvanized sheet metal	1000 x300 x2 mm sheet metal
2	Feed Cup Type Metering Devices	Galvanized pipe	Dia 18mm,length=30mm
3	Seed Tubes	Plastic	40mm dia.and 500mm length
5	Furrow Openers	Flat iron	400 x40 x4mm
6	Boots	Galvanized pipe	18mm dia.and 80mm length
7	Shaft for Seed Metering	Round mild steel	20mm dia and 1200mm length
8	Ground wheel	Flat Iron	500mm dia. and 4mm thick
9	Main Frame and Hitches	Square Pipe	1090x480x305 mm
10	Bicycle sprocket	Cast Iron	24 by 15 teeth
11	Chain	Cast iron	
12	Bolts and nut	Different sizes	
13	Standard finished items	Roller chains, sprockets bolts and nuts and spring washers	

3.3. Physical Properties of Some Selected Wheat Variety

The physical properties of seed are important factors for the design of two-wheel tractor drawn seed drill. The performance of seed metering mechanism in terms of picking, metering and dropping was influenced by the physical and engineering properties of seeds. Therefore, seed properties relevant to the design of seed drill were identified and determined. The most common wheat varieties of Hidase, Shorima ,Ogolicho ,Kekeba and Digelu seeds were selected for the study to determine the geometrical size of the seed based on their physical properties. Parameters like thousand grain mass, geometrical size, sphericity, surface area, bulk density and angle of repose were considered. The methods used for determination of physical properties are described as follows.

Twenty (20) grains were selected randomly from sample and dimensions were measured. Length, breadth and thickness of the seed were taken using digital vernier caliper. The mean and standard deviation of dimensions were calculated.

3.3.1. Size, Sphericity and Surface Area

The size sphericity and surface area were calculated using the following equations (Mohsenin, 1986).

Wheat Size$= \sqrt[3]{a \times b \times c}$ …...3.1

Surface area$= \frac{13}{11}(\mathrm{b} \times \mathrm{c}) \times \mathrm{a}$………………………………………………………… 3.2

Sphericity $= \frac{\text{wheat size} \times 100}{a}$ ………………………………………………….................... 3.3

Where,

a=Length (mm)

b=Breadth (mm)

c=Thickness (mm)

3.3.2. Bulk Density of Wheat Seed

The bulk density was found by taking wheat in a container of cylindrical shape. The volume of the container was found by measuring diameter and height for cylindrical container. The weight of the grain in the container is found separately. The bulk density was calculated. The three samples from each variety listed above on section 3.3 were taken and average bulk density was calculated (Varnmakasti et al., 2007)

$$\text{Bulk density} = \frac{\text{weight of sample}}{\text{volume occupied by the sample}} \quad \text{......} 3.4$$

Where,

Bulk density in kg/m^3

Weight of sample in kg

Volume of sample in m^3

3.3.3. Angle of Repose

The equipment used for measuring angle of repose consisted of a funnel with an adjustable throat opening mounted on a stand. The funnel was filled with seeds by keeping its adjustable throat closed. The throat was fully opened to allow free flow of seeds over and around the plate mounted beneath the funnel. At the end of process, a heap-cone of the seed was formed on the plate. From the heap-cone, base diameter and height of cone were measured. For free-flowing agricultural grains, angle repose is assumed to be approximately 28° (Andrew, 2007). For free-flowing grains the angle of repose can be assumed to be equal to that of the angle of internal friction (Andrew, 2007). The angle of repose was calculated using the equation, (Varnmakasti et al., 2007).

$$\theta = \tan^{-1}\left(\frac{2H}{D}\right) \quad \text{......} (3.5)$$

Where,

θ =is angle of repose, deg

H =is height of cone, mm

D =is base diameter of cone, mm

3.3.4. Thousand Grain Mass

In the laboratory thousand (1000) grains were selected randomly and then weighed on the sensitive weight balance to obtain the thousand grain mass in gram. The ten sample of each variety was weighed and mean thousand grain mass of each variety was found out.

a) Weight balance b) Digital vernier caliper d) Bulk density

Fig: 3.1b. Instrument used for determination of physical properties of wheat

3.4. Design Considerations

The two-wheel tractor drawn wheat seed drill designed as a functional and experimental unit. The design of machine components was based on the principles of operations and lab tests. It was compared with the conventional method, to give a correct shape in form of prototype. The mechanical design details were also given with due attention so that it gave adequate functional rigidity for the design of machine.

3.4.1. Functional Requirements of seed drill

The two-wheel tractor drawn seed drill should fulfill the following functional requirements:

- It should meter the seeds properly with respect to seed rate.
- It should place the seeds in the soil at a specified position i.e. maintain the spacing of plant to plant and depth.
- It should cover the seed.

3.4.2. Agronomic Requirement of seed drill

According to Navneet (2016), the agronomical requirements of wheat seed considered for design of wheat seed drill was 100 to 125 kg/ha seed rate and 20 cm. The agronomic requirements of seed drill are determined according to Hansen et al. (1962) and Bernacki (1972) are as follows:

- Metering of the required seed rate should be reliable and easy to adjust.
- Seeds should not be injured by the seed metering and placement devices. The amount of seed breakage must not exceed 0.5 %.
- Easy removal of the seed left in the box and easy access to clean the inside of the machine.
- Operating efficiency of the drill should not be dependent on its inclination when seeding undulated fields and should be independent to the travel speed.

Assumption Made (data obtained from informal communication with experts)

During designing of 2WT drawn wheat seed drill, the following assumptions were made.

- The seed drill should place seed at a depth of 3 to 5 cm below from ground level.
- The seed rate of seed drill ranged from 100 to 125 kg/ha.
- The row to row spacing should be 20 cm.
- The plant population obtain 2WT drawn wheat seed drill should be 377 plants/m^2

3.5. Design of Two-wheel Tractor Drawn Six Row Wheat Seed Drill

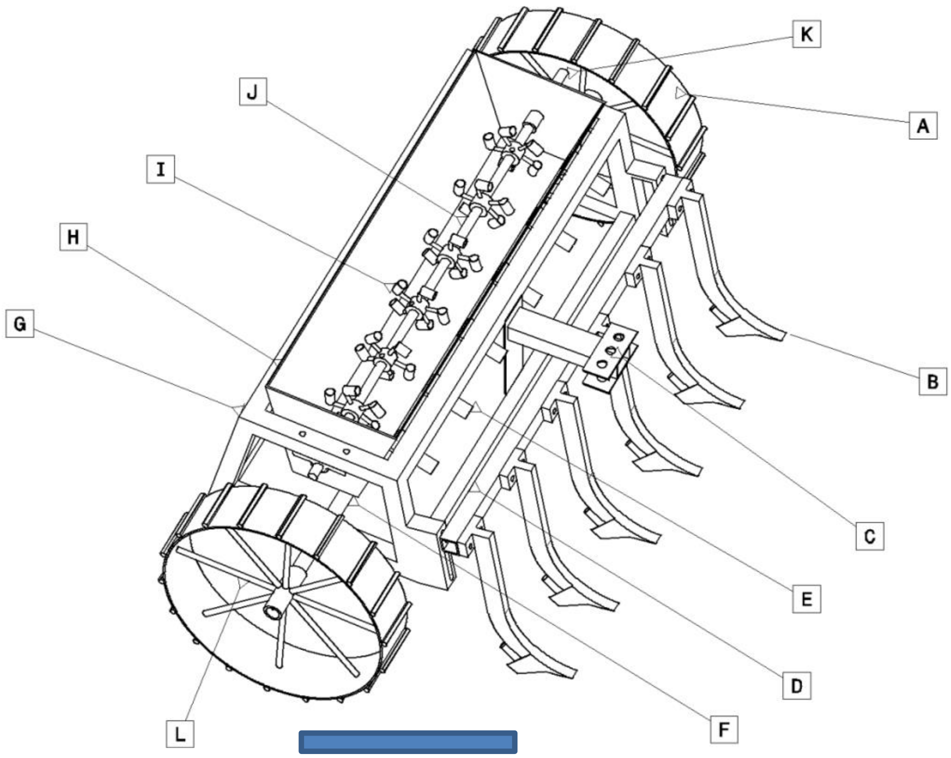
3.5.1. Description of Two-wheel Tractor Drawn Seed Drill

This session described the criteria for design of two-wheel tractor drawn cup type seed drill and their functional parts i.e. metering mechanism, seed hopper, furrow opener, round wheel and shafts. Based on the information collected from the research work under taken by various researchers and studying the existing wheat seed drills, a two-wheel tractor drawn seed drill was designed. The seed drill was designed to performs the following functions: (i) to carry the seeds, (ii) to open furrow to the uniform depth, (iii) to meter the seeds, (iv) to place the seed in furrows in an acceptable pattern, and (v) to cover the seeds and compact the soil around the seed. Based on the design of metering mechanism, a prototype seed drill was developed and evaluated under field conditions. The study was undertaken in the following sequence:

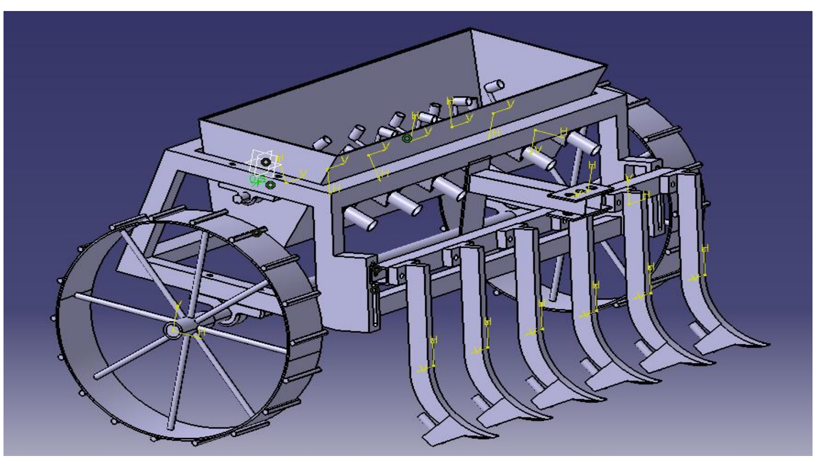
- Determination of physical engineering properties of wheat seeds influencing design value of seed metering mechanism.
- Design, fabrication and laboratory testing of seed metering mechanism.
- Performance evaluation of a seeder

The two-wheel tractor drawn seed drill machine consists of the following parts as shown in Fig: 3.2.

A. Ground drive wheel
B. Furrow openers and boot
C. Draw bar
D. Furrow opener frame
E. Seed outlet orifice
F. wheel shaft
G. Frame
H. Hopper
I. Cup type metering mechanism
J. Seed metering Shaft
K. Chain and Sprocket
L. Spoke



a) 2WT seed drill parts representation



b) 3D view

Fig: 3.2. Two-wheel tractor drawn seed drill assembly draw.

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

Draw bar horse power. (DBHP)=60 % of BHP. The available horsepower of a 2WT is 15 hp

Therefore,

DBHP=60% x15=9 hp---3.6

DBHP$= \frac{\text{draft(kg)} \times \text{speed(km/h)}}{270}$---3.7

The speed of sowing with the developed seed drill is in the range of 1.4 to 2.5 km/h. The two-wheel tractor can be operated at 1.5-2.5 km/h speed for sowing (Anonymous, 2013).

Let the speed of sowing wheat is 2.5 km/h.

Putting the values in the equation,

Draft (kg)$= \frac{270 \times \text{DBHP(hp)}}{\text{speed}}$---3.8

Draft (kg) =$\frac{270 \times 9\text{hp}}{2.5 \text{ km/h}}$

Draft =486 kg

According to CFMT, T1and Bundi, the draft requirement per meter width of wheat seed drill is 150kg/m.

Therefore, width of seed drill is $\frac{486 \text{ kg}}{150 \text{ kg/m}}$=3.24 m

But designing a 3.24 m width seed drill will have a buckling effect and will also create problem in transportation and handling. Therefore, it is better to design a seed drill having 6 furrow openers and 20cm spacing between furrow openers.

Working width of seed drill = 6 furrow opener x 20cm spacing

=120 cm

3.5.2. Weight Determination of seed drill parts and wheat using CATIA

3.5.2.1. A CATIA Software weight determination output of each components

The weight of each part designs was calculated using CATIA software. 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 it material type, the CATIA gave the output of the selected component area, volume and mass.

Table: 3.2. A CATIA software weight determination output analysis for each components of seed drill

Sr. No	Components	Quantity	Area (m^2)	Volume(m^3)	Density (kg/m^3)	Unit mass (kg)	Total mass (kg)
1	Seed hopper with outlets	1	1.75m^2	0.002m^3	7870 kg/m^3	16.63kg	16.66kg
2	Furrow opener frame	1	0.31m^2	0.00061m^3	7870 kg/m^3	4.81kg	4.81kg
3	Furrow opener frame	6	0.08m^2	4.048e-004m^3	7870 kg/m^3	3.186kg	19.11kg
4	Main frame	1	1.14m^2	0.0024m^3	7870 kg/m^3	18.73kg	18.73kg
5	Draw bar(link)	1	0.16m^2	1.848e-004m^3	7870 kg/m^3	1.455kg	1.455kg
6	Combined metering parts	6	0.03m^2	4.286e-005m^3	7870 kg/m^3	0.337kg	2.02kg
7	Metering shaft	1	0.87m^2	3.755e-004m^3	7870 kg/m^3	2.956kg	2.95kg
8	Large bearings	2	0.02m^2	1.658e-004m^3	7860 kg/m^3	1.303kg	2.6kg
9	Small bearing	2	0.02m^2	7.67e-005m^3	7860 kg/m^3	0.603kg	1.21kg
10	Furrow cover		0.21m^2	0.001m^3	7870 kg/m^3	8.552kg	8.552kg
11	Hopper cover	1	0.69m^2	0.001m^3	1200 kg/m^3	1.632kg	1.632kg
							79.75kg
	Weight of parts lay on the wheel shaft including 2% for bolts ,nuts and other						81.35kg
12	Wheel shaft	1	0.15m^2	0.001m^3	7870kg_m3	8.5kg	8.5kg
13	Wheels	2	0.57m^2	0.001m^3	7870kg_m3	9.956kg	19.91kg
	Total weight including wheels and wheel shaft					=	99.61kg

Total mass of all components which lay on the wheel shaft was 79.75kg.

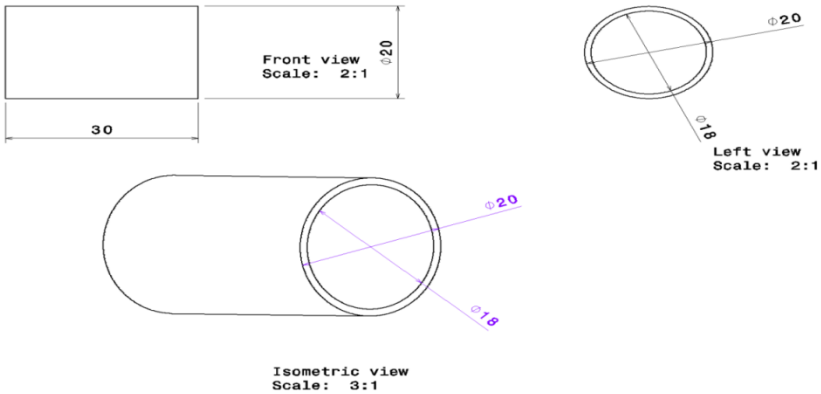
$W = m \times g$

$W = 81.35 \text{ kg} \times 9.81 \text{ m/s}^2$

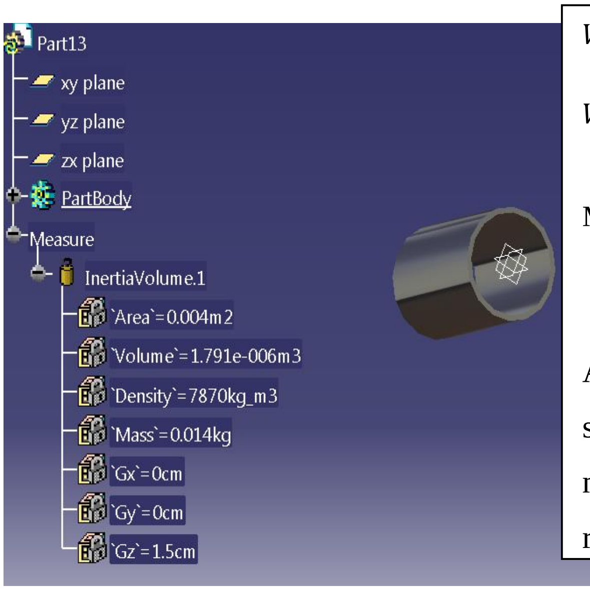
$= 798.04 \text{ N}$

Where, W=weight, m=total mass of the parts, g= acceleration due to gravity, 9.81 m/s^2

Sample weight calculation



A.CATIA calculation



b) manual calculation

$V = \pi(R^2 - r^2)\ x\ l$-- (3.9)

$V = \pi(0.01^2 - 0.009^2) * 0.03$

$= 1.79 \text{ x } 10^{-6}$

Mass=v x mass density-- (3.10)

$= 1.79 \text{ x } 10^{-6} \text{ x } 7870 \text{kg/m}^3$

=0.0141kg

As we see the manual calculation of the sample looks very similar with the software result. The software was needed material type and dimensions with drawing to give exact result.

Fig: 3.3. CATIA weight calculation result

3.5.2.2. Grain Weight Determination

Seeds weight in the hoppers was determined from the net volume of the hopper and bulk density of the seeds. The net volume of hopper is the maximum volume of hopper which able to hold the seed at full load, and the mass of grain was estimated using the following equations (ITSI-SU, 2011).

$M_G = V_S \times \rho_G$………………………………………………………………………….3.11

$V_S = \frac{Sr}{n \times \rho_G}$ ………………………………………………………………………………………3.12

Assume n=8 number of refill was assumed for a hectare.

$$Vs = \frac{112\ \text{Kg/ha}}{8 \times 1118\ \text{Kg/m}^3}$$

$V_S = 0.012 m^3 = 1.2 \times 10^4 cm^3$

Hence, $M_G = 0.012\ m^3 \times 1118\ \text{Kg/m}^3$

$M_G = 13.41$ Kg

The weight of grain was estimated using the following equations (Gat, Uri, 1988).

$W_G = M_G \times g$…………………………………………………………………………………………3.13

But, $g = 9.81 m/s^2$

$W_G = 13.41\ kg \times 9.81 m/s^2$

$W_G = 131.6 N$

Where: -

V_S = Volume of seed/ grain

S_r = Seed rate

ρ_b = Bulk density of grain, $1118 kg/m^3$

n = Number of refill

M_G = Mass of grain

W_G=Weight of grain.

Total weight of a 2WT drawn wheat seed drill was becoming:

W_T = Weight of parts + weight of grain.

W_T =797.99 N + 131.6 N

W_T = 930 N

This weight includes all weights which lay on the wheel shaft. This weight was required to determine the wheel shaft diameter.

3.5.3. Seed Hopper Design

Seed hopper was designed and fabricated to cover the full width of the machine and is located above the main frame. The cross-section of seed hopper is trapezoidal to ensure proper flow of seeds without bridging. For designing the seed hopper, the average bulk density of wheat seeds 770.5 kg/m^3 and the angle of repose 26.6^0 were considered. As the angle of repose of wheat seed was 26.6^0, therefore, the angle of the hopper side wall was kept as 62°. This angle facilitated the smooth flow of wheat seed under the gravitational force towards the metering mechanism. The location of seed hopper was 550 mm above the ground. This height of hopper helps to reduce the angle of inclination of seed delivery tubes. The design of seed hopper is as presented below in Fig 3.4.

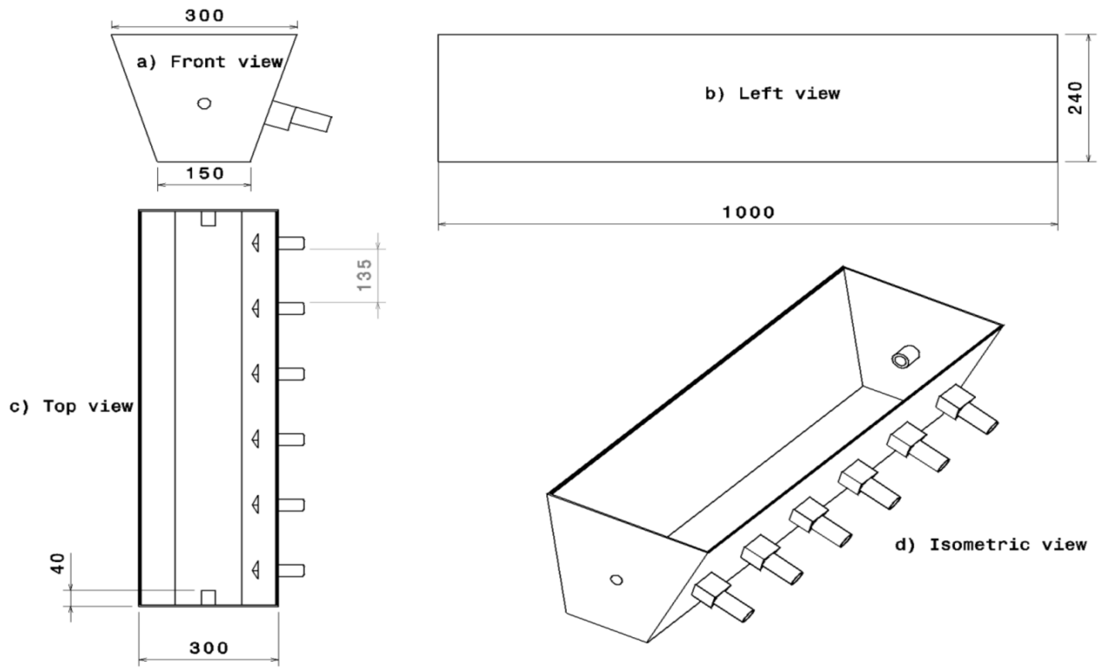


Fig: 3.4. Seed hopper drawing (all dimensions are in millimeter)

The factors considered in the design for determination of hopper capacity are bulk density and seed rate of wheat, which are 1118 kg/$m^3$and 100 to125 kg/ha respectively (data gathered informal communication with experts).

