DESIGN, FABRICATION AND TESTING OF A MANUALLY OPERATED SINGLE-ROW MULTI-CROP PLANTER

BY

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FEBRUARY, 2010

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

FEBRUARY, 2010

DECLARATION

I hereby declare that this project work titled "**Design, Fabrication and Testing of a Manually Operated Single-Row Multi-Crop Planter**" is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

Omolayo-Jimoh, Ibukun Blessing	25/02/10 Date

CERTIFICATION

This project entitled "Design, Fabrication and Testing of a Manually Operated Single-Row Multi-Crop Planter" by Omolayo-Jimoh Ibukun Blessing meets the regulations governing the award of the degree of Bachelor of Engineering (B.ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

17/02/2010

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Date

18/02/10

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Date

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External Examiner

09-02-10

Date

DEDICATION

I dedicate this project work to God Almighty for His unfading love throughout my stay in the Federal University of Technology, Minna.

ACKNOWLEDGEMENTS

First and foremost, I thank the Almighty God for His infinite mercy, love, protection and also for giving me the adequate strength needed for the successful completion of this project work.

I wish to express my profound gratitude to my supervisor Engr. Dr. Gbabo Agidi, Assistant Director/Head, Agricultural Engineering and Mechanization Division of the National Cereals Research Institute Badeggi, for his efforts, continuous help, support and immense contributions to see to the successful completion of this project work.

My sincere appreciation goes to my Head of Department Engr. Dr. A. Balami, and also the entire members of staff of the Department of Agricultural and Bioresource Engineering for the roles they played in ensuring the successful completion of this project.

I also wish to express my profound gratitude to my Parents Mr. Omolayo Jimoh and Mrs. Patricia Omolayo for their parental care and total support throughout the period of my academic pursuit and especially during the period of this project.

I also wish to acknowledge the contributions of Ugwuoke Ikechukwu Celestine of the Department of Mechanical Engineering. His inspiring advice and constant encouragement have so much influence on the accomplishment of this work. He is truly a pillar of strength in my life. I am thankful for his genuine interest in my project work, and his efforts in motivating me through to the end.

ABSTRACT

This project work focused on the design and fabrication of a manually operated single-row multi-crop planter that is cheap, easily affordable by the rural farmers, easy to maintain and less laborious to use. The multi-crop planter has the capability of delivering the seeds precisely with uniform depth in the furrow, and also with uniform spacing between the seeds. . The seed planter consist of the main frame, adjustable handle, seed hopper, seed metering device, adjustable furrow opener, adjustable furrow closer, drive wheels, seed tube and ball bearings. Most of these were fabricated from mild steel material, except for the metering mechanism which was made from good quality wood (mahogany) and the seed funnel and tube, which were made from rubber material. The seed metering mechanism used for this work was the wooden roller type with cells on its periphery. It was designed to be interchangeable to allow for the different varieties and types of seeds. The single-row multi-crop planter is very simple to use, the various adjustments are made with ease, and it is maintenance free, except for the bearings which needs to be lubricated from time to time to allow the planter's ground wheel to move freely. For this design, the drive shaft directly controls the seed metering mechanism which eliminates completely attachments such as pulleys, belt systems, and gears thereby eliminating complexities which increase cost, and increasing efficiency at a highly reduced cost which is the focus of this project work. The results obtained from the trial tests showed that the planter functioned properly as expected with a planting capacity of 0.0486 hectare/hr for maize, 0.0405 hectare/hr for cowpea, and 0.0270 hectare/hr for soya beans. Visual inspection of the seeds that were released from the planter's metering mechanism showed that there were no visible signs of damage.

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Symbol	Definition
V_H	Volume of the hopper
A_{HM}	Surface area of the hopper material
V_{HM}	Volume of the hopper material
t_{HM}	Thickness of the hopper material
M_{HM}	Mass of the hopper material
ρ_{HM}	Density of the hopper material
W_{HM}	Weight of the hopper material
A_{MFM}	Surface area of the main frame material
w_{MFM}	Width of the main frame material
V_{MFM}	Volume of the main frame material
t_{MFM}	Thickness of the main frame material
M_{MFM}	Mass of the main frame material
ρ_{MFM}	Density of the main frame material
W_{MFM}	Weight of the main frame material
V_H	Volume of hopper
M_G	Mass of grain
ρ_G	Density of grain
W_G	Weight of grain
d	Diameter of the shaft