Then theoretically the Volume of seed box was calculated by the following formula (Sharma and Mukesh, 2010).

$$v_b = 1.1 \times v_s \text{ --3.14}$$

$$v_s = \frac{w_s}{\gamma_s} \text{ --3.15}$$

Where:

v_b= Volume of seed box, cm^3

v_s= Volume of seed, cm^3

w_s=weight of seed in the hopper, gm

γ_s=bulk density of seed, g/cm^3

Let 14 kg of wheat seed is filled in the box at a time.

Therefore; $v_b = 1.1 \times \frac{14 \text{ kg} \times 1000 \text{ g/kg}}{1.118 \text{ g/cm}^3} = 13{,}774.59 cm^3$

Isometric drawing of the hopper is given in Fig: 3.5. The assumed trapezoidal shape hopper size dimensions are,

- Top Width =30cm
- Bottom width, a =15cm
- Height, h= 24cm
- Length, l=100cm

Actual volume of the seed hopper was determined on the basis of the assumed dimensions determined above.

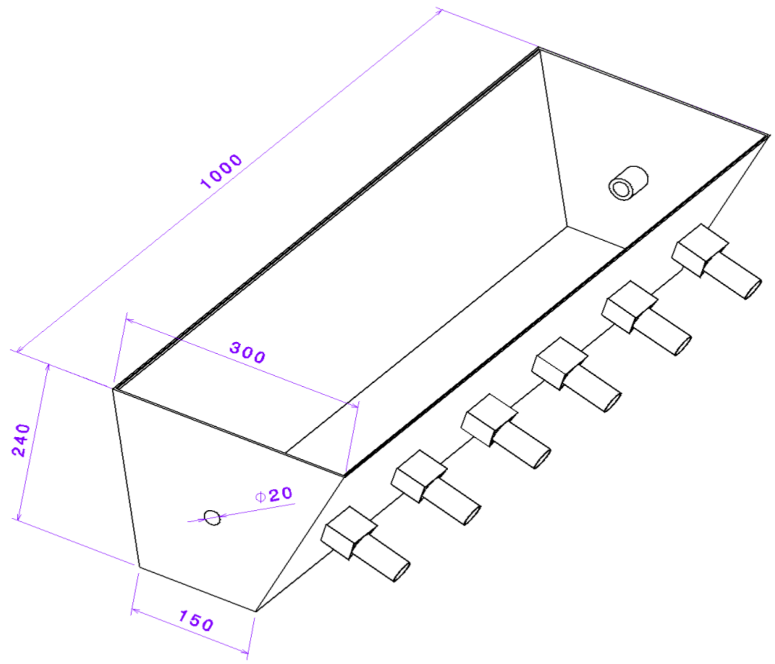


Fig: 3.5. Hopper isometric view drawing

Using the above dimension of the box, its volume was calculated by the following formula (Sharma and Mukesh, 2010).

$V_b = \frac{1}{2}(2 \times a + 2 \times l) \times h \times b$ ---3.16

$V_b = \frac{1}{2}(2 \times 15 + 2 \times 100) \times 24 \times 30$

$V_b = 82800 cm^3$

Since the designed volume of seed hopper 82,800 cm^3, this is much larger than the theoretical volume of 13774.59 cm3. Therefore, the designed dimensions of the hopper were correct. The seed hopper was fabricated with dimension of 1000mm length x 300mm top width x 240 mm of height. The seed hopper was made of 2mm sheet metal (Fig:3.5). The cup type metering mechanism was fixed in the hopper driven shaft. The metering mechanism driven shaft was put through seed hopper and power to drive metering mechanism was taken from ground wheel. The Seed delivery channel was provided in seed hopper for receive the seed from cup and delivered to seed delivery tube.

3.5.4. Design of Metering Mechanism

The metering mechanism helps to meter the seed with its uniform rate and spacing. The metering mechanism maintains the seed rate of a 2WT drawn seed drill. The cup feed mechanism was chosen and selected for metering seeds to avoid seed damage and hence does not affect germination (Patil ,2011) .The design of metering mechanism is given below.

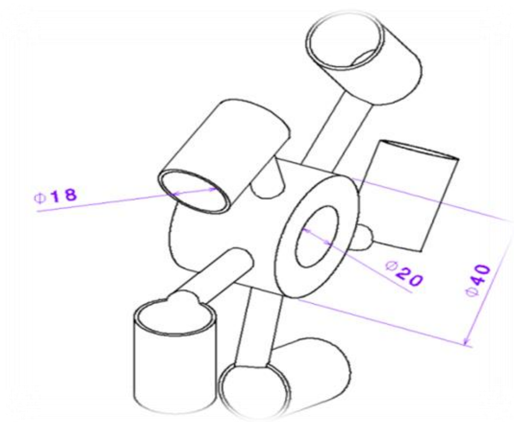


Fig: 3.6. Cup type metering mechanism part drawing.

While designing the seed metering mechanism, prime consideration was given to use simple design not causes any mechanical damage, low cost and easy to fabricate. The cup feed mechanism does not damage seeds and meters the seeds in proper placement. It consists of series of cups were fitted on the rim of a circular bushing that dips into a shallow pool of seed, lifting a few seeds at a time and carrying them over a top.

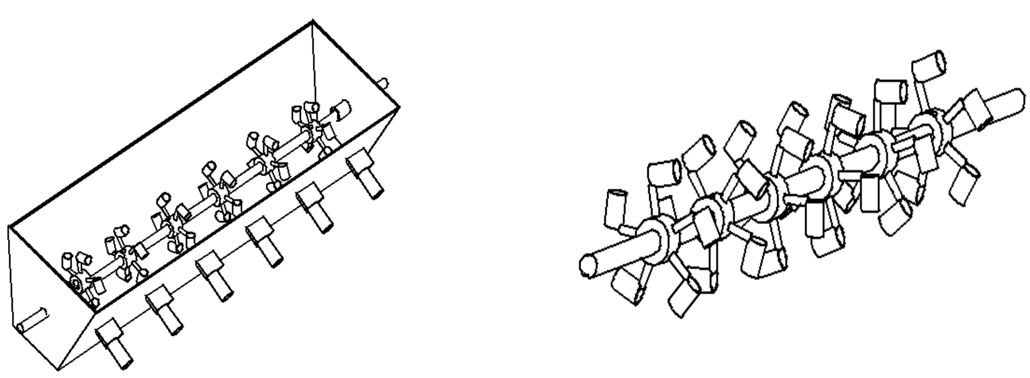


Fig: 3.7. Series of cup feed metering mechanism.

Pradhan and Ghosal (2012) designed proper design of cup in cup feed metering mechanism and they got a very good performance of seed drill. The cups seed holding capacity are easily adjusted to maintain the seed rate. There was no restricted gate area though which the seed must pass, eliminating a possible source of seed damage. The design methods given by Sharma and Mukesh (2010) for seed metering mechanism was adopted.

Number of cups on the seed shaft periphery was calculated by,

$$n = \frac{\pi \times D}{i \times X} \quad \text{.....................................} 3.17$$

Where,

n = Number of cups on the feed shaft

D = Ground wheel diameter, 50cm

x = Required seed to seed spacing, 20cm

i = Gear ratio (1.6:1)

$$n = \frac{\pi \times 0.5}{1.6 \times 0.2} = 5 \text{ cups}$$

Hence, 5 numbers of cups were provided on seed metering shaft perephery.

The distance between consecutive cups (t) found using the following formula (Sharma and Mukesh, 2010).

The spacing between consecutive cups (t) is:

$$t = \frac{\pi \times d_g}{n} \quad \text{.....................................} 3.12$$

$$t = \pi \text{ x } 20\text{mm}/5 = 12.56\text{mm}$$

Where: -

t = distance between consecutive cups

d_g = Diameter of seed metering shaft

n = number of cups on the feed shaft

The seed metering cup was made of circular pipe. Five cups were placed along the periphery of seed roller shaft periphery along 12.56 mm or 72^0 spacing. When the seed roller shaft plate rotates, seeds in the seed hopper fill in the cups. Cups were arranged on the periphery are used for metering wheat seeds as shown in Fig: 3.7. On seed roller shaft per row 5 cups were designed. Cup dimensions were selected on the basis of physical properties of wheat seeds, Cup diameter was 18 mm. The cup depth is 4.5 mm and about 10 to15 seeds picked up in each cup.

3.5.4.1. Rate of Seed Collected along 100 m Length of a Single Furrow Opener

Using a relation of Sharma and Mukesh (2010) to determine the Rate of seed for a 100m length per furrow opener was calculated as by the following expression

$$S_R = \frac{A_S}{N_R} \quad \text{………………………………3.18}$$

The recommended range of seed rate in the Ethiopia context was from 100 to 125 kg/ha (data gathered from informal communication with agronomist / researcher). For the design purpose, assume that an average seed rate of 112 kg/ha.

$$N_R = \frac{W_R}{R_S} \quad \text{………………………………3.19}$$

$$S_R = \frac{A_S}{(W_R/R_S)} \qquad = \frac{112 \text{ Kg}}{(100 \text{ m}/0.2\text{m})}$$

S_R=224 gm/row

Where: -

W_R=Width of a hectare of land, 100m (assuming the area has a square shape)

R_S= Row spacing, 20cm

N_R=Number of rows in a hectare of land for wheat crop

A_S=Amount of seed for a hectare of land, 112 kg/ha

S_R= Amount of seed per 100m row, gm/row

3.5.4.2. Seed Rate Collected by Cups for a Single Revolution of a Wheel

By using Sharma and Mukesh (2010) the Seed rate collected by cups for one revolution of wheels was expression as.

$$SR_{PR} = \frac{\pi \times \text{D1} \times S_R}{100} \quad \text{………………………………3.20}$$

$$SR_{PR} = \frac{\pi \times 0.2 \text{ m} \times 224 \text{ gm/row}}{100 \text{ m}}$$

SR_{PR} =1.41gm/rev

Where: -

SR_{PR} = Seed rate per revolution of the cups, gm/rev

D_1=Diameter of the seed shaft, 0.2m

S_R = Rate of seed per 100m length, gm/row

3.5.4.3. Mass of Seeds Collected by Each Cup

According to Ashebir Tesgaye (2015) the mass of seeds per cups was calculated using the following expression.

$$M_C = \frac{S_{RPR}}{n} \qquad \text{3.21}$$

$$M_C = \frac{1.41\ \mathrm{gm/rev}}{5\ \mathrm{cups/rev}}$$

M_C = 0.28gm/cups

Where: -

M_C = Mass of seeds per cup, gm/cup

m = Number of cups per a revolution (5 cups)

S_{RPR} = Seed rate per revolution, gm/rev

3.5.4.4. Collecting capacity (Volume) of cups

According to Ashebir Tesgaye (2015) the volume of cups was calculated using the following expression.

$$vc = \frac{M_C}{\rho_f} \qquad \text{3.22}$$

$$V_C = \frac{0.28\ \mathrm{gm/cups}}{1.118 \times 10^6\ \mathrm{gm/m3}}$$

$V_C = 2.59 \times 10^{-7}\ m^3$

V_C= 0.259 cm^3

Where: -

ρ_f = bulk density of wheat seed, (1118kg/m^3 = 1.118 x 10^6 gm/m^3)

M_C = Mass of seeds per cup, gm/cup

V_C = Volume of seed cup, cm^3

Thus the minimum depth of seed cup to accommodate 0.28 gm of wheat seed during planting would be found by using the following formula (Sharma and Mukesh, 2010).

$$V_C = \frac{\pi \times {D_c}^2 \times d_c}{4} \qquad 3.23$$

$$d_c = \frac{4 \times V_C}{\pi \times D^2{}_C} \qquad 3.24$$

$$d_c = \frac{4 \times 0.259 cm^3}{\pi \times (1.8\ cm)^2} \qquad 3.25$$

d_c = 0.107cm =1.07 mm

Where: -

V_C = Volume of cup, cm^3

D_C = Diameter of cups, cm

d_C = Design depth of cups, cm

The calculated design depth of cups was 1mm but, the minimum depth of seed cup used in this design was 4.55mm because, the largest dimension of wheat seed measured in laboratory test was 3.07mm.

Individual cup metering mechanism was used on each furrow opener and fitted in the seed hopper. The combined six seed metering mechanism are mounted on common shaft and power is transmitted from ground wheel through chain sprocket to the metering mechanism shaft. The cup picks up seed in group as it rotates and place into delivery channel of metering mechanism and through feed tube to furrow opener.

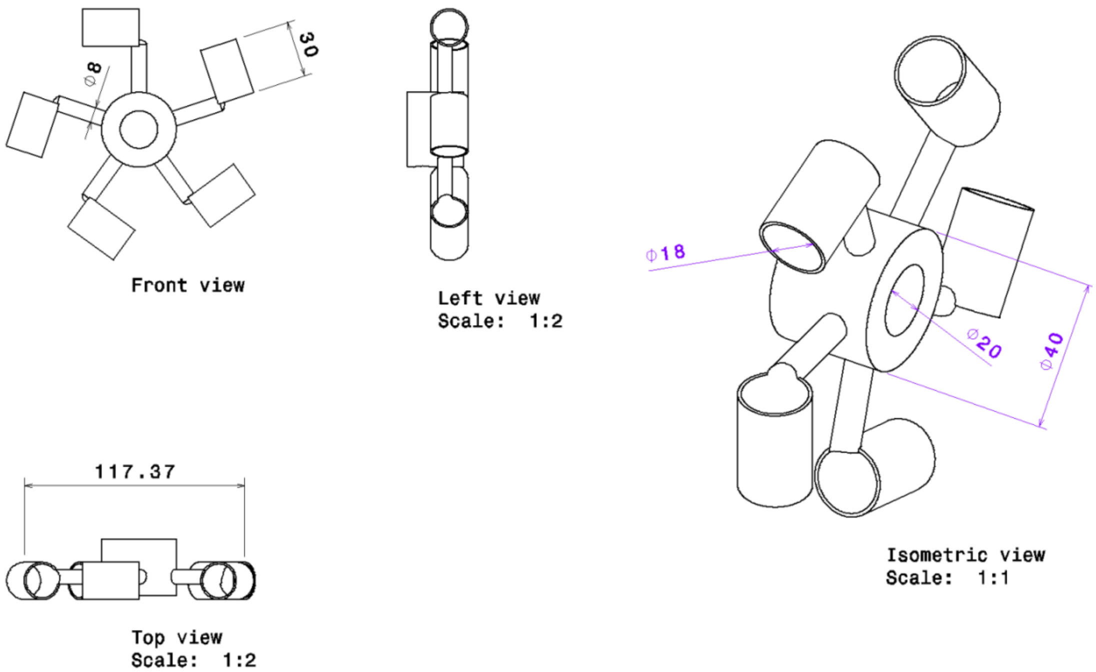


Fig: 3.8. Seed metering mechanism

3.5.5. Design of Shovel Type Furrow Openers

Furrow openers are used to place the seed at the desired depth with minimum dispersion. The depth of placement at which seed is placed in the soil depends on the crop variety and the soil moisture level. Furrow openers should form a neat groove in the moist zone of soil with minimum soil disturbance to avoid mixing the top dry soil with the underlying moist soil at seed level. For seed placement, shoe type furrow openers were used as uniform depth of sowing was required. The furrow opener assembly consists of shank and share.

A shovel type furrow opener fitted at one end of the shank and the other end of the shank was attached with frame by nuts and bolts for adjusting depth. The depth of sowing varies from 3 cm to5 cm. The thickness, width and length of the shank were decided on the assumption given below.

Let,

b x h = Shank cross-section area, mm^2

L = length of breast of shovel

The draft force exerted on the opener was determined using the following equation (Kurtz et al. 1984).

$D = k_o \times n \times w \times d$ …..3.26

D –draft force, kg

K_o-Specific Soil Resistance – 0.25 kg/cm^2, when the condition is very heavy

w– Width of opener, cm

d– Depth of opener, cm

n--number of furrow openers

Table: 3.3. Specific soil resistances at a depth of 15 cm

S.No.	Soil type	Specific resistance, kg/cm^2.
1.	Light	0.12
2.	Medium	0.15
3.	Heavy	0.20
4.	Very heavy	0.25

Source: Dubey, 2003

Assume and take the values of the cross sections of the furrow opener

Width = 3cm , depth=5cm , no. of furrow =6

D= ko x n x w x d

D= 0.25kg/cm^2 x 6 x 3cmx 5cm

D=22.5kgf

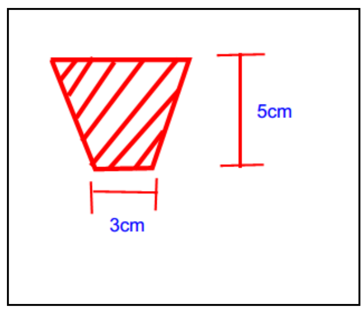


Fig: 3.9. Tyne soil cutting section

Take factor of safety – 3 (Assumed)

D= 3 x 22.5kgf = 67.5 Kgf

D= 67.5 x 9.81==662.17N (Total draft of the seed drill)

D=67.5kgf/6=11.25kgf=110.36 N (For each furrow opener)

It is assumed that the draft force on the furrow opener is 11.2kgf/furrow and acting at a height of h/3 from the bottom of the furrow opener (Sharma, 2010).

Distance of draft application of furrow opener shank (Sharma and Mukesh, 2010) is given as,

a = h/3   where, h is total length of furrow opener.

a = 38cm/ 3 = 12.66cm

Moment arm length = (h-a) = (38 – 12.66) = 25.34≈25cm=250mm

Maximum bending moment for a cantilever length of 25 cm length is:

Bending moment (M) = draft (kgf) x Moment arm length (cm)

M= 11.25kgf x 25cm = 281.25 kgf-cm=281.25 x 10 m/s^2 x 10 mm=28125N-mm

Take factor of safty =2

Maximum bending moment =2 x 281.25kgf= 562.5kgf=56250N-mm

I used flat mild steel for the design of furrow opener and f_b=56N/mm^2 was used for mild steel (senger, 2002).

Section modules of each furrow opener or tyne (Z)=M_b/f_b $= \frac{56250\text{N}-\text{mm}}{56\text{N}/\text{mm2}}$ = 1004.5mm^3

Take, b=40mm size flat M.S

t=thickness of flat M.S

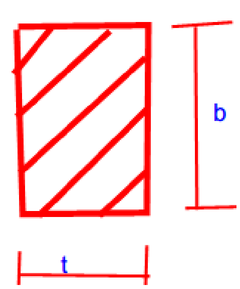


Fig: 3.10. Tyne section size of M.S

Section modulus of the furrow opener, was calculated by using the formula (Seely et al. 1995) and (Timoshenko et al. 1964).

$$Z = \frac{1}{6} \text{ x t xb}^2 \quad \text{..3.27}$$

$$1004.5\text{mm}^3 = \frac{1}{6}\text{t x}(40\text{mm})^2$$

t=3.8mm ≈ 4mm

So, M.S flat tyne of 40mm x 4mm size was quite safe and also I used a 40mm X 4 mm size M.S because the size was available in the market

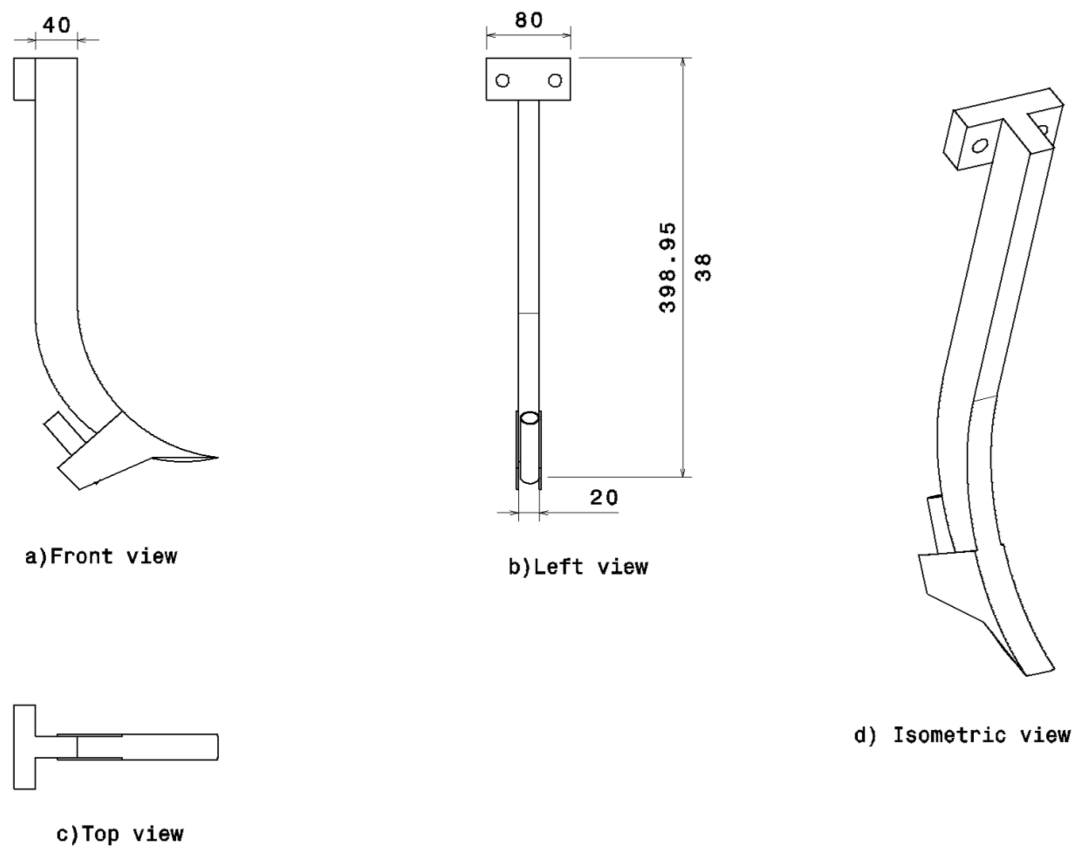


Fig: 3.11. Design of shovel type furrow opener (dimensions are in millimeter)

3.5.6. Frame

Frame of planter has to be rigid and strong as all parts are mounted on it. The furrow openers, driving wheel unit, handle, hitch attachment and hopper were attached to the frame. The frame of the seed drill has 6 rows and made from Mild steel (M.S) square pipe trapezoidal shape of 40 mm × 40 mm × 4 mm square cross section. All components of developed seed drill were assembled and fitted on the frame (Fig: 3.10).

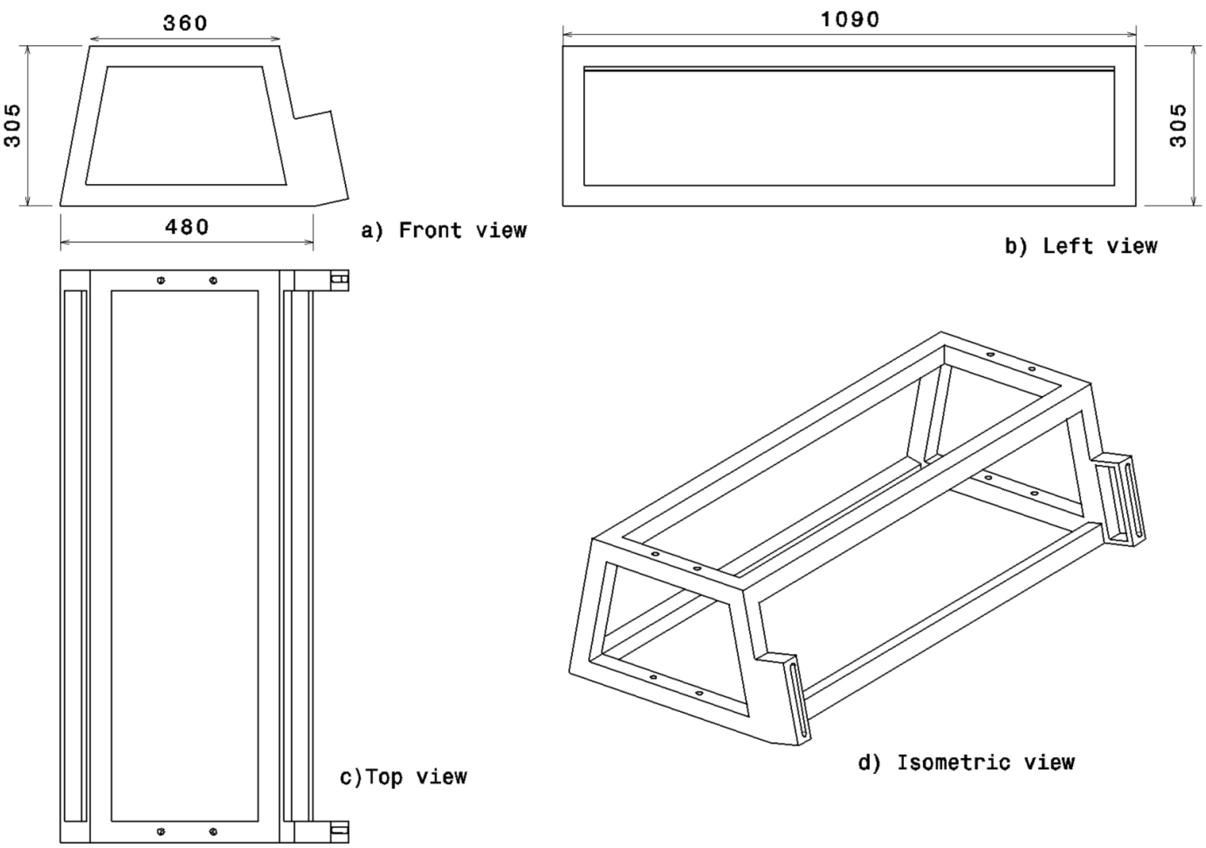


Fig: 3.12. Main frame (all dimensions are in millimeter)

3.5.7. Force Estimation

Estimation of the force required to pull the seed drill

According to (Sharma and Mukesh, 2010).

$F_F = (C_R + i) \times W$ …………………………………………………………………………..3.28

$C_R = \sqrt{\frac{Z}{WD}}$……………………………………………………………………………………...3.29

Therefore, $F_F = (\sqrt{\frac{Z}{W_d}} + i) \times W$ …..3.30

$F_F = (\sqrt{\frac{2cm}{50cm}} + 0.05) \times 465N,$ Total weight is 930N (Refer section 3.5.2.2)

$F_F = 116.25N$

Where: -

F_F= Force required to pull the seed drill, N

C_R = Coefficient of rolling resistance

Z =Maximum tolerable wheel sinkage depth=2cm (Ashebir Tesgaye, 2015)

W_D= Wheel diameter, 50cm

W = weight on each wheel, 930/2 = 465N

i = Gradient of the ground, let i=5% (assuming as flat ground)

3.5.8. Drive Wheel Design of 2WT Drawn Seed Drill

The function of wheel is to provide traction and supply power to metering mechanism. The type of drive wheel to be used on drill depends on the ground conditions. Verma (1986) suggested diameter of power transmission wheels as 22.5 to 40 cm for bullock driven planter and 40 to 60 cm for tractor driven planter. In order to design the diameter of power transmission wheel was taken 50 cm for this work. A 4mm Flat sheet metal wheel was made and used because of their low cost, low maintenance and long life. The selected sheet metal maximum shear strength, τ_{max}, is 80 MPa (see fig: 3.13) so; the wheels are designed to be a traction wheel to enhance movement on loose soils. To develop better traction or grip on the soil, small 12mm lugs rod metal was provided on the periphery of the wheel. The lugs rod metal of 12 mm in diameter and 12cm in length were welded at an angle greater than zero to reduce slip, wear, vibrations and rolling resistance. The dimension of drive wheel was assumed as determined as given below.

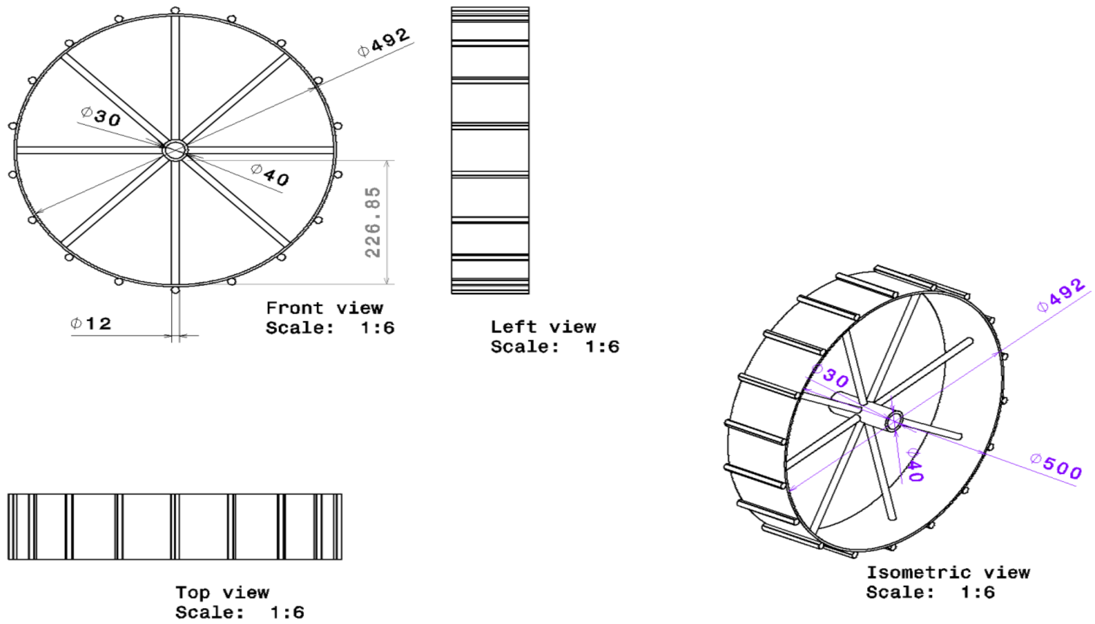


Fig: 3.13. Details of drive wheel of 2WT operated wheat seeder (dimensions are in mm)

3.5.9. 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 and J Nisbett (2011).

D =1.50d + 25.00 mm---3.31

D= 1.50 x 30mm +25mm

D = 70 mm

Where:

D = outside diameter of hub, mm

d = diameter of shaft, mm

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

$L = \frac{\pi \times d}{2}$---3.32

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

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

3.5.10. Wheel Strength

The wheel of the seed drill was made from a 4mm thick sheet metal. the maximum shear strength of sheet metal is 80MPa. The lugs were provided on outer periphery of drive wheel. Considering the lug diameter of 12 mm, 18 lugs were provided. The hub diameter was selected as 70 mm. The hub was made hollow from shaft for inserting axle shaft. Round iron of size 450×12 mm were used as spokes for drive wheel. The wheel was placed on wheel axle of 30 mm diameter.

Shear stress on the wheel

According to Richard and J Nisbett (2011) estimates the shear stress analysis formula as given below

$$\tau = \frac{T}{2A_m \times t_s} = \frac{T}{2\pi r^2 t_s} = \frac{T}{2\pi t_s (r - 0.5 t_s)^2} \quad \text{......3.33}$$

$$T = F_F \times \left(\frac{W_d}{2}\right) \quad \text{......3.34}$$

$$T = 116.25\text{N} \times \left(\frac{0.50\ m}{2}\right)$$

T =29.06Nm

$$\tau = \frac{29.06\ \text{Nm}}{2 \text{x}\ \pi\ \text{x}\ 0.004\ \text{x}\ [0.25\text{m} - (0.5 \times 0.004\text{m})]^2}$$

$\tau = 18{,}799.76$ Pa

$\tau = 18.8$ kpa

Where:

T= the torque produced by the wheel, 29.06Nm

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

r= the outer radius of the wheel, 0.25m

t_s=the thickness of the wall/wheel, 0.004m

τ= Shear stress on the wheel, Kpa

F_F= Force required to drive the seed drill, N

W_d=wheel diameter

Comparing the maximum allowable shear stress of the metal, $18.8kpa << \tau_{max}$,, 80 MPa, the wheel was safe from failure for sowing wheat.

3.5.11. 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).

$$b = \sqrt{\left(\frac{2F}{\pi L}\right) \times \left(\frac{(1-(v_1)^2)}{E_1} + \frac{(1-(v_2)^2)}{E_2}\right) / \left(\frac{1}{d_1} + \frac{1}{d_2}\right)} \quad \text{.........3.35}$$

$$P_{max} = \left(\frac{2F}{\pi bL}\right) \quad \text{.........3.36}$$

The stress created has an elliptical distribution across the contact zone (fig 3.14).

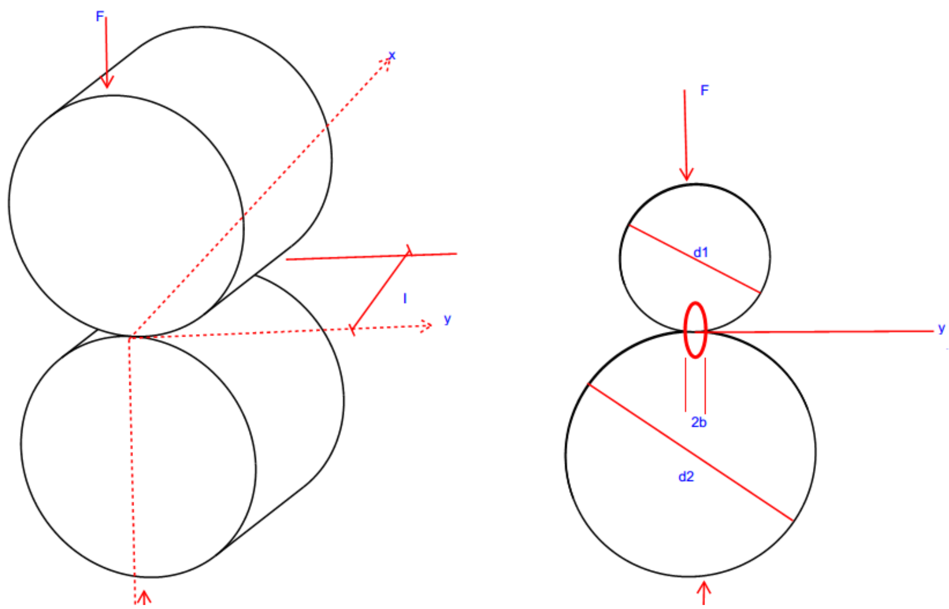


Fig: 3.14. The contact stress between two cylinders

The above equations apply to a cylinder and a plane surface ($d= \infty$) contact (Richard et.al, 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, ∞ (Ashebir Tesegaye, 2015).

F = the force exerted by the wheel, 465N (calculated)

L = Contact length/width of the wheel with the ground, 0.12m

P_{min}= The minimum cone-index of the ground at 0-10cm depth and 13% moisture content in wet basis, 550KPa (Ashebir Tesegaye,2015).

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

v_2= Poisson ratio of sandy 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 soil, 10-50MPa (Norton, 2005).

Two-wheel tractor drawn Seed drill wheel width in the design was 12cm 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),

$$b = \sqrt{\left(\frac{2\times465\mathrm{N}}{\pi\times0.12\mathrm{m}}\right)\times\left(\frac{(1-(0.3)^2)}{200\times10^9\mathrm{P_a}}+\frac{(1-(0.4)^2)}{50\times10^6\mathrm{P_a}}\right)/\left(\frac{1}{0.50\mathrm{m}}+\frac{1}{\infty\mathrm{m}}\right)}$$

$b = 4.81 \times 10^{-3}$m

Calculating maximum pressure (Pmax),

$$P_{max}=\left(\frac{2\times465\mathrm{N}}{\pi\times4.81\times10-3\mathrm{m}\times0.12\mathrm{m}}\right) = 512.936\times10^3\,P_a$$

Pmax = 512.94KP$_a$<<<<<<<< P_{min} =550kpa,

$P_{max}<P_{min}$,

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

3.5.12. Chain and Sprocket

Locally available chain and sprocket were selected for transmitting power from ground wheel shaft to shaft of metering mechanism. The chains are mostly used to transmit motion and power from one shaft to another. The power required to operate the seed metering mechanism was transmitted from the drive wheel through chain drive. Since the power transmitted in the seed drill is very low, the smallest size available chain, i.e. bicycle chain was used for 2WT operated seed drill. For power transmission, 15 teeth a medium size sprocket was fitted on drive wheel. Another sprocket of 24 teeth size was used for driving shaft so that the transmission ratio of approximately 1.5:1 was maintained.

3.5.12.1. Calculation of Chain Length

The chain length is given suggested by (Sadhu Singh, 1988). The length of chain was calculated as number of links x chain pitch i.e.

$L = m \times p$ ……………………………………………………………………………………...3.37

Where,

m = number of chain links

p = chain pitch, mm

But, Number of chain links

$m = 2C_d + \frac{(N_1+N_2)}{2} + \left(\frac{(N_2-N_1)}{2\pi c_d}\right)^2$ ……………………………………………………………3.38

Where:

Cd = Centre distance, mm

P = Chain pitch, mm.

N1 = Number of teeth of pinion.

N2 = Number of teeth of sprocket.

Putting the values in eqn.3.38

m = $2 \times 35.7 + \frac{(15+24)}{2} + (\frac{(24-15)}{2\pi x 35.7})^2$ =90.9 pitches

The nearest even number of pitches for the chain is 90 pitches

Therefore, the corrected length of chain is L= 90 x 6.35 mm = 571.5 mm=57.15 m

Exact center to center distance between the sprockets expressed by(Sadhu Singh, 1988).

C= (e +$\sqrt{e2 - 8m}$) ×P/4 ……………………………………………….............................3.39

But,

e = $L_p - \frac{(N_1+N_2)}{2}$…...3.40

e = $90 - \frac{(15+24)}{2}$ = 70.50

m = $(\frac{(N_2-N_1)}{2\pi})^2$ …………………………………………………………….......................3.41

m = $(\frac{(24-15)}{2\pi})^2$ = 2.051

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

C= (70.50 +$\sqrt{(70.50\ )^2 - 8(2.051)}$) $\times \frac{6.35}{4}$

C = 223.6mm

C ≈224mm

3.5.12.2. Chain Velocity

Average chain velocity (kurtz *et al.* 1984).

$V_{av} = \frac{n \times p \times rpm}{376}$...3.42

$V_{av} = \frac{24 \times 0.25in \times 26.54\ rev/min}{376}$ = 0.423 m/sec

Where:

n= the driving sprocket no. of teeth, 24

rpm = maximum revolution of the driving sprocket, 2.5 km/hr = 26.54 rev/min

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

V_{av}= Average chain velocity, m/sec

3.5.12.3. Chain Force

The chain force is calculated by using (Sharma and Mukesh, 2010).

The total load (force) on the driving side of the chain is given by

$F_T = F + F_c + F_f$ 3.43

Where: - F_T= the total force, N

F = the force due to power transmission, N

F_f= Frictional force, N

F_c= Centrifugal force on the chain, N

$F = \frac{P}{V_{av}}$ 3.44

$$F = \frac{80.7\text{w}}{0.423\ \text{m/sec}}$$

F =190.78N

$F_C = \frac{W \times (V_{av})^2}{g}$ 3.45

$$F_C = \frac{6.60 \times (0.423\ )^2}{9.81\text{m/s2}}$$

$F_C = 0.12$N

$F_f = W \times kf \times Cc$ 3.46

F_f = 6.60N/m×1×0.277m

F_f = 1.83N

Where,

Cc = Nominal center to center distance between the sprockets, 0.277 m

P= Power at the seed drill wheel/ power to be transmitted, 80.7w = 0.08hp

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

W = Weight per meter of the chain, 6.60N/m(measured)

g = Gravitational acceleration, 9.81m/s^2(Norton, 2005).

Thus,

F_T = 190.78 N+ 0.12 N + 1.83 N

F_T = 192.73 N

According to ANSI standard, the minimum tensile strength of the chain is 3470N. To avoid breakage or failure of the chain, the safety factor should be more than one. Checking safety factor, S_f (Sharma and Mukesh, 2010).

$$S_f = \frac{\text{Tensile strength}}{F_T} \qquad \text{……3.47}$$

$S_f = \frac{3470N}{192.73N}$ = 18, the value is greater than unity. It is safe.

3.5.13. Shaft Design

The shaft is expected to be subjected to both torsion and bending moment. This may be due to the rotational effect of the shaft during the forward motion of the machine.

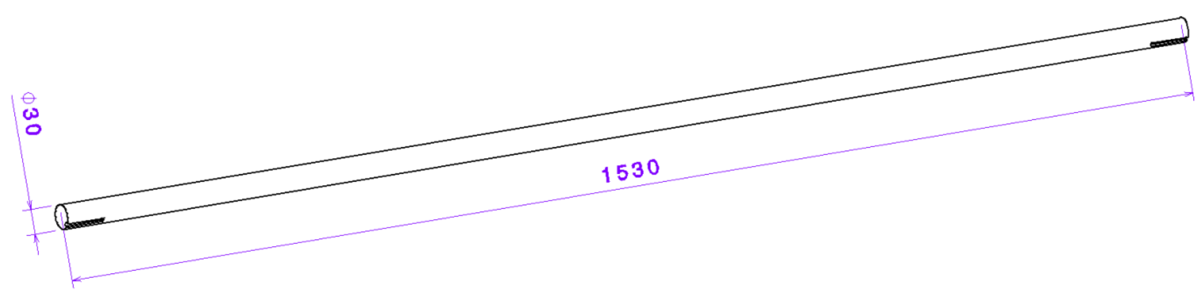


Fig: 3.15. Shaft isometric view

According to Theodre (1985) the failure of the shaft is likely to be in shear stress and the design considered this fact. Therefore, the diameter of the shaft considering this shear stress is given by:

$$d = \sqrt[3]{\frac{16}{\pi \times S_S}[(K_b \times M_b)^2 + (K_t \times M_t)^2} \quad \ldots\ldots 3.48$$

Where,

d = Diameter of the shaft; mm

M_t= Tensional moment; Nm

M_b= Bending moment; Nm

Ss= Allowable stress; MN/m

K_b= Combined shock and fatigue factor applied to bending moment;

K_t= Combined shock and fatigue factor applied to tensional moment;

For rotating shafts, when load is suddenly applied with minor shock, Khurmi and Gupta (2005) recommended that values of K_b = 1.2 to 2.0 and K_t = 1.0 to 1.50 to be used. Furthermore, it was noted that for shaft without key way, the allowable stress (Ss) must be 55 MN/square, and for the shaft with key way the allowable stress (Ss) should not exceed 40 MN/square.

Tensional moment (Mt) on the shaft was calculated using formula: (Ryder, 1989).

$$M_t = \frac{P \times 60}{2\pi \times N} \quad \ldots\ldots 3.49$$

$$P = V \times F \quad \ldots\ldots 3.50$$

Where, P= power required to pull a machine

F_F= Force required to drive the planter, N

V=forward speed, 2.5km/h

P = 0.442 m / s × 116.25 N

P = 51.4 W

Therefore,

$$M_t = \frac{51.4 \text{ W x } 60}{2\pi\ x\ 26.54\text{rpm}}$$

M_t = 18.49 Nm

Where:

P = Power required to drive the machine; w

N = Speed of the shaft, 26.54 rpm

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

$M_b = \sqrt{(M_V)^2 + (M_h)^2}$……………………………………………………….…………………..…3.51

Where: M_b = Maximum bending moment, Nm

M_v = Vertical bending momentum=66.91Nm from bending moment diagram

M_h = Horizontal bending momentum =44.46 Nm from bending moment diagram

$M_b = \sqrt{(66.91\text{Nm})^2 + (44.46\text{Nm})^2}$

Mb=80 Nm

Using equation (3.50)

$d = \sqrt[3]{\frac{16}{\pi \times S_S}[(K_b \times M_b)^2 + (K_t} \times M_t)^2$ and S_S=55 MN/square K_b=2, K_t=1.5

$$d^3 = \frac{16}{\pi \text{ x } 55 \text{ x } 10^6} \times[(2 \text{ x } 80)^2 + (1.5 \text{ x } 18.49)^2]^{1/2}$$

d=0.024813m

d=25mm

Therefore, I used the standard shaft type of 30 mm for the design.

a) Vertical Forces Distribution On the Shaft

The vertical load diagram on the driven wheel shaft is as shown below

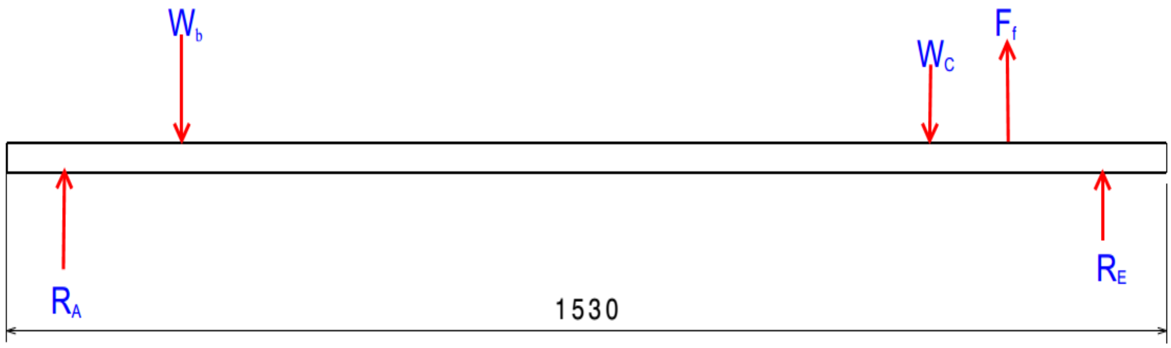


Fig: 3.16. Vertical forces distribution on the shaft

Total weight of the drill which lay on the shaft was 930 N refer section 3.5.2.2

W_B=W_C = 465 N ……………. are Half of total weights

R_A and R_E are support forces at the wheel.