M_b	Bending moment
M_t	Torsional moment
k_b	Combined shock and fatigue factor applied to bending moment
k_t	Combined shock and fatigue factor applied to torsional moment
S_a	Allowable stress
R_1, R_2	Reactions at the support
W_{GRH}	Weight of grain resting on the hopper
W_{GRS}	Weight of grain resting on the shaft
V_{GRS}	Volume of grain resting on the shaft
M_{GRS}	Mass of grain resting on the shaft
F_P	Planter push force
F_R	Horizontal soil resistance force
R_S	Soil frictional resistance force
ϕ	Angle of friction
θ	Angle between planter handle and the horizontal plane
W_P	Weight of planter
D_{FM}	Maximum draft
A_{FO}	Surface area of furrow opener in contact with soil
C_{PA}	Capacity of planter in terms of area covered per time
C_{PN}	Capacity of planter in terms of number of seeds per time

CHAPTER ONE

INTRODUCTION

1.1 Project Background

Agriculture is the oldest of all man's pre occupation. It was decreed by God that man must till the soil before he can feed himself (Genesis 3: 23). Therefore, Agriculture (farming) is as old as man. The hand tools are all that were available to man in the early days of crop cultivation until the advent of industrial revolution that swept across Europe in the 17^{th} century, that machines were developed to complement human effort in this regard. In Africa, especially in the sub-Saharan Africa countries, the use of hoes and cutlasses for crop cultivation is still prevalent due to abject poverty within the region. 95% of farmers can not afford the cost for sophisticated farming machines used in the western world hence this attempt to design and fabricate a seed planting machine that will be cheap and affordable to our rural farmers in their quest to produce more food for the teeming population in Nigeria.

1.2 Seed Planter

A seed planter is a device or tool used to sow seeds over a certain area. In small scale landscaping and gardening, manually operated seed planters designed for smaller tractor use, such as the ones shown in Figures 1.1 and 1.2 can be used, while in large farm cultivations, the planter can be a massive device as shown in Figure 1.3, usually attached to the back of a tractor. Seed planters work in one or two ways. Some will make a small hole in the ground and lay the seed in, then cover the seed and hole back. The process is usually covered in a single pass. Others will spread the seed out on the ground where it will eventually take root by itself. For the manually operated seed planters, there is usually a guide offset from the planter's wheel that will mark out the next row, allowing the user to keep neatly spaced rows. All the operator will do after planting the first row is to follow the wheel guide for the second row. This does not only save time, but allows for a more efficient utilization of available space.

Fig. 1.1: Two Rows Seed Planter

Fig. 1.2: Three Rows Seed Planter

Seed planters depend on both human and machine effort for its operation. It plant seeds at a greater speed than human. It can be adapted to the different varieties and kinds of seeds simply by interchanging the planter's seed metering mechanism. For manually operated seed planters, a little effort is needed by the operator who gives it a slight but steady push through the handle for the planting process. The main frame carries the seed container, the adjustable soil opener (furrow opener) and the furrow closer. The furrow opener determines the depth at which the seeds are to be buried in the planting field. The seed planter is very simple to use, the various adjustment are made with ease, and it is maintenance free except for the bearing lubrication which allows the wheel to move freely.

Fig. 1.3: Trailed Seed Planter

1.3 Objectives

The objectives of this project include the following:

1) Design, fabrication and testing of a cheap and affordable manually operated single-row multi-crop planter using wooden cells metering mechanism suitable for use by rural farmers and youths.
2) Produce a planter that delivers the seeds in the furrow precisely at uniform depths in a single file (in a straight line) and with uniform spacing between seeds.
3) Highlight the positive impact of mechanization on crop cultivation
4) Demonstrate the application of engineering technique to reduce human labour.

1.4 Justification

Successful crop production requires optimum planting performance and substantial preparation. Ninety percent of producing a crop is accomplished during sowing. Although high yield in crop production certainly requires field scouting and management inputs during the planting season, problems created by poor planting cannot be corrected during the season. The planting process and pre-planting decisions, including hybrid choice, seeding rate, seed placement, and planting date determine many important factors which influence yield. Poor seed spacing and depth uniformity may affect yield potential as much as plant population. Research indicates that most growers could improve their yields simply by just improving planter's performance. The project work simply focused on the design and fabrication of a cheap and affordable manually operated single-row multi-crop planter with an interchangeable wooden cell seed metering mechanism to accommodate the different varieties and types of seeds. The essence of the design was to improve on seed spacing and depth uniformity in the seed planting process currently being practiced by rural farmers in Nigeria. The benefits of the project includes: Increased agricultural output; Reduced production cost, making the planter cheap and affordable; Makes crop cultivation less laborious; Makes farming more attractive to youths; Reduced urban migration by youths in search of white collar jobs; Ensures capacity utilization of available farm land; Saves tremendous amount of time during farming.

1.5 Project Scope

The project scope covers the design, fabrication, and testing of a cheap and affordable manually operated single-row multi-crop planter with an interchangeable wooden cell seed metering mechanism, capable of delivering the seeds precisely with uniform depth in the furrow, in a straight line, and with uniform spacing between the seeds.

CHAPTER TWO

LITERATURE REVIEW

2.1 General

Over eighty percent of mankind diet is provided by the seeds of some plants species. The root of seed cultivation is believed to have begun in the areas of the present day Turkey and the Middle East about 10,000 years ago. This was where the evidence of people taking wild grasses, using the seeds for food and planting some for the next year's food, was first discovered. These seeds are what is now known as cereals and make up large percentage of the world food supply (Binswanger, 1986). Early seed planting was done by hand. Seeds were planted by a method known as broadcasting. Broadcasting is simply throwing the seeds onto the ground. The system made it more difficult to weed and harvest the crops and birds eat up most of the seeds before it germinates. A dibbler was later used for some crops. A dibbler is a board with holes evenly spread apart. Normally, a sticker would be pushed through the dibbler holes creating holes in the soil, seeds are then placed in these holes. It was a very effective but tedious and time consuming method. The method was first used in Mesopotamia about 1500 B.C. In 1970, Jethro Tull invented the first seed drill (Mayne, 1956). The implement would cut small channels into the soil and the seed is then dropped into the channel and covered. The seed drill had many advantages over the broadcast system. First, a much higher percentage of seeds germinated and produced crops. Less seeds were lost to birds or other animals. Finally, with rows, it was easier to weed and harvest the crops. The invention was met with scepticism and was not really appreciated or accepted till after Jethro Tull's death in 1741.

2.2 Industrial Revolution

When we think of the phrase "industrial revolution" today, we think of huge smoking chimneys, large families living in tiny tenement houses, grim cotton mills, coal mines and work homes. For many people in the 17th, 18th and 19th century, the vast majority of the working population spent their days working on the land. But from the middle of that century all this began to change with James Watt's improvement to the steam engine, machine tools and other technological innovation. Britain moved from an economy based on agriculture to one based on industry and were able to transform their society's capacity to feed and sustain a growing population. The industrial revolution was made up of four different but connected revolutions

1) The population revolution
2) Agriculture revolution
3) Transport revolution and
4) Manufacturing revolution.

Agricultural revolution led to a large increase in the production of crops. With mechanized method of farming, new farm implements were employed which led to the increase in the production rates.

2.3 Agricultural Mechanization/Machinery

When viewed across the span of the 20th century, the effect that mechanization has had on farm productivity and on society itself is profound. At the end of the 19^{th} century it took, for example, 35 to 40 hours of planting and harvesting labour to produce 100 bushels of corn. A hundred years later, producing the same amount of corn took only 2 hours 24minutes and fewer workers were needed on the farm. Throughout most of its long history, agriculture, particularly the growing of crops, was a matter of human sweat and draft animal labour. Oxen, horses and mules pulled ploughs to prepare the soil for seed and hauled wagon filled with the harvest, up to 20% of which went to feed the animals themselves. The rest of the job required backbreaking manual labour such as planting the seed, tilling or cultivating to keep down weeds and then reaping the harvest. It was a complex and arduous task. This problem gave people with inventive flare the urge to develop tools to ease the farming burdens. The manufacture of the tractor as shown in Figure 2.1 gave room for dramatic changes in farm cultivation that followed (Ehui and Polson, 1992).

Julious Nyerere, then President of Tanzania is reported to have told a Western Journalist back in 1970, “We are using hoes to cultivate our crops, if two million farmers in Tanzania could jump from the hoe to the oxen plough, it would be a revolution. It will double our living standard and triple our products. This is the kind of thing China is doing”. Thirty years later in Tanzania, as in most countries of sub-Saharan Africa, the hand hoe is still used for eighty percent of the cultivated land, with only fifteen percent done with draught animal technology (DAT) and the remaining five percent using tractors. This is an indication that we have not yet “arrived” as far as mechanization of agricultural implements is concerned (FAO, 2003).