To know the unknown forces of R_A and R_B, we use equilibrium equations methods.

$\sum M_A = 0$

RE x 1.47 m +192.73 N x 1.35 – 465 N x 0.21 m – 465 N x 1.27 m=0

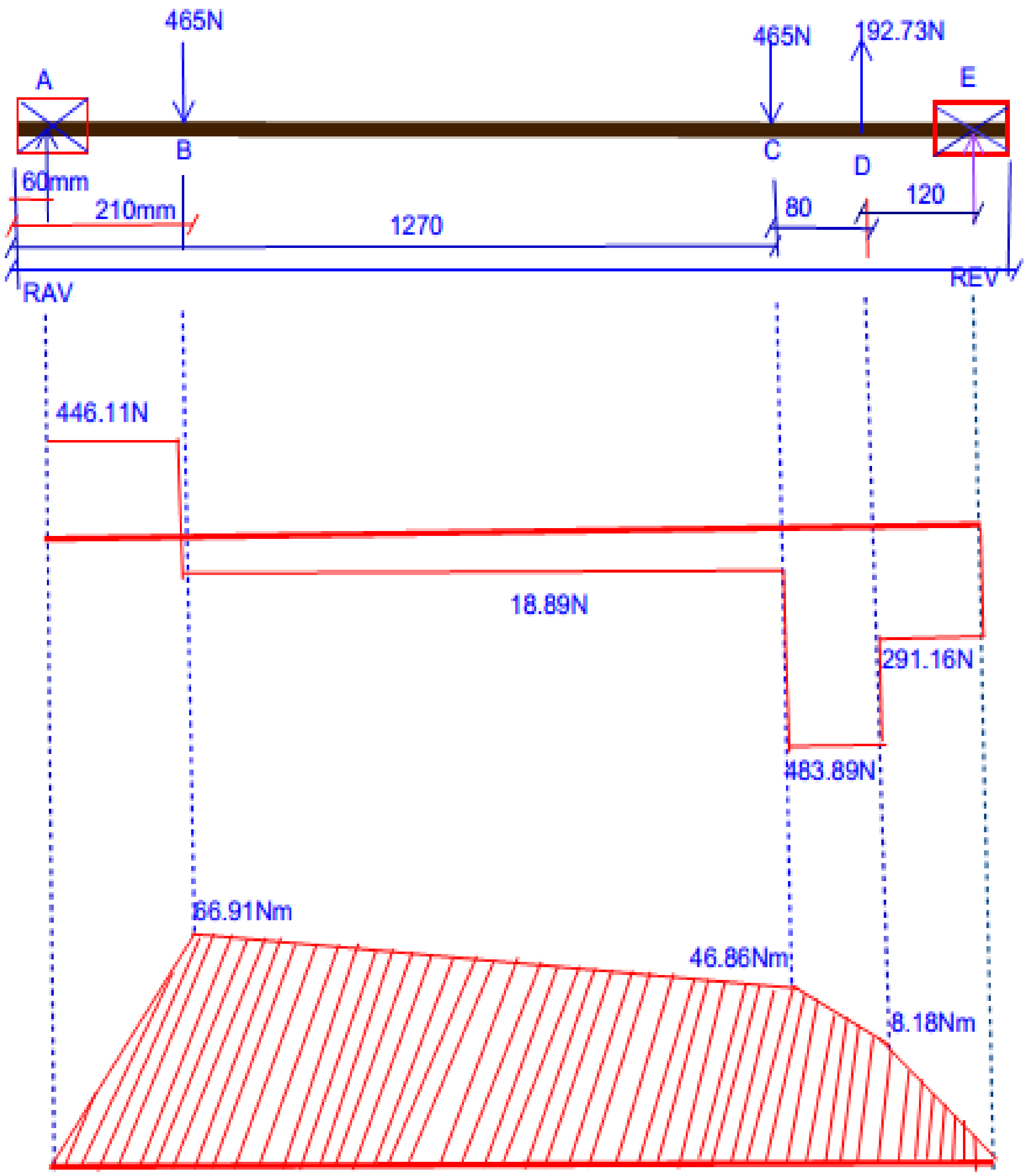
R_E=291.16 N

The summation of all forces gave the unknown value.

R_A+291.16 N + 192.73 N -465 N -465 N =0

R_A=446.11 N

b) Vertical Shear Force and Bending Moment Distribution



The maximum moment is 66.9 Nm

Fig: 3.17. Shear force and bending moment diagram representation

c) Horizontal Force Distribution On the Shaft

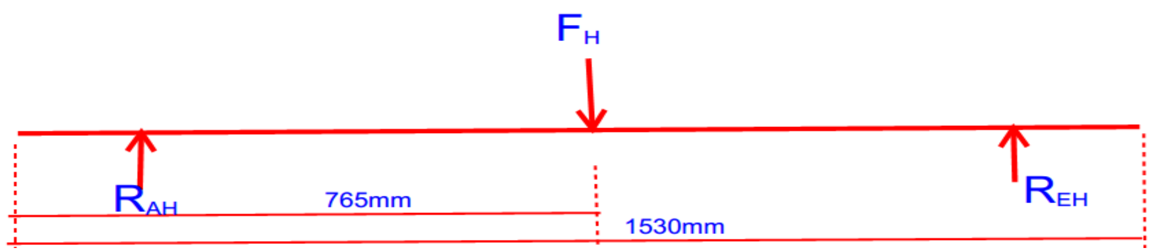


Fig: 3.18. horizontal force distributions

$$\sum F_H = 0$$

$R_{EH} + R_{AH}$=116.25N, where F_H=116.25N

$R_{EH}=R_{AH}$=116.25N/2

$R_{EH}=R_{AH}$=58.125N

d) Horizontal Shear Force and Bending Moment Distribution

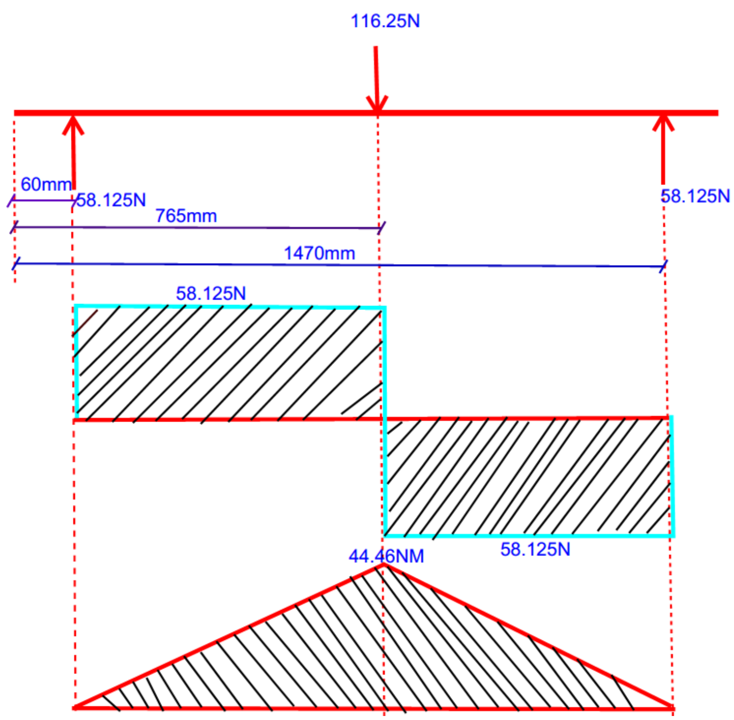


Fig: 3.19. Horizontal shear force and bending moment diagram

3.6. Fabrication of Two-wheel Tractor Drawn Seed Drill

CATIA drawing (fig.3.20) was used for the design, and fabrication of the two-wheel tractor drawn seed drill. The different component of the planter mentioned in previously described subheadings was fabricated and assembled in the workshop of MARC.

The frame of the seed drill was made of MS angle iron of 40 x 40 x 4 mm with a square cross section. The size of frame was 1090 mm length and 480mm width. The seed box was fabricated from M.S sheet metal. All the sides of sheet metal were marked and cut, then joined by welding. Triangular holes were provided at the front side of the hopper for the flow of seeds the cross section of the box was trapezoidal. The bottom of seed box was flat. Cup feed type of metering mechanism was used and made from 18mm diameter metal pipe.

Two sprockets, one having 15 teeth and other having 24 teeth were used to transmit the power from ground wheel to the seed metering device. Small sprocket was mounted on feed shaft whereas sprocket of 24 teeth was mounted on axle of ground wheel. Suitable bushes were prepared on the lathe machine to mount the sprocket with the help of bolt on feed shaft and ground wheel axle. The sprockets were directly connected by standard pitch roller chain which could be fixed at any position.

The ground wheel was made up of 50 x 4mm M.S flat metal having length 157 cm by bending in circular shape. It consists of 8 spokes made from MS rod of 12 mm dia. and 450 mm long. These spokes were welded with the inner periphery of the rim and at the outer periphery of the hub. The hub was made of MS tube of 47mm length and with 70 mm outer and30 mm inner dia. Nut and bolt type locking arrangement was provided on wheel hub for its mounting on the shaft.

The square box draw bar mechanism was designed taking into consideration the way it is hitched to the two-wheel tractor and easy maneuverability. The box was made out of hollow square bar of 70 mm sides. This square box slide forward and backward inside the hollow square section of two-wheel tractor. In the square box, circular holes (12mm) at a regular interval have been made for attachment of two-wheel tractor seed drill.

Fig: 3.20. Fabrication pictures of 2WT seed drill

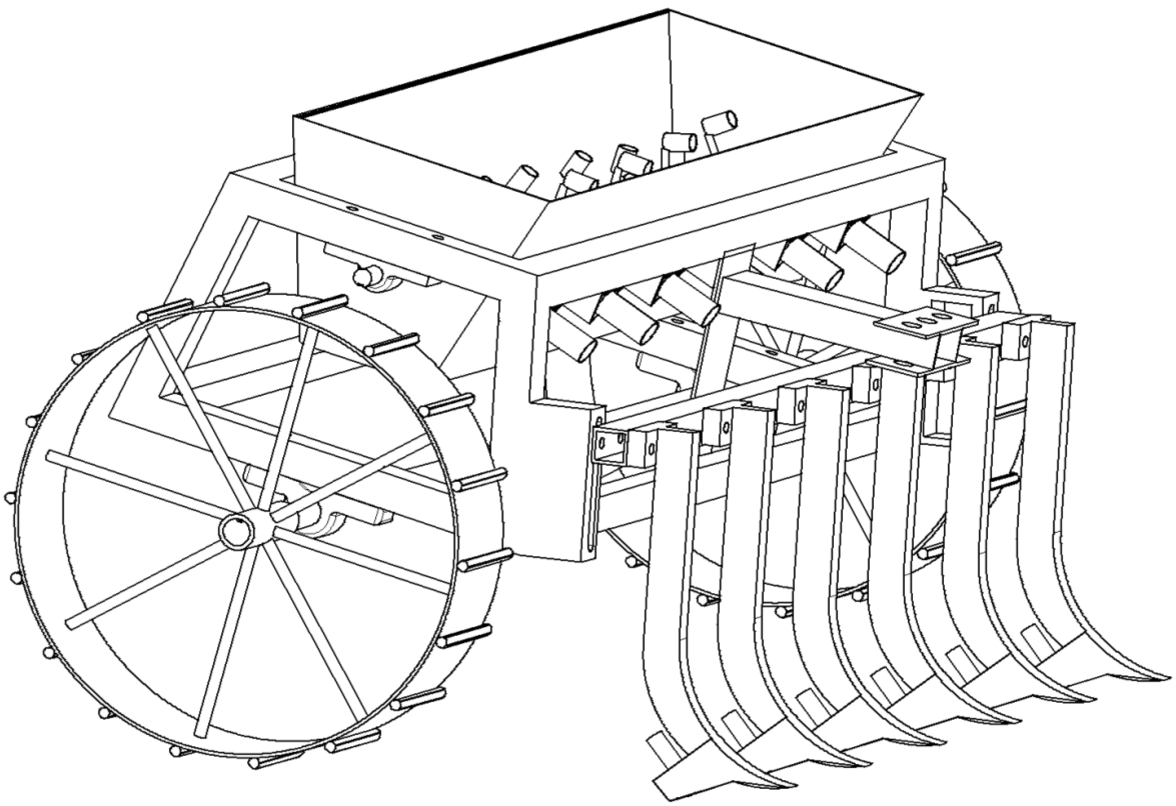


Fig: 3.21. Isometric drawing of 2WT seed drill

3.7. Performance Evaluation of 2WT Drawn Wheat Seed Drill

The Developed walking tractor drawn wheat seed drill was tested in the laboratory and Field. It was tested on the Melkassa Agricultural Research Center agronomy farm for its performance evaluation. The machine was operated in the laboratory for metering test and for checking uniformity of seeding.

3.7.1. Laboratory Test

This test encompassed the calibration of the seeder and seed germination test. It was done to determine the seed dropping rate obtainable at different settings and the variation among furrow openers when the seed drill was stationary. The step by step procedure for calibration was as follows:

Calibration Procedure

- The two-wheel tractor drawn seed drill was tested on flat and leveled surface and ground wheel was supported drill to rotate freely.
- The plastic bags were placed and hinged at the outlet tip of the hopper for collecting seed.
- Two-wheel tractor drawn seed drill ground wheel was marked at one point with a marker and rotated for 20 revolutions at three different speeds i.e.1.4, 2.0 and 2.5 km/h. The area covered by the two-wheel tractor drawn seed drill was calculated theoretically. The quantity of seed collected in the plastic bags was measured for each furrow opener.

3.7.1.1. Seed Damage Test (%)

This test was carried out to determine the percentage of seed damage during calibration. For each tests, one kilogram of seed from each bag was taken and was labeled with test number and opener. The seeds which were used for metering was tested before and after the test to ensure its invisible (germination) damage and the samples of the seed obtained after passing though the metering was tested to ensure its visible damage. Then, Count the number of seeds with visible damage. The percentage of damaged seed was calculated using (Rangapara J., 2014).

$$\text{Damage percentage} = \frac{\text{weight of damaged seed}}{\text{total weight of seeds collected}} \times 100 \text{------------------------------------} 3.52$$

3.7.1.2. Uniformity of Seeding

This test was carried out to determine seed uniformity among furrow openers during drilling. The test was carried out in the laboratory by using 10 m long grease polishing (sticky) mat. A sticky layer of grease was applied to the belt to facilitate the proper embedding of seeds without any displacement. The seed tube was kept as close to the mat layer as possible. The drill was operated and the number of seeds dropped for each meter of mat layer length for recommended seed rate was observed. The steps were repeated at least three times and average of readings was taken.

3.7.1.3. Seed Emergence Test

This test was conducted to find visible damage to seed if any by metering mechanism. The seeds before and after metering mechanism test carried out for germination. Take the Petri dish and it covers with blotting paper and add some amount of water for wetness. Take the 100 grains from seed metering mechanism and place on wetted blotting paper. After 7 days seed was germinated.

The germinated seed were counted and percentage of seed germination was found out. The percentage of germination was calculated using (Rangapara, 2014).

$$\text{Percent germination} = \frac{\text{number of seeds germinated}}{\text{number of seeds planted}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.53$$

3.7.2 Field Test

The seed drill was attached to the two-wheel tractor. Three different operating speeds were found out at different gear and throttle position. The 1.4 km/h, 2 km/h and 2.5 km/h speed was selected for sowing operation and effect of different operating speed on seed rate, seed uniformity and seed damage was observed. The best results' giving operating speed was chosen for sowing wheat varieties.

The drill was operated in a well prepared seed bed. The drill was operated in the field by side to center method of operation. At each speed three replications were taken. The sowing of different variety of wheat was carried out in field. For each variety, the seed drill was calibrated, theoretical field capacity, effective field capacity, field efficiency and power requirement was found out.

3.7.2.1. Field Description

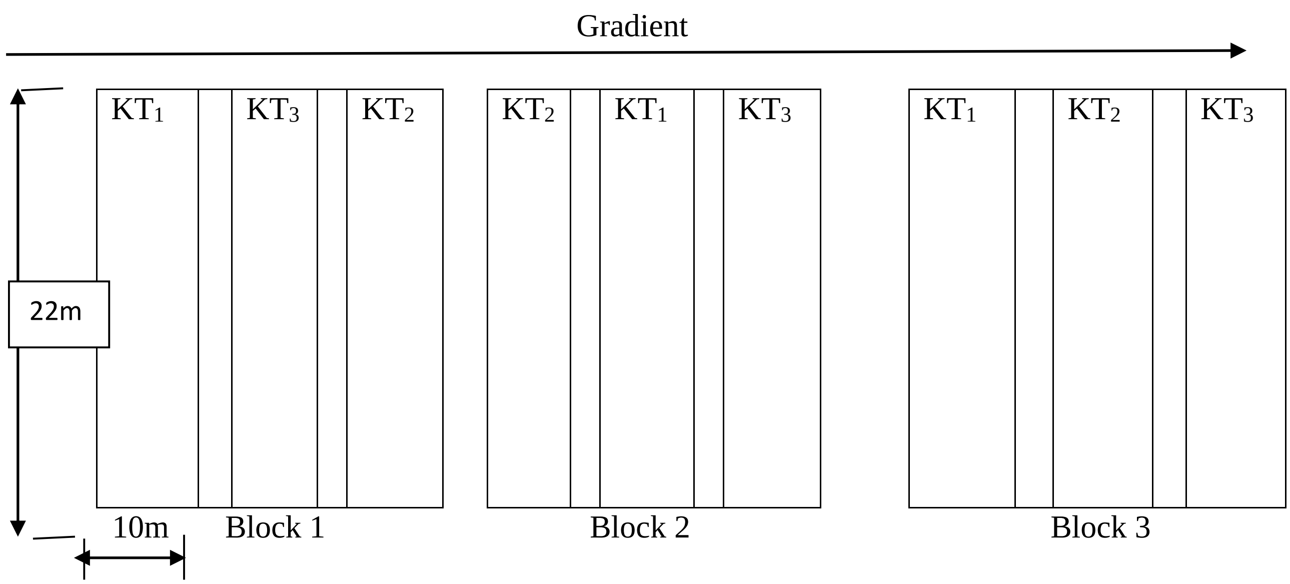
The condition of field was affected on seed germination and crop yield. Therefore, field condition is important for sowing operation. The following parameters were determined before sowing.

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

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 of developed walking tractor drawn seed drill in the field.

Experimental Design

The Experiments were conducted in the field with Kekeba wheat variety (K) and three forward speed of two-wheel tractor of 1.4 km/h, 2 km/h and 2.5 km/h with forming three treatments. Each treatment replicated three times with using Randomized Complete Block Design (RCBD). RCBD is one of the most widely used experimental designs in agricultural research. The design is especially suited for field experiments where the number of treatments is not large and the experiments area has a predictable productivity gradient. The primary distinguishing features of the RCBD is the presence of blocks of equal size, each of which contains all the treatments. Therefore, the design has three treatments which is not large and the experimental area has a predictable productivity gradient



Where, K-Kekeba wheat variety

T-Treatment with index number 1, 2, 3

Fig: 3.22. RCBD plot size sample representation

The well prepared experimental field was divided into 9 plots each having an area of 220 m^2 (i.e. 10 m x 22 m plot size). Various adjustments in the machine were done to get required seed depth and plant to plant distance before testing. After preparing the field plot, the fertilizer was broadcasted on the plot as per the recommended rate of 100kg/ha (data gathered by informal communication from research expert). The seed drill was prepared and adjusted for sowing operation. The two-wheel tractor drawn seed drill was adjusted at 1.4 km/h, 2 km/h and 2.5 km/h throttle position and sowing operation was carried out for each randomly selected plot samples by taking a performance evaluation data. The data was analyzed in result and discussion section.

3.7.2.2. Soil Parameters

3.7.2.2.1. Moisture Content

The samples were collected from 0 to 15 cm depth of soil surface before operations for determination of moisture content and bulk density. The soil moisture was determined by oven dry method. Three samples were collected randomly from the test plots. The samples were kept in oven for 24 hours at temperature of 105°C. The samples were weighed before and after drying. The moisture content (Dry basis) was determined by the following formula (Rangapara, 2014).

Moisture content (%) $= \frac{\mathrm{Wd}-\mathrm{Ww}}{\mathrm{Wd}}$ x100---3.54

Where, W_w= Weight of wet soil sample, and

W_d= Weight of dry soil sample

3.7.2.2.2. Bulk Density of Soil

To determine bulk density of a soil, metallic core sampler was used to take sample from field having 100 mm diameter and 128 mm length. The samples were weighed and dry weights of the samples were calculated with the help of moisture content (d.b.). The ratio of dry weight of soil to the volume gave the bulk density. Bulk density of soil was calculated by using following formula (Rangapara J., 2014).