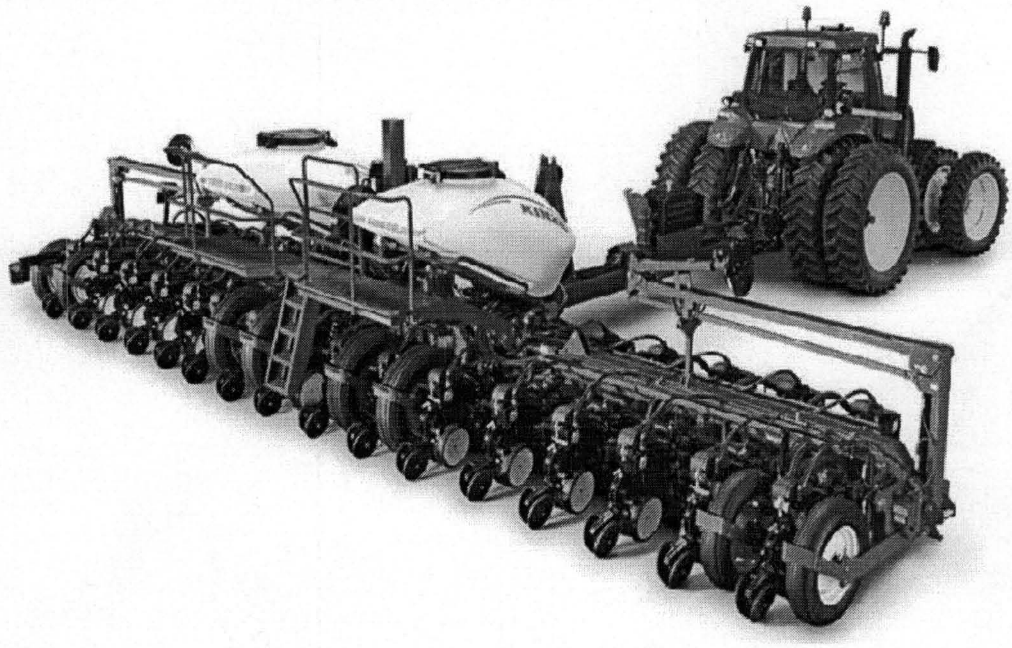

Fig. 2.1: Tractor attached with multi-row seed drills

Agricultural Mechanization is the use of mechanical powered equipment and machinery in farming to boost crop production. Mechanization not only allows previously unutilized land to be cultivated, but also results in timelier field operation. It reduces the need for hired labour to perform power intensive and arduous field operation such as hoeing. Agricultural machinery is a device used to till soil and to plant, cultivate, harvest and process crops. Since ancient times when cultures first began cultivating plants, people have used tools to help them grow and harvest crops. They use pointed tools to dig and keep soil loosed, and sharp, knifelike objects to harvest ripened crops. Modification to these early implements led to the development of hand tools that are still being used today in small scale gardens. Much of the world's arable land is still being tilled under conditions that do not permit the use of expensive modern methods.

2.4 Implements/Equipment for Land Preparation and Sowing Crops

Many implements have been developed for the activities involved in planting crops. The activities include loosening the soil, planting, weeding, fertilizing and combating pest. Ground is broken by ploughs to prepare the seed-bed. A plough consists of a bladelike object that cuts under, then lifts, turn and pulverizes the soil. Harrows are used to smoothen the ploughed land and sometimes cover the seeds and fertilizer, with earth. The disk harrow is used to cut-up the crop residues before ploughing and to bury weeds during seedbed preparation. The seeds are planted by broadcasting, or by the use of drills which produce continuous furrows of uniform depth, while the seed is planted along in the furrow and covered with earth. The uses of agricultural machinery substantially reduces the amount of human labour needed for raising enough crops and have food to feed the nation. The basic objective of sowing operation is to put the seed and fertilizer in rows at desired depth and seed to seed spacing, cover the seeds with soil and provide proper compaction over the seed. The recommended row to row spacing, seed rate, seed to seed spacing and depth of seed placement vary from crop to crop and for different agro-climatic conditions to achieve optimum yields. Improved seed-cum-fertilizer drills are provided with seed and fertilizer boxes, metering mechanism, furrow openers, covering devices, frame, ground drive system and controls for variation of seed and fertilizer rates. The major difference in the different designs of seed drills/planters is in the type of seed and fertilizer metering, and furrow openers.

2.5 Traditional Sowing Methods

Traditional methods include broadcasting manually, opening furrows by a plough and dropping seeds by hand. For sowing in small areas, dibbling i.e. making holes or slits by a stick or tool and dropping seeds by hand is practiced. Multi-row traditional seeding devices with manual metering of seeds are quite popular with experienced farmers. Traditional sowing methods have the following limitations:

i. In manual seeding, it is not possible to achieve uniformity in distribution of seeds. A farmer may sow at desired seed rate but inter-row and intra-row distribution of seeds is likely to be uneven resulting in bunching and gaps in the field.
ii. Poor control over depth of seed placement.
iii. The effect of inaccuracies in seed placement on plant stand is greater in the case of crops sown under dry farming conditions.
iv. Labour requirement is high.
v. Placement of seed at uneven depth may result in poor emergence because subsequent rains bring additional soil cover over the seed and affect plant emergence.

2.6 Seed Metering Devices

Amount of seeds in rows is an important factor in crop production, which can affect growth and yield and this to a great extent depends on the performance of the metering mechanism of the planter. Metering mechanism is the heart of sowing machine and its function is to distribute seeds uniformly at the desired application rates. In planters it also controls seed spacing in a row. A seed planter may be required to drop the seeds at rates varying across wide range. Proper design of the metering device is an essential element for satisfactory performance of the seed planter. Common type of metering devices used on seed planters are:

1) **Adjustable orifice with agitator:** In this type of metering device, seed flow is regulated by changing the size of opening provided at hopper bottom. An agitator fixed above seed

opening helps in continuous flow of seeds. This does not give precise control over the seed rate and uniformity of distribution in rows. Many designs of conventional animal and tractor operated machines have adopted this mechanism on account of its simplicity and low cost. Figure 2.4 shows a closed hopper system for easy seed plate change.

2) **Fluted roller (Standard):** Fluted roller metering mechanism is a more positive metering device. Axial or helical flutes are machined or cast on an aluminium, cast iron or plastic roller. Rotation of fluted roller in a housing, filled with seeds, causes the seeds to flow out from roller housing in a continuous stream. Seed rate is controlled by changing exposed length of fluted roller in contact with seeds and fairly accurate seed rate can be achieved for a variety of medium size seeds like wheat, soybean, sunflower and safflower etc. However, metering of small seeds like mustard and sesamum at 2 to 5 kg/ha seed rate is not accurate with normal size flutes, designed for seed rates of 20 to 120 kg/ha. Therefore, fluted rollers with smaller size flutes were developed.

3) **Fluted roller (Small Flutes):** For sowing of small seeds like rapeseed-mustard and sesamum fluted roller with small flutes have been developed at Pantnagar and Ludhiana. These can be fitted by replacing the standard fluted rollers on the seed planter. The roller is provided with 10 small flutes of 2x2 mm size. Low seed rates of 3 to 5 kg/ha can be achieved with this metering roller with an accuracy of ± 10 per cent.

4) **Vertical rotor/Roller with cells:** Vertical rotors with cells are suitable for metering individual or hill of seeds. The rotor with grooves or cells on its periphery is fixed in the hopper. The size and number of cells on the rotor are according to the size of seed and desired seed rate. A cut-off device is provided above the rotor for regulating the flow of seed to cells. In some designs seed rotor is fixed in a secondary hopper and rotor lifts the seeds in cells and drops these into seed funnel. For varying the seed rate and sowing different seeds, separate rotors are required.

5) **Plate with cells:** Horizontal, inclined or vertical plate with cell type metering mechanism picks and drops individual seed or a hill of seeds depending on design of cell on the plate. Spacing between seeds/hills is controlled by drive ratio and number of cells on plate. Separate plates are required for sowing different crops. It is desirable that seeds be graded and have high germination percentage for achieving recommended plant population and uniform seed spacing. Figures 2.2 and 2.3 shows horizontal plate metering device used in precision planters and an array of optional seed plates respectively.

6) **Cup feed:** Seed picking cups or spoons are provided on periphery of a vertical plate. When the plate rotates, cups pick seeds from seed hopper and drop them in seed funnel. Size of cups depends on size and number of seeds per hill. This type of metering is used for seeds, which are easily damaged by mechanical devices.