Bulk density of soil (g /cc)$= \frac{\text{weight of dry soil sample(g)}}{\text{volume of core sampler(cc)}}$

3.7.2.3. Seed Drill Performance Parameters

3.7.2.3.1. Operating Speed

The operating speed of seed drill was carried out by observing the time required for traveling 20 m distance with the help of stop watch along the longest direction.

3.7.2.3.2. Total Operating Time

Total operating time for the complete operation of sowing was measured by subtracting the time losses from adjustment, turning and machinery breakdown.

3.7.2.3.3. Fuel Consumption

The fuel consumption was measured as per the standard method by observing the fuel required for traveling 20 m long distance. A known volume cylinder was directly attached to fuel tank and was filled up to some level by keeping the tractor on level land and after completing the operation, final measurement of cylinder was noted down. The volume of fuel used was taken into account as fuel consumed for a particular time period.

3.7.2.3.4. Theoretical Field Capacity

It is the rate of field coverage of the implement, based on 100 per cent of time at the rated speed and covering 100 per cent of its rated width.

$$\text{Theoretical field capacity (ha/h)} = \frac{\text{Theoretical width (m)} \times \text{ speed (km/h)}}{10} \text{…………...3.55}$$

3.7.2.3.5. Effective Field Capacity

It is the actual area covered by the implement, based on its total time consumed and its width. Rangapara (2014) expressed the relation of effective field capacity as:

$$\text{Actual field capacity (ha/h)} = \frac{\text{area covered ,ha}}{\text{time taken to cover the test area,h}} \text{-------------------------3.56}$$

3.7.2.3.6. Field Efficiency

The field efficiency is the ratio of the effective field capacity to the theoretical field capacity, usually measured in terms of percentage (Rangapara, 2014).

$$\text{Field efficiency } (\eta), \% = \frac{\text{TFC}}{\text{EFC}} \times 100 \text{…………………………………….……………...3.57}$$

Where,

TFC = Theoretical field capacity, ha/h

EFC = Effective field capacity, ha/h

3.7.2.3.7. Wheel Slip

The wheel slip was calculated by recording total number of revolutions at no load and total number of revolutions at load. Wheel slip represents a loss of forward motion of the implement and it represents the loss of power. Wheel slip for any given load is determined by the expression of (Rangapara J., 2014).

$$\text{Wheel slip} = \frac{m_o - m_1}{m_o} \times 100 \quad \ldots\ldots 3.58$$

Where,

m_0 = wheel revolution with no pull

m_1 = wheel revolution with pull

3.7.2.3.8. Wheel Skid

Wheel skid was measured by operating the seed drill for four revolutions of ground wheel and actual distance covered at load and no load condition (Rangapara, 2014).

$$\text{Wheel Skid} = (L_2 - L_1)/ L2 \quad \ldots\ldots 3.59$$

L_1 = Actual distance covered, m

L_2 = Theoretical distance covered for the same number of revolutions, m

3.7.2.3.9. Draft and Power Requirement

a) Walking tractor drawn seed drill was operated at a recommended speed of 1.4 km/h, 2.0 km/h and 2.5 km/h.
b) The tractor (another power source) was used for pulling the walking tractor.
c) The spring type dynamometer was attached in between walking tractor and tractor.
d) Pull the walking tractor with the help of tractor and note the readings (unloaded condition).
e) The seed drill was attached to the walking tractor and pull the walking tractor with the help of tractor. (Loaded condition).
f) Note down the readings and repeat the procedure five times
g) Draft required to pull seed drill can be calculated by (Rangapara, 2014).

   Draft requirement (kgf) = D_L- D_U 3.60

   Where,

D_L= Draft required to pull 2WT in loaded condition, kg.

D_U= Draft required to pull 2WT in unloaded condition, kg.

The power requirement (hp) can be calculated by (Rangapara, 2014).

$$\text{Power requirement (hp)} = \frac{\text{draft(kgf)x speed(m/s)}}{75} \quad \text{......3.61}$$

The observations related to placement of seeds i.e. depth of seed, and horizontal spacing between seed were noted. The size, sphericity, surface area, bulk density, thousand grains mass and angle of repose properties of wheat variety were determined. These properties were considered and walking tractor operated seed drill was developed. Two-wheel tractor drawn seed drill six (6) row wheat seed drill with 14 kg capacity of seed hoppers and cup feed type seed metering mechanism was developed and fabricated. The shoe type furrow opener was provided for place the seed at desired with minimum dispersion. the performance in term of seed damage, uniformity, seed germination and theoretical field capacity, effective field capacity, field efficiency, wheel slip and power requirement of walking tractor operated seed drill was evaluated

CHAPTER 4

RESULTS AND DISCUSSION

In this section, wheat seed engineering properties related to the design and fabrication of seed planter are studied. The influence of selected variables on operation efficiency, number of seeds per square meter, and seed spacing are discussed. The performance evaluation of the designed two-wheel tractor drawn wheat planter, the results of the studies related to these aspects and their discussion are presented in this section.

4.1. Details of Two-wheel Tractor Drawn Wheat Seed Drill

The developed walking tractor drawn wheat seed drill is consisting of seed hopper, seed metering mechanism, ground wheel, furrow openers and others. The trapezoidal shape hopper was made for free flow of seed at an angle of inclination of 62^0 with the vertical and angle of repose 26.5^0 was made with capacity of 14 kg holding capacity hopper. Seed hopper was mounted on the frame. Cup feed metering mechanism was used for seed metering and delivering. The diameter of seed cup was 18mm with 5 cups were mounted along the periphery of the shaft.

The seed rate could be varied between 100 to 125 kg/ha (data gathered from informal communication from research experts). The metering mechanism was actuated by the ground wheel which transmits power by means of chain and sprocket. Polythene tubes of 30 mm diameter and 2 mm thick were used to convey seed from orifice to furrow opener by gravity. Furrow openers were used to place the seed at the desired depth. A shovel type furrow opener at the rake angle of 41^0 was used to place the seed at a depth of 3 to 5 cm. The seed emergency percentage of shovel type furrow opener was 95%. This result was shown good result as compared with Verma et al. (2007) seed emergency result of 94%. A provision was made to change the row to row spacing and depth by adjusting by the help of nut and bolts. A slot was fabricated on the frame to adjust the depth of furrow opener on each end sides to give ease of attachment and adjustment, uniform depth and stability to the developed walking tractor drawn wheat planter.

4.2. Physical Properties of Soil of Experimental Site.

4.2.1. 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: 4.1). The soil of the field was loam and clay sandy loam soil. Moisture content on dry basis 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 8.0 cm diameter and 12 cm height.

Table: 4.1. Moisture content and bulk density of soil

Observation	Weight of a soil (gm)	Weight of soil after oven dried(gm)	MC (%)		Bulk Density (kg/m^3)
			%Wb	%Db	
1	750	620	17.33	20.99	1390.74
2	741	610	17.46	21.4	1388.15
3	761	636	16.42	19.65	1405.11
4	752	617	17.95	21.88	1410.02
5	763	641	15.99	19.03	1379.13
Average	753.4	624.8	17.03	20.59	1394.63
S.D	8.905054744	13.1415372	0.8023403	1.20389	12.68912

Moisture content at 5 different places was found to be 17.33%, 17.46%, 16.42%, 17.95% and 19.03% on wet basis respectively. The average moisture content of the experimental field was 17%. Bulk density of soil was measured by core sampler. Bulk density of soil was found to be 1390.74 kg/m^3,1388.15 kg/m^3,1405.11 kg/m^3,1410.02 kg/m^3 and 1394.63 kg/m^3 respectively (Table:4.1). Average value of moisture content and bulk density of experimented plot was found 17.03% (Wb) and 1394.63 kg/m^3 respectively.

4.3. Physical Properties of Wheat Seed

Seed properties are important for optimizing the design parameters of the seeder. The physical properties of seeds are among the most important factors to be considered for selecting a suitable metering mechanism for its better performance. The attempt was made to study the physical properties of wheat seeds grown at Kulumsa Agricultural Research Center (KARC). The seeds were cleaned to remove foreign matter, broken and immature seeds. The moisture content of seed was determined by oven dry method and was found to be 13 per cent (wet basis). The similar result of moisture content of selected Wheat seed was determined as 10.9% on wet/dry basis by (Navneet,2016). The most popular varieties of Wheat like Kekeba, Shorima,Digelu,Ogolicho and Hidase seeds were selected and studied their physical properties. The physical properties of wheat namely; thousand grain mass, sphericity, size and surface area, bulk density and angle of repose were measured using the standard procedure.

The geometrical parameters namely dimension of the principal axes (L is length, B is the breadth and T is the thickness) of randomly selected wheat seeds were measured using digital vernier caliper. Size, surface area and sphericity were calculated. The mean length (L), breadth (B), thickness (T), size (S), surface area (SA), sphericity (Sp), thousand grain mass (TGM), angle of repose (AR) and bulk density (B.D) of different wheat variety was found as ranges from 5.31 to 6.28 mm ,3.18 to 3.33 mm ,2.72 to2.83 mm,3.56 to3.89 mm ,37.52 to 52.17 mm ,0.61 to 0.67 ,32.57 to 32.9 gm ,26.5 to 26.6 gm and 770.2 to770.85 kg/m^3 respectively. Clover (1998) found an angle of repose of wheat was 28°. The average value of bulk density for wheat was 770.5 kg/m^3 which is a similar result was observed with (Navneet,2016) with average value of bulk density for wheat determined as 768 kg/m^3. The details of varieties are given in Table:4.2.

Table: 4.2. Physical properties of selected varieties of wheat

Sr.No	Wheat variety	L (mm)	B(mm)	T(mm)	Size(mm)	S.A(mm)	Sphericity
1	Shorima	6.12 ±0.45	3.08 ±0.26	2.83 ±0.37	3.75 ±0.24	42.85 ±5.10	0.62±0.03
2	Hidse	6.68 ±0.46	3.40 ±0.45	3.07 ±0.29	4.11 ±0.31	51.37 ±7.21	0.61±0.03
3	Kekeba	6.22 ±0.44	3.86 ±0.46	2.78 ±0.39	4.04 ±0.32	52.17 ±19.11	0.67±0.05
4	Digelu	5.31 ±0.41	3.18 ±0.31	2.72 ±0.53	3.56 ±0.34	37.52 ±6.41	0.67±0.04
5	Ogolicho	6.28 ±0.61	3.33 ±0.46	2.83 ±0.46	3.89 ±0.47	46.26 ±9.53	0.62±0.04
Minimum value		5.31	3.18	2.72	3.56	37.52	0.61
Maximum value		6.68	3.86	3.07	4.11	52.17	0.67

Table: 4.3. Bulk density, Thousand Grain Mass and Angle of repose

Sr. No.	Wheat Variety	TGW,gm	AR,degree	B.D Kg/m^3
1	Shorima	33.04±0.74	26.6 ±0.88	770.85 ±2.94
2	Hidse	38±0.93	26.5 ±0.94	770.8 ±2.94
3	Kekeba	35.97±0.52	26.5 ±0.88	770.2 ±3.48
4	Digelu	32.9±0.52	26.6 ±0.88	770.8 ±2.94
5	Ogolicho	32.57±0.55	26.5 ±0.94	770.75 ±2.93
	Minimum value	32.9	26.5	770.2
	Maximum value	38	26.6	770.85

The angle of repose and bulk density were important for designing of seed hopper as well as seed metering mechanism. For designing the different sizes of cup on the basis of shape, surface area, sphericity and thousand grains mass and bulk density. The sphericity was 61% to 67%, which indicate that the shape of grains makes it easy to roll on cylindrical round surface. Sphericity is the measure of how closely the shape of an object approaches that of a mathematically perfect sphere i.e. the standard sphericity of round cylindrical surface is about greater than 60% (Wadell, 1935). Navneet (2016) determined as the shape of the wheat grain in terms of its sphericity was 59%. The angle of repose of all varieties are nearly equal to 26^0.this value was in the range of 20^0 to 29^0 angle of repose which indicate that the grain has a shape of round characteristics see

Appendix B: 6. The angle of repose determines the maximum angle of grain with the horizontal plane and it is important in the seed hopper design.

Among the selected wheat verities Kekeba wheat variety has better seed rate, germination result and roundness shape than others. Therefore, for this work Kekeba variety was selected for performance evaluation of the developed seed drill based on the above laboratory test point out reason.

4.4. Performance Evaluation of Seed Drill

Performance evaluation of wheat seed drill was carried out by conducting both laboratory test and field test at Melkassa Agricultural Research Center. Two-wheel tractor was used to drawn the wheat seed drill (technical specifications for dongfeng power tiller in appendix C: 4). the results of the study are discussed in appendix table: B.3.

4.4.1. Laboratory Tests

A laboratory test of the seed drill was carried out to check the seed rate and germination result of the selected Kekeba wheat variety.

4.4.1.1. Seed Drill Calibration

The seed drill was tested in the laboratory for mechanical damage to seed during metering and for seed rate. The width of two-wheel tractor drawn wheat seeder was 1.2 m. The diameter of the ground wheel diameter was 50cm.the nominal width of the seeder was calculated by,

W=n x d…….……………………………………………………….………………………...4.1

=6 x 0.2m=1.2m

Circumference of ground wheel (∏ x D) =3.14 x 0.5=1.57m. Let, the length of a strip of plot was 100 m. The ground wheel was revolved 63 times for 100 m length i.e. X = 100/ (π × 0.2) =63revolution for a 120 meter square area (i.e. 1.2 m x 100m). The 63 revolution was given to the wheel and the seeds from all the furrow openers were collected separately. All the collected seeds were weighed separately. The total weight of the seeds collected from six furrow openers was 1.34 kg. In one ha there are 83.33 turnings (i.e. 100m/1.2m=83.33 turnings).

Therefore, 83.33*1.34kg=112kg wheat was required for one hectare. The process was repeated by suitable adjusting the speed on the 2WT till we get desired seed rate recommended for a wheat variety under sowing.

Three replications were carried out for calibrating the drill in the laboratory. The available cup metering mechanisms depth of 4mm, 4.5mm and 5mm were used for the study. Looking to the observed values of seed size and cup size of cup metering mechanism, cup depth of 4.5mm was selected for calibration of developed seed drill for wheat. Data revealed that with cup metering depth of 4.5mm gave nearest values of seed rate in the range of 100.13kg/ha to 112.04 kg/ha. The obtained seed rate result was laid on the recommended range of wheat seed rate of 100kg/ha to 125kg/ha (data gathered from informal communication of research expert). Average value of 106.08 kg/ha was obtained which is nearest to the minimum recommended seed rate of 100kg/ha of wheat.

The average seed rate for 1.4 km/hr, 2 km/hr and 2 km/hr speed of operation from the calibration were observed as 100.13 kg/ha, 105.58 kg/ha and 112.04 kg/ha respectively.

Table: 4.4. Seed rate obtained from developed seed drill

speed, km/h	Rep.No.	weight of seed from each furrow opener per 14 revolution, gm						Total Seed Collected, gm	Seed Rate, kg/ha
		1	2	3	4	5	6		
1.4	1	44.4	43.9	44.8	44.2	44.2	43.9	264.41	99.40
	2	44.9	44.07	44.9	43.6	44.2	44.3	265.97	99.98
	3	44.5	44.9	44.7	44.9	44.8	44.9	268.7	101.02
	Average	44.6	44.29	44.8	44.1	44.4	44.1	266.36	100.13
2	1	46.8	47.1	46.8	47.2	45.7	45.9	279.5	105.07
	2	45.9	46.8	45.5	47.9	47.8	47.8	281.7	105.90
	3	47.8	48.5	45.9	45.3	46.8	47.1	281.4	105.78
	Average	46.8	47.46	46.06	46.8	46.7	46.9	280.86	105.58
2.5	1	49.4	50.9	48.9	49.2	50.1	48.8	297.3	111.76
	2	48.5	50.1	49.1	49.2	49.8	50.1	296.8	111.55
	3	49.9	51.1	49.8	48.9	49.1	51.2	300	112.78
	Average	49.2	50.7	49.26	49.1	49.6	50.0	298.03	112.04

The recommended seed rate of wheat variety is ranges from 100kg/ha up to 125kg/ha. Therefore, the calibrated seed rate of developed tractor drawn wheat seeder was lies in the recommended range.

4.4.1.2. Uniformity Test

Seed uniformity test was conducted as per method given in the Sec above. The average number of seeds fallen in the row per meter distance and the distance between two rows. The variation in seed dropping among furrow was in range of 0.35 to 4.62 % among the sample tested. The selected wheat was having thousand grain mass ranges from 23 to 32.9 g and accordingly cup size was designed. As less variation had observed, the variation in seed rate from the six row metering was lower. This result show that per cent variation were within the allowable limit of ± 5 % (Tomar,1983). The similar results were also reported by Senger et al. (2011) for sowing wheat in dry soil by animal drawn rice cum green manure crop seeder.

Table: 4.5. Seed uniformity obtained by two-wheel tractor operated

Sr.No	Furrow Rows	Variety	Seed Rate (kg/ha)	No. Seeds Fallen Per Meter Distance
1	Row1	Kekeba	118.8	66
2	Row2		109.1	61
3	Row3		107.5	64
4	Row4		111.1	63
5	Row5		112.8	65
6	Row6		102.5	62

4.4.2.3. Mechanical damage

The Mechanical damage test was carried out as per the method in section listed above and it was observed that there was no visible damage during all types of cup rows test in laboratory test. This result occurred due to cup design based on the physical property. The similar findings were reported by Pradhan and Ghoshal (2012). However, the internal damage of seeds was measured by sowing of seeds in plastic trays for laboratory germination test and found that the seed damage for wheat was not significant (0 %).

Table: 4.6. Mechanical damage to wheat seeds by seed drill

Sr.no	Crop variety	Weight of broken seeds, gm	Total weight of sample, gm	Damaged seeds %
1	Kekeba	0.09	1000	0.009%
2	Kekeba	0.10	1000	0.01%
3	Kekeba	0.05	1000	0.005
4	Kekeba	0.08	1000	1.008
5	Kekeba	0.12	1000	0.012
Average		0.088	10000	0.088%
Seed collected in 20 wheel revolutions				

4.4.1.4. Seed Emergence Test

The seed emergence test was conducted and results observed germination of wheat before metering and after metering of selected variety were carried out. The results of test conducted are presented in Appendix.B.5. The variation in germination values were within 1% before and after metering which is within acceptable limit. The similar results were reported by Senger et al. (2011).

For a 100m length of trip distance the seed drill dropped a 1340 gm of seeds for the 120 m^2 areas. Then calculate the rate of seed sown for a 1m distance i.e. for 1.2 m^2 area. The result became 13.4 gm. The average value of a thousand grain mass was 35.5gm (see table: 4.7). From this data obtained the number seed fallen in a 1.2 m^2 area would be about 377 seed.

Table: 4.7. Germination data obtained

Field Germination Count Per 1.2 m^2				
Sr.NO	Speed, km/h	Recommended	Count	% Germinated
1	1.4	377	369	97.8
2	2	377	364	96.7
3	2.5	377	358	95.2

Table:4.7. Evaluated the germination result of the seed planted by different speed operation conducted at experimental field site. Seed damage was assessed through using germination test. Germination per cent decreased with increase in forward speed of the planter shown in the Fig: 4.1. The 97 % wheat seed was germinated before passing through the metering mechanism of the seed drill. After testing the seed drill, germination per cent was found as 97.8%, 96.7% and 95.2 % at speed 1.40, 2.0 and 2.5 km/h, respectively. The 95% similar result of seed germination percentage was observed by (Rangapara J., 2014)

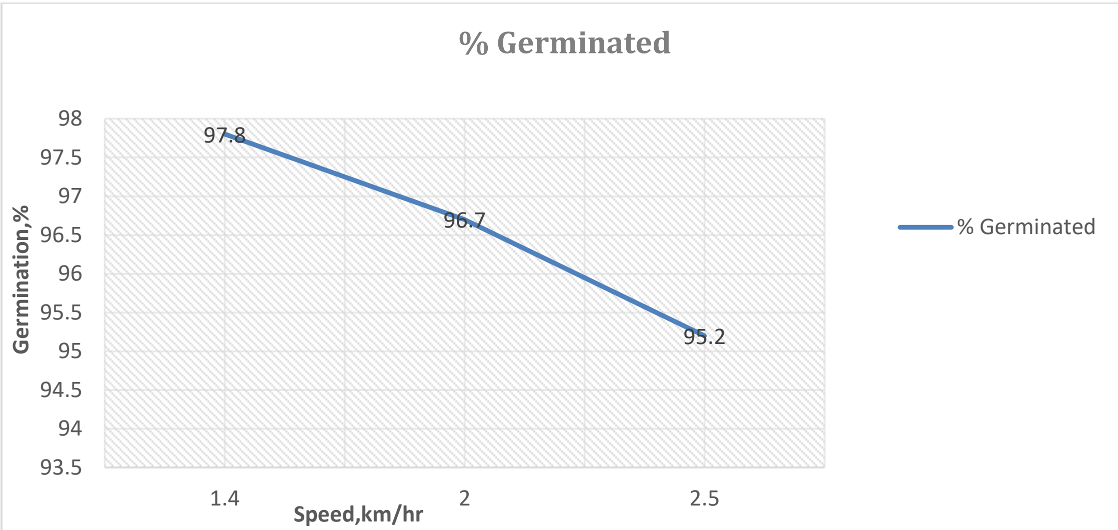


Fig: 4.1. Seed germination rate at different speed operation

This test was conducted to find visible damage to seed if any by metering mechanism. The seeds before and after metering mechanism test conducted for germination. The seed germination test was carried out in the field as per section stated above. It is observed that number of seeds was germinated per 1.2 m^2 was counted. The result is shown in Appendix B. This shows that there was minimum visible damage from metering mechanism. The observed plant population per 1.2 m^2 shows that metering mechanism accurately metering the seeds without damage. The germination percentage shows that there was not much mechanical damage of seed during process of calibration of seed drill. As per the test code visible damage to the seed after drilling should not exceed 5%.

4.4.1.5. Effect of Seed Rate on 2WT Speed

The seed drill was attached to the 15hp Dongfeng two-wheel tractors. Three different operating forward speeds were found out at different gear and throttle position. The 1.4 km/h, 2 km/h and 2.5 km/h forward speed was selected for sowing operation and its effect of different operating speed on seed rate, seed uniformity and seed damage was observed. The two-wheel tractors can be operated at 1.5 to 2 km/hr speed for sowing (Anonymous, 2013). At 1.4 km/h speed operation seed rate, spacing between rows and seed damage for Kekeba variety was 100.13 kg/ha, 20 cm, and 0.088% respectively. At 2 km/h speed of operation seed rate, spacing between rows and seed damage for Kekeba variety was 105.6 kg/ha, 20 cm and 0.088% respectively. At 2.5 km/h speed of operation seed rate, spacing between rows and seed damage for Kekeba variety was 112.604 kg/ha, 20 cm and 0.088% respectively.

At 1.4 km/h speed was observed that relatively less rotational speed of the cups due to lower gear speed. These resulted cups were not dropping all the picking seeds in to the outlet. Some of the seeds dropped back to the hopper. At this speed operation the seed were drilled in row continuously and lower seed rate was observed but it was in the recommended range of seed rate. At 2 km/h speed was gives better results than the 1.4 km/h speed, but in this speed seed rate was not reached to the average recommended seed rate. It gives less seed rate than average seed rate. The 2.5 km/h speed was giving an average seed rate. In 2.5 km/h operating speed seed rate as well as seed spacing was properly maintained as per requirement as observed in laboratory test. Therefore 2.5 km/h speed was selected for sowing operation and gives better results than the other operating speed. The recommended rate of wheat sowing in Ethiopia is 100 kg/ha to 125kg/ha (informal communication with experts). The similar effect of forward speed was observed by Chauhan et al. (1999) as reported by (Celik et al., 2012). Fig:4.2 have shown the effect of different operating speed on the seed rate.

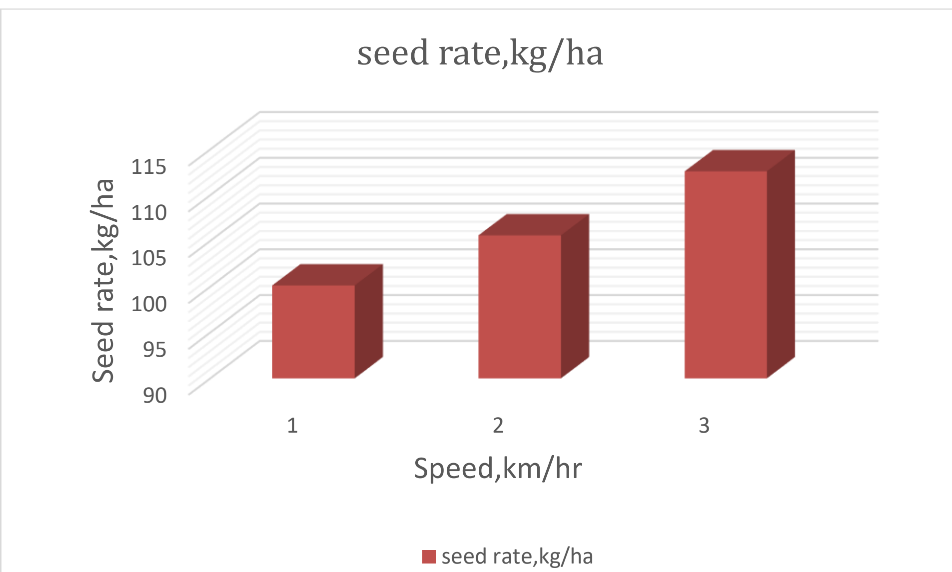


Fig: 4.2. Effect of different operating speed on seed rate

4.4.1.6. Hopper Filling Effect on Seed Delivery Rate

Table 4.8 indicates the seed rate of wheat for different observation varied with the hopper filling (Full, 3/4th and half). It was observed that the entire samples collected for same observation were nearly same and there was very little deviation among the sample.

Table: 4.8. Effect of hopper filling on seed rate (kg/ha) of wheat crop

Observation	Seed rate kg/ha at 4.5mm cup depth		
	full	3/4th	half
1	98.14	99.62	100.65
2	98.9	101.12	102.65
3	105.15	106.14	107.54
4	107.02	108.98	109.68
5	113.14	114.54	120.68
Mean	**104.47**	**106.08**	**108.24**

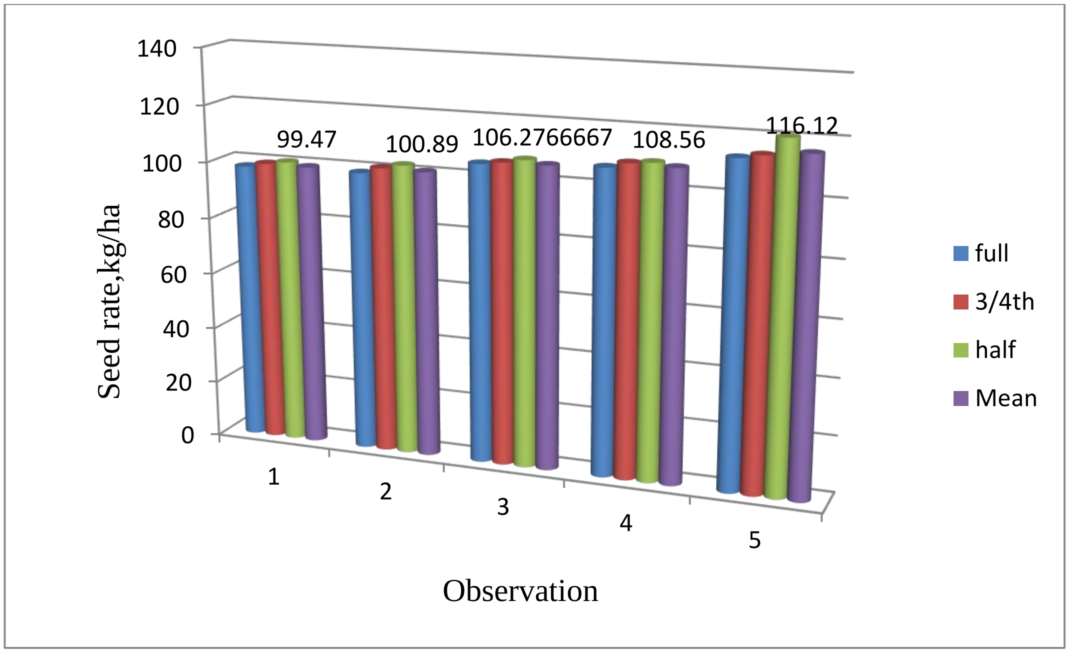


Fig: 4.3. Hopper filling effect

4.4.1.7. Calibration of Seed Drill by Varying Cup Depth

The calibration test in the laboratory was conducted at different cup depth. The Kekeba variety was used for laboratory calibration by varying the depth of the cup at 4 mm, 4.5 mm and 5 mm. The ends of seed tubes were removed and a plastic bag was attached to each end rods to collect the seeds. The average seed in the laboratory was observed as, 102,112.6 and 136 kg/ha for 4mm, 4.5mm and 5mm as shown in table: 4.9.

Table: 4.9. Seed rate at 4.5 mm depth adjustment at 2.5 km/hr

Sr.No.	variety	Cup depth	Seed rate(kg/ha)
1	Kekeba	4 mm	102
2		4.5 mm	112.6
3		5 mm	136

4.4.1.8. Effect of Seed Delivery between Rows

Table: 4.10 indicate the variation in seed rate of wheat among furrow openers. It was observed that the entire samples collected for the samples taken were nearly the same.

Table: 4.10 Seed rate (kg/ha) for wheat crop for different furrow openers at 2.5 km/h

Sample	F.O-1 (gm)	F.O-2 (gm)	F.O-3 (gm)	F.O-4 (gm)	F.O-5 (gm)	F.O-6 (gm)	Mean	SD	Seed Rate(kg/ha)
I	45.11	48.98	41.21	42.5	45.01	43.89	44.45	2.68	111.12
II	45.5	47.5	44.01	40.5	39.6	43.9	43.5	2.99	108.75
III	38.98	47.99	44.92	45.9	42.85	45.18	44.3	3.09	110.75
IV	49.56	43.93	45.25	45.98	48.11	44.98	46.3	2.12	115.75
V	45.11	48.6	42.1	45.9	42.12	44.01	44.64	2.26	111.6
Average seed rate, kg/ha									111.59

F.O-1: furrow opener of row 1, F.O-2: furrow opener of row 2, F.O-3: furrow opener of row 3, F.O-4: furrow opener of row 4, F.O-5: furrow opener of row 5, F.O-6: furrow opener of row 6

4.4.2. Field Test

4.4.2.1. Description of Field Evaluation

The field calibration of two-wheel tractor drawn wheat seeder was carried out at the experimental field of Melkassa Agricultural Research Center. Three plots of size 10m x 22m were selected for field testing. The field was well prepared which was at least 15 cm deep, firm, fine structure, smooth and level, relatively free of surface trash.

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

- Type of soil clay loam
- Soil moisture content in percent 20 %
- Bulk density - 1.73 t/m^3
- Size of clods- 0.32 mm diameter
- Depth of seed bed- 15-18 cm
- Method of sowing- Side to center
- Size of plot- (10 X 22) m^2

The seeder was operated in the field and side to center method of operation was adopted. In the field test, three replications for an area of 10 x 22 m^2 field plot size seeder calibration, seed placement, power requirement and the plant population were carried out.

4.4.2.2. Performance Evaluation of Seed Drill

Field performance tests were carried out to obtain actual data on overall performance of the drill. The field test was done in the experimental farm of Melkassa Agricultural Research Center (MARC). The performance of the two-wheel tractor drawn seed drill in terms of seed drill agricultural machine parameters was assessed at different forwards speeds of 1.4, 2.0 and 2.5 km/h. Since, variety of seed has no effect on seed drill, therefore, seed variety was not considered during this test. During field performance test, the parameters determined was theoretical field capacity, effective field capacity, field efficiency, wheel slippage and power requirement of walking tractor operated seed drill with three replications of each. The detail data of these seed drill parameters are given in Appendix B.3.

Table: 4.11. Mean of Measured Performance Evaluation of Seed Drill during Field Test

Sr. No.	Parameters	Operating speed, km/hr		
		1.4km/hr	2km/hr	2.5km/hr
1	Fuel consumption, l/hr	1.42	1.66	1.53
	Draft requirement, kg	61	67	69
	Power Requirement, hp	2.93	6.43	8.28
4	Wheel slip,%	4.94	6.19	8.67
5	Theoretical field capacity, ha/hr	0.17	0.24	0.3
6	Effective field capacity, ha/hr	0.14	0.19	0.23
7	Field efficiency, %	81.61	78.43	77.91

The theoretical field capacities were observed that 0.17, 0.24 and 0.30 ha/h at an operating speed of 1.4, 2.0, and 2.5 km/hr respectively. The average effective field capacities were observed that 0.13, 0.19 and 0.230 ha/h at an operating speed of 1.4, 2.0, and 2.5 km/hr respectively. The field efficiency was observed that 81.6 %, 79.4 % and 77.9 % at an operating speed of 1.4, 2.0, and 2.5 km/hr respectively.

4.4.2.3. Speed of Operation

The speed of operation was found and carried on the speed limit at 1.4 km/h, 2 km/h and 2.5 km/h (Appendix Table: B.3). The speed was measured using an instrument of a Tachometer. The optimum speed of operation of 2WT drawn seed drill for sowing selected seeds was found to be 2.5 km/h, for a distance of 20m.

4.4.2.4. Fuel Consumption

The fuel consumption measurement shown that when the operating speed increased the fuel consumption rate also increased. During operation, fuel consumption was observed as 1.42, 1.49 and1.53 l/hr at the speed of 1.4, 2.0 and 2.5 km/h, and respectively.

4.4.2.5. Draft requirement

The draft requirement increased with increase in forward speeds with values 61, 67 and 69 kg on 1.4, 2.0 and 2.5 km/h speed, respectively. The data presented in Table: 4.11indicates that the operating speed of the two-wheel tractor significantly affected the draft requirement.

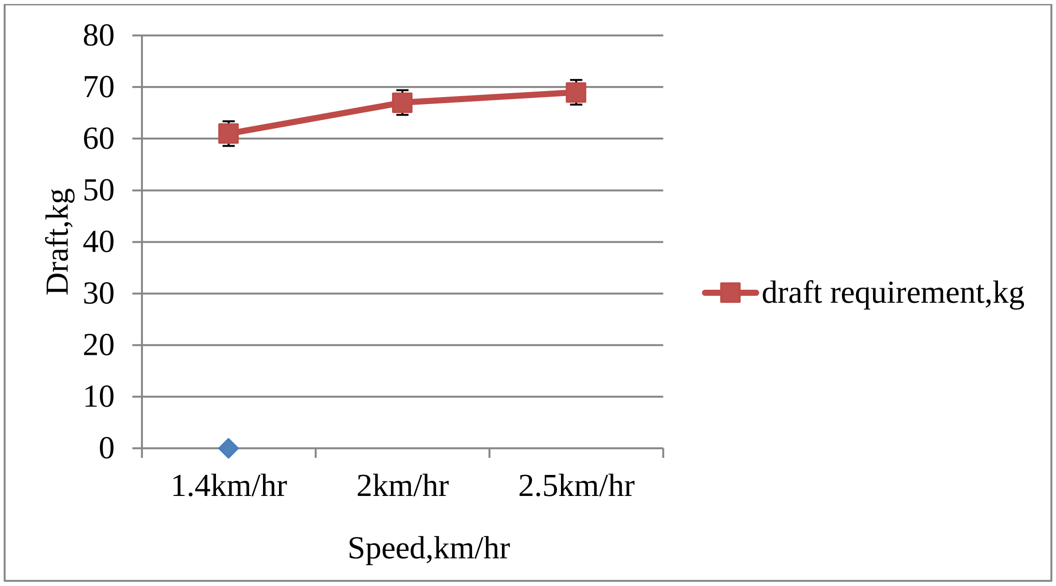


Fig: 4.4. Effect of forward speed on draft

4.4.2.6. Power Requirement

About 8.28 hp Power requirements was found maximum for speed at 235 km/h and minimum power requirement of 2.93 hp was observed speed at 1.4km/h. The Fig: 4.5 show that the power requirement increased with increase in speed.

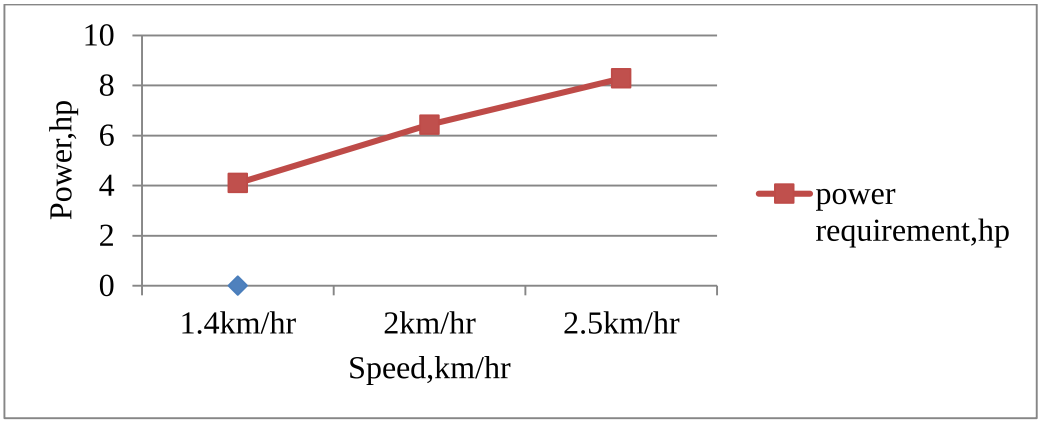


Fig: 4.5. Forward speed Effect on power requirement

4.4.2.7. Labour Requirement

The seed drill was required two persons for manipulation and operation of sowing activity of wheat on the well prepared land. The first person was required for to perform a sowing operation i.e. one skilled labour for operating the two-wheel tractor and the seed drill attached to the two-wheel tractor while the second one required for refilling of the seeds

4.4.2.8. Wheel Slip

The wheel slip of two-wheel tractor drawn seed drill was determined by using the method mentioned earlier and the results obtained for wheel slip data obtained at different operating speed was shown in Appendix B Table B.4. The wheel slip increased with increase in speed. The minimum wheels slip i.e. 4.94 % and maximum wheel slip i.e. 8.67 % was observed at speed of 1.4 km/h and 2.5 km/h, respectively. The Fig: 4.6 show that the wheel slip increased with increase in speed.

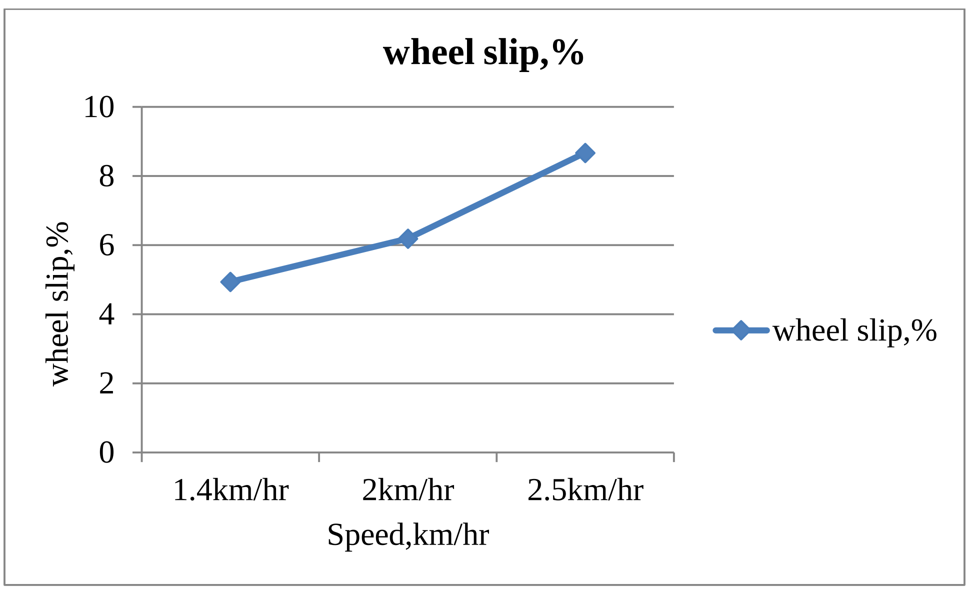


Fig: 4.6. Forward speed Effect on wheel slip

4.4.2.9. 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 1.4 km/hr speed was 0.17 ha/hr and maximum values at 2.5 km/hr speed was 0.3 ha/h. The values of effective field capacity on 1.4, 2.0 and 2.5 km/hr were 0.13, 0.19 and 0.23 ha/h, respectively. The Fig: 4.7 show that theoretical and effective field capacity increased with increase in speed.

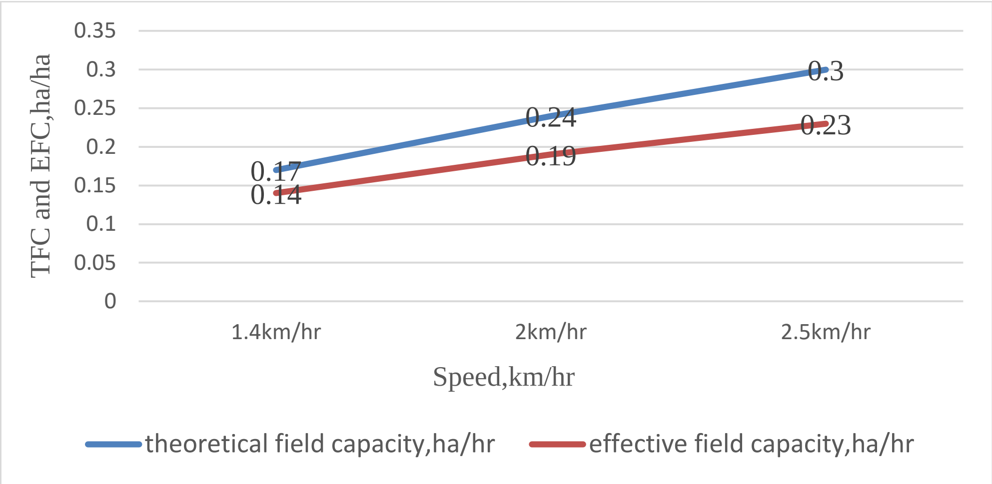


Fig: 4.7. Effect of forward speed on theoretical and effective field capacity

4.4.2.9. Field efficiency

The field efficiency mean values obtained were listed above in Table: 4.11. The minimum field efficiency occurred at 2.5 km/hr operating speed was 77.91% and the maximum field efficiency noticed that at a speed of 1.4 km/hr was 81.61%. The Fig: 4.6 shows that field efficiency decreased with increased in speed. Rangapara (2014) suggested that the field size was decreased; number of passes of the drill increased too, which leads to increase in time losses and gave lower values of field efficiency. The highest 82.48 % field efficiency was observed at lower speed. The major reason for the reduction in field efficiency by increasing forward speed was due to the less theoretical time consumed in comparison with the other test plots.