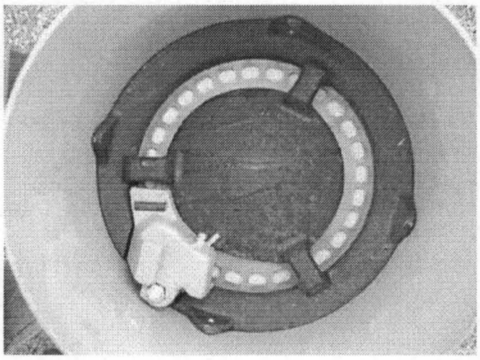

Fig. 2.2: Horizontal plate metering device used in precision planters

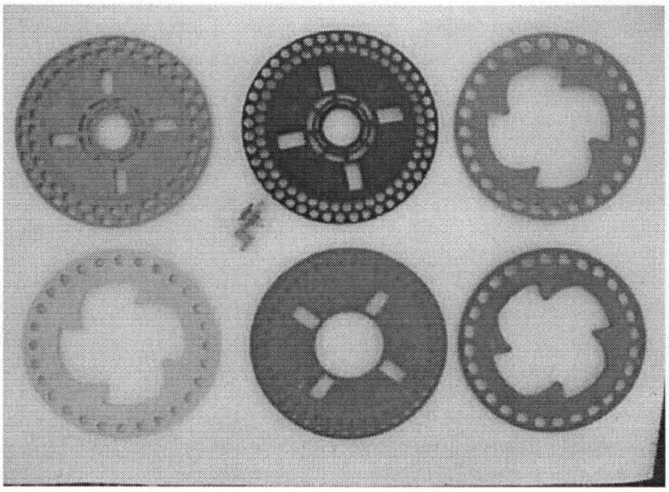

Fig. 2.3: Array of optional seed plates

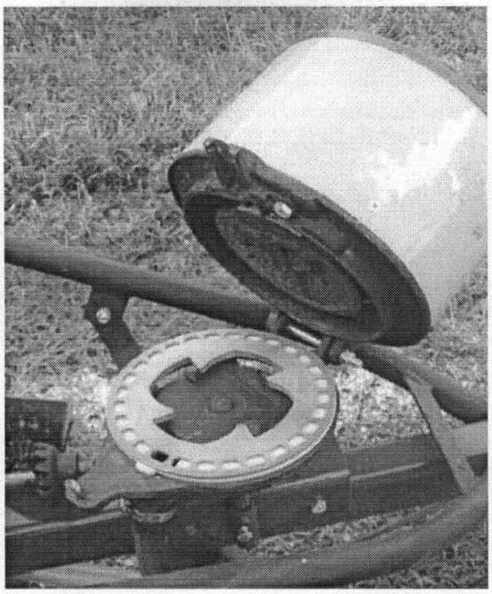

Fig. 2.4: A closed hopper system for easy seed plate change

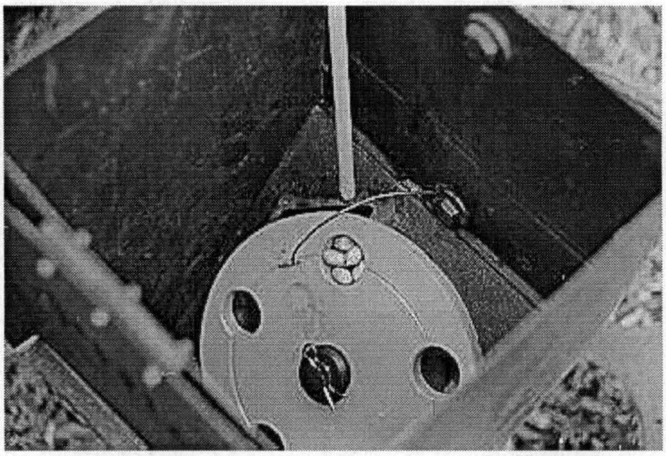

Fig. 2.5: Mechanism for pushing seeds out of seed cells

2.7 Factors Affecting Seed Germination and Emergence

Mechanical factors which affect seed germination and emergence are: Seed damage during metering; Uniformity of depth of placement of seed; Uniformity of distribution of seed along rows; Transverse displacement of seed from the row; Prevention of loose soil getting under the seed; Degree of soil compaction above the seed; Uniformity of soil cover over the seed and; Mixing of fertilizer with seed during placement in the furrow. To achieve the best performance from a seed drill or planter, the above factors are to be optimized by proper design and selection of the components required on the machine to suit the needs of the crops. The seed drill or planter can play an important role in manipulating the physical environment. The metering system selected for the seed should not damage the seed while in operation. The speed of the metering device is a very important factor with regards to damage, seed placement and seed spacing. Planter speed of operation has received considerable attention in recent years. It has the potential to affect both seed placement and seed spacing. Planting speed should be based on the farmer's knowledge of equipment operation, soil conditions, and the actual operation of the planter. Planting speed needs to be a balance between seed placement issues and planting timeliness. Farmers may want to establish their own strip trials under common ground conditions operating at different speeds to get a better feel for their situation. Seed damage can be avoided by selecting the proper spring loading rate of the cut-off device and knock-out device in the case of plate type planters. Seeds should be handled in such a way that physical injury is avoided. Metering devices, seed conveying tubes and their location on the machine affect the seed distribution uniformity in the row. Their selection is affected by the furrow openers and the depth requirements for placement of the seed. The soil physical environment affected by the machine is the availability of soil moisture and mechanical resistance. The planter's performance is improved by manipulating the depth of sowing and thickness of soil cover over the seed as well as pressing the soil cover. Under arid conditions the top soil becomes very dry; therefore, the seeds are placed 80-100 mm deep in the furrow. This requires the proper furrow opener. Further, the soil cover over the deep-placed seed should be lightly packed to achieve good emergence. In arid regions, dry seeding with deep placement of seed is recommended because the seeds will germinate only when there is sufficient rainfall or adequate moisture at the seed zone.

Crop growth parameters such as specific leaf area (SLA), net assimilation rate (NAR), and specific leaf mass (SLM) are important traits in crop physiology and ecology because they are associated with many critical aspects of plant growth and survival (Li et al., 2005; Garnier et al., 2001; Shipley and Vu, 2002). It has been shown that SLA and other growth parameters could play a role in explaining variation in potential relative growth rate (Poorter and van der Werf, 1998) and ecological behaviour in plants (Garnier et al., 2001). Many studies have evaluated growth parameters under both controlled and natural conditions involving various nutrient and water gradients (Garnier et al., 2001), sand dunes (Li et al., 2005), vegetation types (Poorter and de Jong, 1999), and plant functional types (Garnier et al., 1997). Growth parameters have been reported to influence crop growth. Tsubo et al. (2003) showed that plant density affected crop productivity and resource use in intercropping and concluded that good crop growth resulted in high crop yield.

2.8 Selection of Sowing and Planting Machines

Different designs of improved seed drills/planters have been developed for sowing of crops. Basic difference in the design of these seed drills is mainly in the type of seed metering mechanism and furrow openers. Therefore, it is essential to select the machine with a metering unit and furrow opener suitable for the crop and soil conditions.

- For small seeds like rapeseed-mustard, a seed drill or planter with vertical roller with cells, inclined seed plate with cells or small grooved fluted roller metering system is recommended.
- For medium seeds such as wheat, soybean, safflower and linseed, seed drills with standard fluted rollers are recommended.
- For bold seeds like groundnut and castor planters with inclined cell plate or cup feed type metering system are recommended.

Furrow openers should be selected according to type of soil and depth of seed placement.

- For trashy, stony and light to medium soils, shovel type openers are used. The depth of seed placement from 50 to 100 mm is achieved with these openers.
- Small shoe or shovel type openers are also used for shallow (20 to 50 mm deep) placement of seeds in dry farming areas.

- Shoe type openers with single or twin boots are used for sowing in heavy and medium soils for seed placement at 20 to 70 mm depth.
- Runner type opener is widely used for placement of seeds at shallow depth where soil disturbance required is minimum. Soil cover over seed is also minimal.
- Covering chains and wooden planks are widely used to cover and compact the soil over seeds in the furrows and level the fields after sowing operation

2.9 Seedbeds for Seeding and Planting

Depending upon climatic and soil conditions, seeds are sown on well prepared and levelled fields, on ridges, in furrows or on beds. Flat seeding and planting refer to operation when the field being sown is levelled and smooth. Seeds and tubers are planted on ridges either to improve soil drainage due to high rainfall or it may be a cropping requirement. Seeding in furrows is done in arid regions to conserve soil moisture and improve plant growth. When two or more rows of seeds are planted in beds and separated by furrows, it is known as bed planting. Bed planting helps in conserving soil moisture, avoids soil compaction and promotes plant growth.