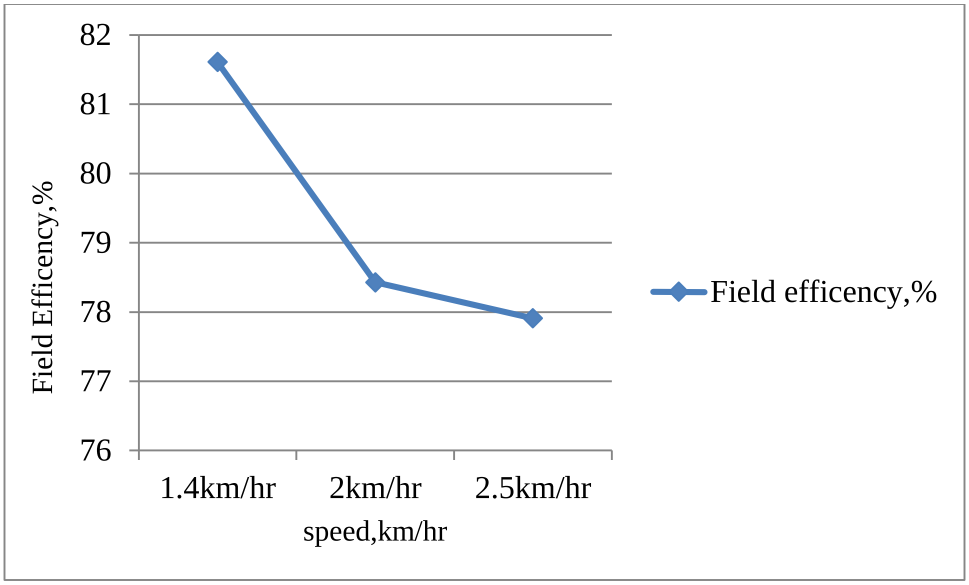


Fig: 4.8 Effect of forward speed on field efficiency

4.4.2.10. Depth of Seed Placement

The depth of seed placement in the field was observed that 4.4 cm. The depth of placement of seeds was adjusted raising or lowering the furrow opener. The furrow openers were fixed on a single hollow square bar by bolts. This square bar was attached to the main frame of the planter on their ends using bolt and nuts. The bar has a mechanism of moving up and down side to adjust the furrow depth by loosening the bolts attached on each end side.

4.4.1.11. Cost Estimation and Cost of Operation

The unit cost of a two-wheel tractor drawn six row seed drill was determined by calculating the cost of different components and their fabrication cost as given in Appendix-C. The estimated cost of the one unit of two-wheel tractor drawn six row seed drill was determined as 7686.92EB.

Table: 4.12. Cost summary

No.	Cost Variables	Summary
A	Raw Material Cost	5253.73EB
B	Material Wastage 2.5%	131.34EB
C	Machine Cost	336.75EB
D	Labor Cost	321.87 EB
E	Overhead Cost 5%(C+D)	32.93EB
F	Profit 10 %(A+B+C+D+E)	607.66EB
G	Sells Tax 15 %	1002.64EB
	Selling Price	**7686.92EB**

CHAPTER 5

SUMMARY AND CONCLUSIONS

This work was conducted to design and a two-wheel tractor drawn six row wheat seed drill six row wheat drill for sowing operation suitable for medium farmers and to evaluate its performance. The machine was powered by 15hp diesel engine walking tractor. The seed box was made up of sheet metal. The capacity of seed box was 14 kg for 75% of filling the hopper. The cup feed metering mechanism, fitted in the unit, gets the drive from pegged ground drive wheel of 50cm diameter through chain and sprocket. The shovel type furrow opener was designed with non-clogging boot place the seed at desired depth. The spacing between two furrow openers was designed 20 cm and laid on the fixed frame which has a depth control mechanism on each end surface. It is known that Ethiopian wheat sowing system was carried out using broadcasting and animal drawn technique. This technique is mostly labor and time consuming operation.

The present investigation was carried out with the following objectives.

- To study the physical properties of wheat
- To design and fabricate two-wheel tractor drawn six row drill
- To evaluate the performance two-wheel tractor drawn six row drill

The two-wheel tractor drawn six row drill has the following benefit:

- The seed drill is a low cost machine, which can be afforded by small and marginal farmer. It is undoubtedly an intermediate technology between bullocks and tractor farming.
- The maintenance of two-wheel tractor drawn six row drill is easy.
- A two-wheel tractor drawn six row drill can easily be manufactured by local artisan.
- A two-wheel tractor drawn six row drill can be operated even by unskilled operator.
- A two-wheel tractor drawn six row drill has better maneuverability, uniform in seed dropping, stability.
- A two-wheel tractor drawn six row drill reduces human drudgery compare to operation by animals.

The geometrical parameters of different varieties of wheat which prevalent some common variety in the country were selected. The mean length (L), breadth (B), thickness (T), size (S), surface area (SA), sphericity (Sp), thousand grain mass (TGW), angle of repose (AR) and bulk density (BD) of different wheat variety was found as ranges from 5.31 to 6.28 mm ,3.18 to 3.33 mm ,2.72 to2.83 mm,3.56 to3.89 mm ,37.52 to 46.26,0.62 to 0.67 32.57 to 32.9 gram ,26.5 to 26.6 and 770.2 to770.85 respectively.

These properties were considered and accordingly a two-wheel tractor drawn six row drill was developed. The developed accordingly a two-wheel tractor drawn six row drill is consisting of seed hopper, seed metering mechanism, ground wheel, furrow openers and cut-off device. The trapezoidal shape hopper was made for free flow of seed with the angle of inclination of 62^0 and is made with the vertical with capacity of 14 kg of seed. Cup feed metering mechanism was used for seed delivery. The diameter of seed shaft was 20 cm with 5 cups were mounted along the periphery of the seed shaft bushing. The seed rate can be varied between 100 to 125 kg/ha. The metering mechanism was actuated by the ground wheel which transmits power by means of chain and sprocket. Polythene tubes of 30 mm diameter and 2 mm thick were used to convey seed from orifice to furrow opener by gravity. Furrow openers were used to place the seed at the desired depth. A shovel type furrow opener with the rake angle of 41^0 was used to place the seed at a depth of 3 to 5 cm. A depth adjustment was made for furrow opener with the help of bolts and nuts. A detachable draw bar link was fabricated for attachment, pull and adjustment of the developed two-wheel tractor drawn wheat drill. It gives ease of attachment and adjustment, uniform depth and stability to the developed two-wheel tractor drawn wheat drill.

Two-wheel tractor drawn wheat drills was tested in the laboratory and field. The seed drill was tested in laboratory for mechanical damage to seed during metering and for inter row variation and seed rate. The results of calibration test show average seed rate for Kekeba wheat variety was 112 kg/ha. It was observed that there was no visible damage during the test done in the laboratory. The seed germination percentage before metering and after metering was conducted and shows very low variation among them. The variation in seed dropping among furrow was in range of 0.35 to 4.62 % among the variety tested.

The field testing of two-wheel tractor drawn wheat drills was carried out at the field of MARC. Three plots of 10 m × 22 m (size) were selected for field test. The field was well prepared which was 15 cm deep, firm, fine structure, smooth and level, relatively free of surface trash. In Preliminary test two-wheel tractor drawn wheat drills was operated with 1.4, 2 and 2.5 km/h speed.

Two-wheel tractor drawn wheat drills was operated on these three speeds and its effect on seed rate, seed uniformity and seed damage was observed. At 2.5 km/h operating speed seed rate as well as seed spacing was properly maintained as per requirement and was selected for sowing operation as its gives better results than the other operating speed. The average seed distribution in the field was observed as 112kg/ha. Field performance tests were carried out to obtain actual data on overall performance of two-wheel tractor drawn wheat drills. The theoretical field capacity, effective field capacity and field efficiency was observed 0.30 ha/h, 0.23 ha/h and 77.9 % respectively during 2.5 km/h operating speed. The power required for to operating the seed drill in the field found 8.28 hp. the wheel slip was 8.67% occurred.

5.1. Conclusions

The following conclusions are made from the study of two-wheel tractor drawn wheat drills

- Two-wheel tractor drawn wheat drills works satisfactorily in the field with required seed rate, seed uniformity with minimum damage to seed.
- The operating speed of 2.5 km/h speed was suitable for sowing and gives desired seed rate, seed uniformity and spacing.
- The theoretical field capacity and actual field capacity were 0.3ha/h and 0.25ha/h, at average speed of 2.5 km/h for shovel type furrow opener respectively and the average field efficiency was 77.9 per cent.
- Under normal moisture content (13%) the slip was found to be only 8.67% with diameter of ground wheel of 50cm.
- The average depth placement of seed and spacing between row were obtained as 3 to 5cm and 20 cm respectively. The plant population of 377 per m^2 was obtained.
- There was no visible damage notice during field test.
- The estimated cost of the one unit of two-wheel tractor drawn six row seed drill was determined as 7686.92EB the performance of two-wheel tractor drawn wheat drills was good for working in the well prepared seed bed.

5.2. Suggestions for Future Work

The following suggestions may be exploring to improve the performance of two-wheel tractor drawn wheat drills

- Number of rows covered be increased to improve field capacity and field efficiency of developed two-wheel tractor drawn wheat drills.
- The drill may be tested for different crops and feedback received may be used for further design refinements, if any.
- The drill can be used for multi-crop sowing purpose.

REFERENCES

Abera Adamo. (2001): Participatory agricultural research processes in eastern and central Ethiopia: Using farmers' social networks as entry points for pr activities. Network on bean research in Africa, occasional publications series, No. 33, CIAT, Kampala, Uganda.

Adekoyeni, O., Rahman, A. and Malomo, O. (2012): Some physical properties and yield of ada rice. J. of basic. Appl. Sci. Res.

Ali, Z., Samiullah, A. and Rehman, F. (1993): Development of seed drill for rain-fed farming, J. of Agricultural mechanization in Asia, Africa and Latin America.

Ajit K., Carroll G.,Roger R. and Dennis B. (2012). Engineering principles of agricultural machines, 2nd edition. ASABE

Anonymous. (1997): Annual report of AICRP on Utilization of Animal Energy, Chaudhary Charan Singh Haryana Agricultural University, Hisar

Asfaw Negassa, Jawoo Koo, Kai Sonder, Bekele Shiferaw, Melinda Smale, Hans Joachim Braun, Dave Hodson, Sika Gbegbelegbe, Zhe Guo, Stanley Wood, Thomas Payne and Bekele Abeyo(2012):The Potential for Wheat Production in Sub-Saharan Africa: Analysis of Biophysical Suitability and Economic Profitability, CIMMYT, Addis Ababa, Ethiopia.

Ashebir Tsegaye (2015): Development of Animal Drawn Multicrop Planter. Thesis, Haramaya University, Ethiopia,unpublished

Ashenafi Tariku (2015): Design, development and performance test of a precession type manual wheat planter ,Adama Science and Technology University ,unpublished.

Bansal,R. K., Gharras, O. E. and Hamilton, J. H. (1989): A roller type positive feed mechanism for seed metering. J. of agric. Engg. In Agric. Res.

Baruah D.C. (2006): Comparative assessment of manual paddy drums seeders. J. of Agri. Engg.

Behera, B. K., Swain, S., Sahoo, P.K. and Behera, D. (1995): Evaluation of seeding devices for dry land paddy. /1M4.26 (4): 17-21.

Bernacki, H. R. (1972): Seeding machines. Agricultural machines theory and construction. U.S Department of Commerce, National Technical Information Service, USA. Vol.1.

Çelik, A. and Altikat, S. (2012): Seeding performances of no-till seeders equipped with different furrow openers, covering components and forward speeds for winter wheat. J. of Agri. Sci., 18:226-238.

Bill,A.S. (1999): Hand Book of agricultural Engineering, Plant Production Engineering,vol-3,ASAE,USA.

CIMMYT (2014): Farm mechanization and conservation agriculture for sustainable intensification (FACASI) project.Market analysis for small mechanization Ethiopia,Ethiopia.

CSA (Central Statistical Agency) (2005): Report on area and production of major crops, private peasant holdings, meher season, Addis Ababa

CSA (Central Statistical Agency) (2011): Report on area and production of major crops, private peasant holdings, meher season, Addis Ababa.

CSA (Central Statistical Agency) (2013): Report on area and production of major crops, private peasant holdings, meher season, Addis Ababa.

Dash, R. C., Pradhan, S. C., Behera, D. and Mahapatra, M. (1993): Evaluation of bullock farming and power tiller farming systems for groundnut crop in the state of Orissa, India. J. of Agril. Mechanization in Asia, Africa and Latin America.

Dhiman, S.D.; Sharma, A.P. and Sachan, P.L. (1985): Seed-cum-fertilizer drill for higher wheat yields. Indian Farming. 35(5):37-39.

Dhruw, U. K. (2003): Design and fabrication of bullock drawn zero till seed cum fertilizer drill. M. Tech. (Agril. Engg.) Unpublished Thesis. IGKVV, Raipur,C.G.

Dorosh P and Rashid S. (2013): Food and Agriculture in Ethiopia: Progress and Policy Challenges. University of Pennsylvania Press. Philadelphia, USA.

Dubey, A. K. (2003): Teaching material for training on computer aided design and design methodology for agricultural machinery.National agricultural technology project on team of excellence on agricultural machinery design and development. CIAE, Bhopal. Pp 79.

Ethiopian Agricultural Research Organization (2000): National Crops Research Strategy. Addis Ababa, Ethiopia.

Ethiopian Agricultural Transformation Agency (EATA) (2014): Annual report transforming agriculture in Ethiopia. Addis Ababa, Ethiopia. http://www.ata.gov.et/wpcontent/uploads/Annual Report.

FAO (Food and Agriculture Organization of the United Nations) (2009): How to feed the world in 2050. (www.fao.org/fileadmin/templates/wsfs/docs/expertpaper/How to feed the World.

Friew Kelemu, Mubarake Mohammed, Abiy Solomon (2016): Developing and Introducing Pre-Harvest Implements. Melkassa Agricultural Research Center, Ethiopian Institute of Agricultural Research (EIAR). Ethiopia, unpublished.

Gat, Uri (1988): The weight of mass and the mess of weight. In Richard Alan Strehlow.Standardization of Technical Terminology: Principle and Practice second volume.ASTM International. pp. 45–48.

Gogoi, A.K. and Kalika, H. (1995): Effect of sowing methods and herbicide on weeds and growth and yield of wheat (Triticum aestivum). Indian Journal of Agronomy, 40(2): 209-211.

Gopalan, C., Sastri, S. B. V. and Balasubramanian, S. (2007): Nutritive value of Indian food s, National Institute of Nutrition (NN), ICMR, India.

Guarella, P., A. Pellerano, and S. Pascuzzi (1996): Experimental and theoretical performance of a vacuum seed nozzle for vegetable seeds. Journal of Agricultural Engineering,64 (1): 29-36.

Gupta, M. L., Vatsa, D. K. and Verma, M.K. (1999): Development and evaluation of multi crop planter for hill regions. AMA, 30(1): 17-19.

Gupta, R. A., Mohnot, P., Satasiya, R. M. and Marvia, R. B. (2004): Development and testing of a seed-cum-fertilizer drilling attachment to tractor-driven cultivator. J. of Agril. Mechanization in Asia, Africa and Latin America

Hansen, C. M., Rebertson L. S., Retzer H. J. and Brown H. M. (1962): Grain drill design from an agronomic standpoint. Transactions of the ASAE 5(1):008-010

ITSI-SU, January 26 (2011): Mass, volume and density of regularly and irregularly shaped object. Internet: http://www.pdesas.org/module/content/resources/14756/view.ashx.

Jagvir, Dixit; Belh, V.P. and Singh, Sukhbir (2004): No-till seed-cum-fertilizer drill in wheat crop production after paddy harvesting. Agricultural Mechanization in Asia. 35(1):19-22.

Kamruzzaman M and Mohammad HI. (2008): Technical efficiency of wheat growers in some selected sites of Dinajpur district of Bangladesh. Bang. J. Agri. Res.

Khan, A.S., M.A. Tabassum and J. Khan. (1990): Selection of seed-cum-fertilizer drill: technical consideration. Agri. Mech. Asia. 21: 35-39.

Khurmi, R.S. and Gupta, J.K. (2005): A Textbook of Machine Design. Eurasia Publishing House (Pvt.) Ltd., Ram Nagar, New Delhi, India.

Kumar, K., Naresh, N.K., Ojha, T. P. (1986): Design, construction and performance of manually operated seeding attachment for an animal-drawn cultivator. AMA, 17(2): 35-38.

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

Lara-L´opez, A., Chancellor, W. J., Kepner, R. A., and Kaminaka, M. S. (1982): A Two-Wheeled Tractor for Manufacture in M´exico. ASAE.25 (5): 1189–1194, 1203.

Maleki, M. R., J. F. Jafari, M. H. Raufat, A. M. Mouazen, and J. De Baerdemaeker (200: Evaluation of seed distribution uniformity of a multi-flight auger as a grain drill metering device. Biosystems Engineering, 94(4): 535-543.

Mohsenin, N. N. (1986): Physical properties of plant and animal materials, Vol-1. Goedan and Breach Science Publishers, New York.

Navneet Kumar Dhruwe(2016): Development of light weight five row animal drawn multi crop planter. Agricultural Engineering,India,unpublished.

Nicole MM, Jayne TS, and Bekele Shiferaw (2012): Wheat Consumption in Sub-Saharan Africa: Trends, Drivers, and Policy Implications. MSU International Development, Working Paper 127.

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

Obi, O. F., Anyadike, C. C. and Onyeke, C. O. (2014): Moisture-dependent physical properties of pigeon pea grown in nigeria. World Applied Sciences Journal.

Patil, A. S. (2011): Development and performance evaluation of bullock-drawn dry Paddy seed cum fertilizer drill. Unpublished M. Tech. thesis: Dr.B.S.K.K.V., Dapoli. (M.S.)

Pradhan, S. C. and Ghosal, M. K. (2012): Design modification of cup in cup feed metering seed drill for seed pattern characteristics study of paddy seeds. J. of Engg. and Tech. in India

Rashid S. (2010): Staple Food Prices in Ethiopia. A paper prepared for the COMESA policy seminar on “Variation in staple food prices: Causes, consequence, and policy options”, Maputo, Mozambique, 25-26, under the African Agricultural Marketing Project (AAMP).

Rangapara Dineshkumar J. (2014): Development of mini tractor operated picking type pneumatic plante.r Anand agricultural university,Godhra,

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

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

Unadi, A. and Gupta, C.P. (1994): Development of two-wheel tractor operated seed cum fertilizer drill. Agril. Mechanization in Asia, Africa and Latin America.

Seely, F. B., and Smith, J. O. (1995): Advanced mechanics of materials (IInd Ed.). John Wiley and Sons Inc. London.

Senger, S. M. (2002): Design and development of animal drawn seeder for rice cum green manure crops for biasi cultivation system. M. Tech. (Agril. Engg.) Thesis, Indira Gandhi Agricultural University. Raipur, Chhattisgarh.

Sengar, S. S., Nikhade, J. S., Tayade, N. H. and Quasim, M. (2010): Modification and Performance evaluation of rice cum manure crops seeder. J. of Agri. Engg., 4(1):8-12.

Shafii, S., and R. G. Holmes (1990): Air jet seed metering a theoretical and experimental study. Transactions of the ASAE,33(5): 1432-1438.

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

Singh, S. and Vasta, D. (2007): Development and evaluation of a light weight power tiller operated seed drill for hilly region. J. of Agril. Mechanization in Asia, Africa and Latin America.

Singh, R. C., G. Singh, and D. C.Saraswat (2000): Optimization of design operational parameters of a pneumatic seed metering device for planting cottonseeds. , 92(4): 429-438.

Timoshenko, S., and Youngh, D. H. (1964): Elements of strength of materials (FourthEd.). Affiliated East West Press, Pvt. Ltd. New Delhi.

Theodre,B.(1985):Mechanical Engineering Hand Book.Mc-GrawHill Company Inc.,New York,PP6-16.

Varnmakhasti, M. G., Mehdi, G. V., Hossein, M., Ali, J., Shahin, R., Mohsen, H. and Kamran, K. (2007): Some engineering properties of Paddy (var. Sazandagi). International J. of Agriculture and Biology.

Varshney, A. C., Bohra, C. P. and Narang, S. (1991): Design, development and evaluation of power tiller-drawn seed-cum-fertilizer drill. J. of Agril. Mechanization in Asia.

Verma,S.R. (1986): Small Farm Equipment for developing countries. The International Rice Research Institute, Manila Philipines., 254-255.

William Andrew (2007): Handbook of farm, dairy, and food machinery.Norwitch,NY,U.S.A.

APPENDICES

Appendix A

Physical properties of wheat Sample calculations

1) Size (mm)

$$\text{Size}= \sqrt[3]{\text{length} * \text{breadth} * \text{thickness}}$$

$$\text{Size} = \sqrt[3]{6.22 * 3.86 * 2.78}$$

$$=4.06\text{mm}$$

2) Surface area (mm^2)

$$\text{Surface area} = 13/11\ (\text{breadth} * \text{thickness}) * \text{length}$$

$$=13/11(3.86+2.78) \times 6.22$$

$$=48.81\ mm^2$$

3) Sphericity

$$\text{Sphericity} = \frac{\text{Size}}{\text{Length}} \text{x}100$$

$$= \frac{4.06}{6.22} \text{X}100$$

$$=65\%$$

4) Angle of repose (deg)

$$\theta = \tan^{-1}\left(\frac{2H}{D}\right)$$

$$= \tan^{-1}\left(\frac{2*20.65}{2.65}\right)$$

$$= 26.13^0$$

Table: A.1.Measured physical properties of Shorima wheat seed variety

Sr. No	L (mm)	B (mm)	T (mm)	Size (mm)	S.A (mm^2)	Sphericity	Thousand grain mass, gm	Angle of repose (deg)	B.D kg/m^3
1	6	3	2.45	3.53	38.64	0.58	23.8	27	770
2	6	3	2	3.6	38	0.6	23.5	27	772
3	6	3	2.95	3.75	42.19	0.62	23.1	26	775
4	6	3.3	3	3.90	44.67	0.65	23	25	769
5	6.6	3	2.6	3.72	43.68	0.56	23.5	27	771
6	6	3	2.4	3.50	38.29	0.58	23.9	26	770
7	6.1	2.6	3	3.62	40.37	0.59	22.9	28	777
8	5	3.3	2	3.20	31.31	0.64	22.5	27	769
9	6.6	3.8	3	4.22	53.04	0.63	22.8	25	768
10	6.35	3	3	3.85	45.02	0.60	21	26	769
11	6	3.45	3	3.96	45.73	0.66	22.9	28	770
12	6	3	3.8	4.08	48.21	0.68	23.1	27	769
13	6	3	2.6	3.60	39.70	0.60	23.8	27	765
14	5.75	3.3	3	3.84	42.81	0.66	23.7	26	771
15	6	3	2.7	3.64	40.41	0.60	23	28	772
16	6	2.7	2.5	3.43	36.87	0.57	23.5	26	775
17	5.8	3	3	3.73	41.12	0.64	23	27	770
18	7	3	3	3.97	49.63	0.56	22.3	27	776
19	6.1	3	3	3.80	43.25	0.62	22	26	769
20	7	3	2.95	3.95	49.25	0.56	24	26	770
Mean	6.11	3.07	2.79	3.74	42.61	0.61	23.06	26.6	770.85
S.D	0.44	0.25	0.40	0.23	5.08	0.03	0.72	0.88	2.94
Min	5	2.6	2	3.20	31.31	0.56	21	25	765
Max	7	3.8	3.8	4.22	53.04	0.68	24	28	777

Table:A.2.Measured physical properties of Digelu wheat seed variety

Sr. No	L (mm)	B (mm)	T (mm)	Size (mm)	S.A (mm^2)	Sphericity	Thousand grain mass, gm	Angle of repose (deg)	B.D kg/m^3
1	6	3	3	3.77	42.54	0.62	33.00	27	770
2	5.5	3.5	2.5	3.63	39.00	0.66	33.10	27	772
3	5	3	3	3.55	35.45	0.71	32.90	26	775
4	5.2	3.1	2.5	3.42	34.41	0.65	33.20	25	769
5	5	2.5	2	2.92	26.59	0.58	32.80	27	771
6	4.6	2.9	2.5	3.21	30.63	0.69	32.90	26	770
7	4.8	3	2	3.06	28.36	0.63	32.70	28	777
8	5.5	4	2.3	3.69	40.9	0.67	33.20	27	769
9	4.7	3	2	3.04	27.77	0.64	31.60	25	768
10	5	3	2.4	3.30	31.90	0.66	33.10	26	769
11	5.8	3.2	2.6	3.64	39.75	0.62	33.60	28	770
12	5.7	3.5	3.8	4.23	49.17	0.74	33.80	27	769
13	5.6	3	2.4	3.42	35.73	0.61	33.10	27	765
14	5	3	2.5	3.34	32.5	0.66	32.10	26	771
15	5.3	3.2	2.6	3.53	42.17	0.66	32.60	28	772
16	5.4	3.4	2.9	3.76	40.20	0.69	33.00	26	775
17	5.7	3.3	3	3.83	42.43	0.67	33.50	27	770
18	5.4	3.6	3.1	3.92	42.74	0.72	32.00	27	776
19	6	3	3.6	4.01	46.85	0.66	33.00	26	769
20	5	3.3	3.7	3.93	41.36	0.78	32.90	26	770
Mean	5.31	3.17	2.72	3.56	37.527	0.67	32.90	26.6	770.8
S.D	0.41	0.31	0.53	0.34	6.4	0.04	0.52	0.882	2.94
Min	4.6	2.5	2	2.92	26.59	0.58	31.60	25	765
Max	6	4	3.8	4.23	49.17	0.78	33.80	28	777

Table:A.3.Measured physical properties of Hidase wheat seed variety

Sr. No	L (mm)	B (mm)	T (mm)	Size (mm)	S.A (mm$^{2)}$	Sphericity	Thousand grain mass, gm	Angle of repose (deg)	B.D kg/m^3
1	7	4.5	3	4.55	62.04	0.65	39.7	27	770
2	6	3	2.5	3.55	39	0.59	39	26	772
3	6.7	3	3	3.92	47.50	0.58	38.1	25	775
4	7.5	3.5	3.4	4.46	61.15	0.59	39	27	769
5	6.5	3	3.5	4.08	49.93	0.62	39.2	26	771
6	6	2.5	2.5	3.34	35.45	0.55	38	28	770
7	7	3	3	3.97	49.63	0.56	39.9	27	777
8	7	3.6	3.5	4.45	58.73	0.635	38	25	769
9	6.5	3.5	3	4.08	49.93	0.62	38.9	26	768
10	7	3.5	3.6	4.45	58.73	0.63	39	28	769
11	6.5	3.5	3.5	4.30	53.77	0.66	38.7	27	770
12	6.5	4	3	4.27	53.77	0.65	36	27	769
13	7	4	3	4.37	57.90	0.62	37.1	26	765
14	7.5	3.5	3	4.28	57.61	0.57	39.1	28	771
15	6	3	3	3.77	42.54	0.62	38.9	26	772
16	6.5	3	3	3.88	46.09	0.59	38	27	775
17	6.5	3.5	3	4.08	49.93	0.62	39.5	27	770
18	6	3.5	3	3.97	46.09	0.66	39	26	776
19	7	3.5	3	4.18	53.77	0.59	38	26	769
20	7	3.5	3	4.18	53.77	0.59	37.9	25	770
Mean	6.68	3.40	3.07	4.11	51.37	0.61	38.55	26.5	770.9
S.D	0.46	0.44	0.29	0.31	7.20	0.03	0.92	0.94	2.94
Min	6	2.5	2.5	3.34	35.45	0.55	36	25	765
Max	7.5	4.5	3.6	4.55	62.04	0.66	39.9	28	777

Table: A.4.Measured Physical Properties of Kekeba Wheat Seed Variety

Sr. No	L (mm)	B (mm)	T (mm)	Size (mm)	S.A ($mm^{2)}$	Sphericity	Thousand grain mass, gm	Angle of repose (deg)	B.D kg/m^3
1	6	3.5	2.5	3.74	42.54	0.62	26.32	26	768
2	6	4	2.5	3.914	46.09	0.65	26.4	26	772
3	6.5	3.5	3	4.0	49.93	0.62	25	25	775
4	6	3	2	3.30	35.4	0.50	26.6	27	769
5	6.2	3.5	2.5	3.78	43.96	0.61	25	26	771
6	6.5	4	2.5	4.02	49.91	0.61	25.9	28	770
7	5.5	4.5	2.5	3.95	45.5	0.71	25.8	27	777
8	6.5	3.5	3	4.08	49.93	0.62	26	25	769
9	7	4.5	3.5	4.79	66.18	0.68	26.1	26	768
10	6.5	4	2.5	4.02	49.93	0.61	26	28	769
11	6.8	4	3	4.33	56.25	0.63	25.8	27	764
12	5.25	4	2.75	3.86	41.88	0.73	26.3	27	769
13	6.55	3.5	3	4.09	50.31	0.62	26.35	26	765
14	6.25	3.25	2.5	3.70	42.47	0.59	27	28	771
15	6.55	3.5	2.5	3.85	46.44	0.58	24.9	26	772
16	6.25	4.5	3	4.38	55.39	0.70	25.9	27	775
17	6.5	3.5	3.5	4.30	53.77	0.66	26.36	27	770
18	6.2	4.5	2.5	4.11	51.29	0.66	25.98	26	776
19	5.5	4	3.25	4.15	47.12	0.75	25.87	26	769
20	6	4.5	3.25	4.44	54.95	0.74	26	26	765
Mean	6.22	3.86	2.78	4.04	48.96	0.65	25.97	26.5	770.2
S.D	0.44	0.46	0.39	0.31	6.61	0.05	0.52	0.88	3.48
Min	5.25	3	2	3.30	35.45	0.55	24.9	25	764
Max	7	4.5	3.5	4.79	66.18	0.754	27	28	777

Table: A.5.measured Physical Properties of Ogolicho Wheat Seed Variety

Sr. No	L (mm)	B (mm)	T (mm)	Size (mm)	S.A (mm^2)	Sphericity	Thousand grain mass ,gm	Angle of repose (deg)	B.D Kg/m^3
1	6.3	3.1	2.2	3.50	39.46	0.55	32.4	27	770
2	6.1	4.2	3.7	4.55	56.95	0.74	33	26	775
3	5.5	2.6	2.2	3.15	31.2	0.57	32.3	25	769
4	4.6	2.3	2	2.76	23.37	0.60	33.5	27	771
5	6.8	3.5	3	4.14	52.23	0.61	32.5	26	770
6	6.35	3.3	2.7	3.83	45.02	0.60	32.1	28	777
7	6.6	3.55	2.9	4.08	50.31	0.61	31	27	769
8	6.3	3.4	2.4	3.71	43.18	0.59	33	25	768
9	6.3	3.5	3.6	4.29	52.86	0.68	33.3	26	769
10	5	2.6	2.4	3.14	29.54	0.62	32.6	28	770
11	6.6	3.4	3	4.06	49.92	0.61	32.4	27	769
12	7	3.9	3	4.34	57.08	0.62	32.4	27	765
13	6.2	3	2.5	3.59	40.3	0.57	32.6	26	771
14	6.7	3.9	3.3	4.41	57.01	0.65	32.8	28	772
15	6.9	3.5	3.3	4.30	55.45	0.62	33.1	26	775
16	6.4	3.25	3	3.96	47.27	0.61	32.9	27	770
17	6.15	3.5	2.95	3.98	46.87	0.64	33	27	776
18	6.8	3.6	3	4.18	53.04	0.61	32	26	769
19	6.7	3.1	2.5	3.73	44.34	0.55	32.4	26	770
20	6.45	3.55	3	4.09	49.92	0.63	32.1	25	770
Mean	6.28	3.33	2.83	3.89	46.26	0.61	32.57	26.5	770.8
S.D	0.61	0.46	0.46	0.46	9.53	0.04	0.55	0.94	2.93
Mini	4.6	2.3	2	2.76	23.37	0.55	31	25	765

Appendix B

Laboratory Test

Table: B.1. Seed rate (kg/ha) calibration of wheat crop for each furrow openers

Samples	F.O-1 (gm)	F.O-2 (gm)	F.O-3 (gm)	F.O-4 (gm)	F.O-5 (gm)	F.O-6 (gm)	Mean	SD	Seed rate(kg/ha)
I	45.11	48.98	41.21	42.5	45.01	43.89	44.45	2.68	111.12
II	45.5	47.5	44.01	40.5	39.6	43.9	43.5	2.99	108.75
III	38.98	47.99	44.92	45.9	42.85	45.18	44.3	3.09	110.75
IV	49.56	43.93	45.25	45.98	48.11	44.98	46.3	2.12	115.75
V	45.11	48.6	42.1	45.9	42.12	44.01	44.64	2.26	111.6
	Average seed rate, kg/ha								111.59

Note: - F.O means Furrow Opener

Table: B.2. Seed uniformity collected for 2.5km/h speed operation and a 4.5mm cup depth metering

Parameters	Test no.	Mat Length , m					
		1	2	3	4	5	Average/m
Number of seed fallen	1	32	35	32	36	34	33
	2	31	34	35	32	34	33
	3	32	35	34	33	32	33
Average		31	34	33	33	33	32.8

Field Test

Table: B.3.Seed drill performance evaluation result on different speed operation

Rep.	seed drill width, m	Distance, m	Time ,s	Time Loss, s	Speed, km/h	Fuel Consumption		TFC, ha/hr	EFC, ha/hr	FE,%
						Total,ml	l/hr			
1	1.2	22	63	7	1.41	24	1.31	0.16	0.14	80.24
2	1.2	22	62	9	1.45	24.3	1.45	0.17	0.13	76.93
3	1.2	22	60	5	1.39	24.8	1.52	0.16	0.14	87.65
mean					1.41	24.36	1.42	0.17	0.13	81.61
1	1.2	22	47	5	2.05	20.7	1.55	0.24	0.18	74.29
2	1.2	22	44	4	2.01	21.1	1.68	0.24	0.19	82.09
3	1.2	22	41	5	2.1	19.9	1.44	0.25	0.20	81.98
mean					2.05	20.56	1.49	0.24	0.19	79.45
1	1.2	22	37	4	2.49	15.2	1.47	0.29	0.23	77.57
2	1.2	22	35	5	2.5	16.1	1.65	0.3	0.23	79.2
3	1.2	22	36	5	2.51	14.8	1.48	0.30	0.23	76.96
mean					2.5	15.36	1.53	0.3	0.23	77.9

Table: B.4.Wheel slips percentage determination

Replication	Speed, km/h	Distance covered in 10 revolution		Wheel Slip,%
		Under no load, m	Under Load, m	
1	1.4	16.02	15.21	5.05
2		15.96	15.19	4.82
3		15.92	15.13	4.96
Mean		15.967	15.177	4.94
1	2	15.85	14.91	5.93
2		15.82	14.84	6.19
3		15.79	14.77	6.45
Mean		15.82	14.84	6.19
1	2.5	15.62	14.29	8.51
2		15.56	14.21	8.67
3		15.51	14.14	8.83
Mean		15.563	14.21	8.67

Table: B.5. Seed germination rate obtained during field test

Speed, km/h	Replication	Field germination count Per 1.2 m^2		
		Recommended	Count	% Germinated
1.4	1	377	369	97.87
	2	377	371	98.40
	3	377	372	98.67
	4	377	368	97.61
	5	377	365	96.81
	6	377	369	97.87
	Average	377	369	97.87
2	1	377	359	95.22
	2	377	363	96.2
	3	377	369	97.87
	4	377	360	95.49
	5	377	367	97.34
	6	377	371	98.40
	Average	377	364.83	96.77
2.5	1	377	355	94.16
	2	377	356	94.42
	3	377	366	97.08
	4	377	351	93.10
	5	377	369	97.87
	6	377	356	94.42
	Average	377	358.83	95.18

Table: B.6. Angle of repose and material characteristics (CEMA, 1979)

0°-19° *Angle of repose*	20°-29° *Angle of repose*	30°-34° *Angle of repose*	35°-39° *Angle of repose*
Material characteristics			
Uniform size, very small rounded particle, either very wet or very dry, such as dry silica sand, cement, wet concrete, etc.	Rounded, dry polished particles, of medium weight, such as whole grain and beans.	Irregular, granular or lumpy materials of medium weight, such as anthracite coal, cottonseed meal, clay, etc.	Typical common materials such as bituminous coal, stone, most ores, etc.

Appendix C

Production and Operational Cost of the planter

Table: C.1. Materials for constructions of the planter and its cost

No	Type of material	Standard size	Unit Price	Used material	Total Price
1	Sheet metal 2 mm	2 x1000x2000 mm	770	630,000 mm^2	170.00
2	Sheet metal 4 mm	4 x1000x2000 mm	1750	376,800mm^2	285.00
3	Sheet metal 3 mm	3 x1000x2000 mm	1500	12,000 mm^2	9.00
4	Plate 5mm	5 x1000x2000 mm	2175	18,100 mm^2	19.68
5	Hollow Square pipe	40 x 40 x 3000 mm	350	6,820 mm	795.50
6	Angle iron	3 x 30 x 6000mm	310	2500 mm	129.16
7	Round bar	Ø8x6000 mm	120	1,300 mm	26.00
8	Round bar	Ø20x6000 mm	598	1,250 mm	124.58
9	Round bar	Ø30x6000 mm	920	1,530 mm	234.60
10	Circular hollow pipe	Ø34 x 6000 mm	725	850 mm	102.71
11	Hinge	5x20x2000 mm	600	700 mm	180.00
12	Metal bolt and nut	2.5”	10	3pcs.	30.00
13	Metal bolt and nut	M-8x80	7.5	15pcs.	112.5
14	Metal bolt and nut	M-12x100	9	5pcs.	45
15	Electrode	Ø 2.5	130	1,200 mm	130
16	Chain	Ø 2.5(pack)	130	1pack	130.00
17	Sprocket	15 teeth	400	1pcs	400.00
18	Sprocket	24 teeth	520	1pcs	520.00
19	Bearing(pcs)	P204	345	2pcs	690.00
20	Bearing(pcs)	P207	345	2pcs	690.00
21	Plastic bucket		30	1	30.00
22	paint		200	2pcs	400.00
Subtotal					5253.73 EB

Table: C.2. Machine and labor costs

No.	Type of machine	Machine cost/hr	Working hour	Cost	Labour Cost/hr	Working hour	Total Price
1	Universal metal cutting	11	3	33	6.25	3	18.75
2	Welding machine	6	21	126	6.25	21	131.25
3	Power hack saw	4	8	32	6.25	8	50.00
4	Lath machine	15	8	120	6.25	8	50.00
5	Rolling machine manual	3.5	0.5	1.75	6.25	0.5	3.12
6	Radial drill machine	3	4	12	6.25	4	25.00
7	Grinding machine	1	5	5	6.25	5	31.25
8	Bending machine	3.5	2	7	6.25	2	12.5
Subtotal				336.75EB			321.87 EB

Table: C.3. Cost summary

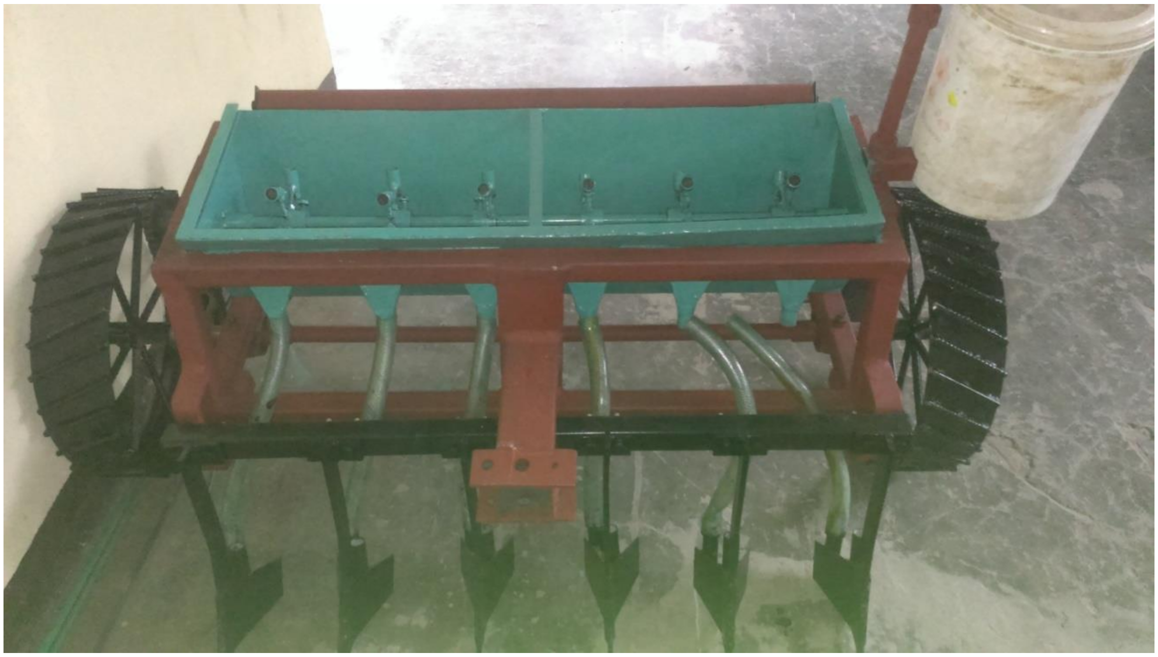
No.	Cost Variables	Summary
A	Raw Material Cost	5253.73EB
B	Material Wastage 2.5%	131.34EB
C	Machine Cost	336.75EB
D	Labor Cost	321.87 EB
E	Overhead Cost 5%(C+D)	32.93EB
F	Profit 10 %(A+B+C+D+E)	607.66EB
G	Sells Tax 15 %	1002.64EB
	Selling Price	**7686.92EB**

Table: C.4.Main Technical Specifications for Dongfeng Power Tiller

Model of Power Tiller		Unit	DF-15L
Structure weight	without rotavator	Kg	360
	with rotavator		465
Working Weight (with rotavator)		kg	505
Turning speed of rototilling shaft		rpm	188
Overall dimensions (L×W×H)		mm	2680×960×1250
Number of blades		PCS	18
Rototilling width		mm	600
Type of tractor			Single axle, dual-purpose for both tractor &drive
Traveling speed	Forward	km/h	1.4, 2.5, 4.1, 5.3, 9.4, 15.3
	Reverse		1.1, 3.8
Tyre Size			6.00-12
Wheel track		mm	800,740,640,580(normally use 800)
Min.ground clearance		mm	185
Min.turning radius		m	0.9(with no rotavator)
Model of engine			S1100A2N
Type of engine			Horizontal 4-stroke
Bore×stroke		mm	100×115
Total displacement		L	0.903
Compression ratio			19.5:1
Turing speed of crankshaft		rpm	2000
1-hour rated output		kW/hp	10.50/14.30
12-hour rated output		kW/hp	9.8/13.33
Specific fuel consumption		g/kW.h	257
Specific lube oil consumption		g/kW.h	≤2.04

Appendix D

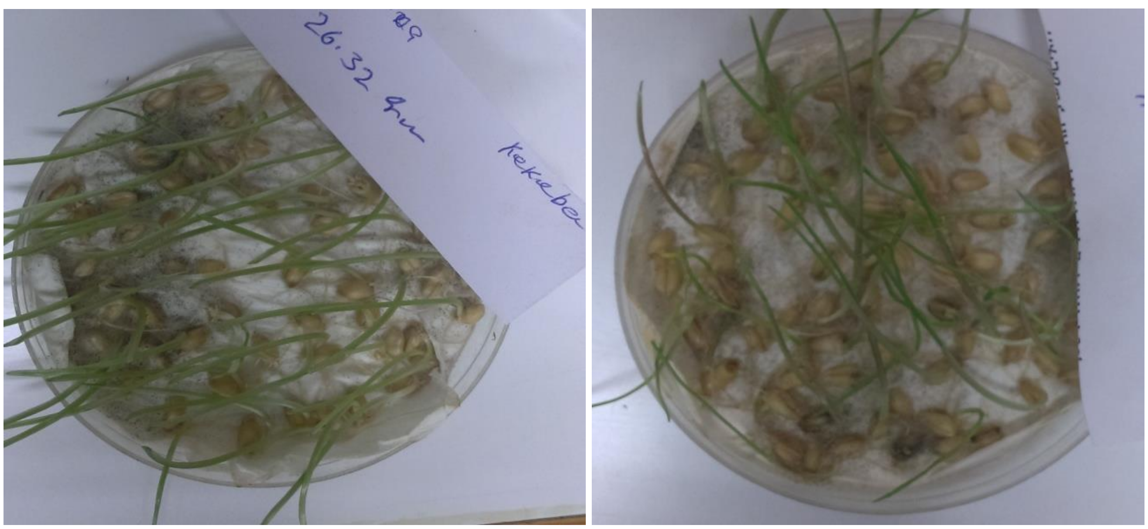
1. Photographic view of seed rills and germination results



a) Fully fabricated seed drill

b) Under fabrication

c) Isometric Drawing



d) Germination test

e) Seed emergence stage