2.10 Furrow Openers

The design of furrow openers of seed drills varies to suit the soil conditions of particular region. Most of the seed cum fertilizer drills are provided with pointed tool to form a narrow slit in the soil for seed deposition. Common types of furrow openers are described as follows:

1) Double end pointed shovel type furrow openers of 100 to 200 mm size are used on seed planters in light to medium soils for medium to deep placement of seeds.
2) Pointed bar type (diamond shaped) furrow openers are used for forming narrow slit under heavy soils for placement of seeds at medium depths.
3) Shoe type openers are used in black soil regions. Seeds are dropped through a tube connected to boot at rear of opener for placement at shallow to medium depths. When

used on seed cum fertilizer drills or planters a special narrow boot is designed to place seed and fertilizer in soil at same depth but separated by a small distance.

4) Runner or sword type openers are used on planters for shallow sowing. Soil over seed flows back in furrow during operation and seeds are covered with a levelling bar, chain or by operating a wooden plank behind the drill. Figure 2.6 shows some of the types of furrow openers

Fig. 2.6: Types of furrow openers

CHAPTER THREE

DESIGN ANALYSIS

3.1 Determination of the Physical Properties of Seeds

Seed flow through a planter is dependent on the physical properties such as size, shape, sphericity, true density and angle of repose (Jayan and Kumar, 2004). In addition, the impact of seeds on the internal components of the planter is influenced by the coefficient of restitution of seeds on various impinging surfaces. Physical properties of seeds namely, size, shape, sphericity, thousand seed weight, true density, angle of repose and coefficient of restitution may be determined following standard procedures.

3.1.1 Determination of the Size and Shape of Seed

For estimating the size and shape of seed, 10 random seeds were spread at their natural rest position on the glass panel of a Leica Quantimet 500^{+} Digital Image Analyzer (Mahadevan et al., 1999). The image of the seed was captured using a digital camera and calibrated to scale. These images were transferred to the software Quantimet 500^{+} to identify the object based on the boundary of seeds, and the parameters such as length, breadth, area, roundness, and equivalent diameter were worked out. For a more accurate result, the measurement may be replicated for 20 samples of the seed and the mean computed.

3.1.2 Determination of Seed Sphericity

For sphericity characterization, seeds were placed at their natural rest position on an overhead projector and the outline of the projected boundary was traced on the screen (Waziri and Mittal, 1983). The seed was rotated 90^{o} about its longitudinal axis and the projected image was traced again. From the outline of the projected image, the diameter of the largest inscribed circle (di) and the diameter of the smallest circumscribed circle (dc) were drawn and sphericity was calculated as

$$Sphericity = \frac{d_i}{d_c} \qquad (3.1)$$

The measurement may be repeated for 50 random seeds and the average worked out. Thousand seed weight may be determined for ten random samples of 1000 seeds in an electronic balance having sensitivity of 0.01 g.

3.1.3 Determination of the True Density of Seed

True density of seed may be calculated using the following expression

$$True\ density = \frac{Bulk\ density}{(1 - Porosity)} \qquad (3.2)$$

For this, porosity may be determined using a standard porosity apparatus with five replicates and bulk density determined as the ratio of the weight by volume using containers of different shapes.

3.1.4 Determination of the Angle of Repose of Seed

The angle of repose of seed may be determined using the method explained by Waziri and Mittal (1983). In this method, seeds were allowed to fall from a height of 300 mm on circular discs of 200, 150, and 100 mm diameter until maximum height was reached and the height of seed heap was noted. The experiment may be replicated five times and the average value computed. The following equation may be used to calculate the angle of repose of the selected seed

$$Angle\ of\ repose = \tan^{-1}\left(\frac{Heigth\ of\ cone\ (mm)}{Radius\ of\ cone\ (mm)}\right) \qquad (3.3)$$

Table 3.1 gives the size and shape, sphericity, thousand seed weight and true density of maize, red gram and cotton seeds at 95% confidence limit (Jayan and Kumar, 2004).

3.1.5 Determination of the Coefficient of Restitution of Seed

Coefficient of restitution of seed may be determined using the method described by Kumar (1995). In this method, a seed is dropped from a height of 50, 100, 150, 200, 250, and 300 mm on

3 mm thick mild steel and rubber sheets. A graduated scale of 500 mm was kept at the background and the maximum height of seed rebounce recorded using a high-speed digital video camera. Height of rebounce was measured in the monitor using the video editing unit. This may be replicated 10 times and the coefficient of restitution calculated using the following equation (Whitney and Porterfield, 1968).

$$Coefficient\ of\ restitution = \sqrt{\frac{Height\ of\ rebound\ (mm)}{Height\ of\ drop\ (mm)}} \tag{3.4}$$

Table 3.2 gives the coefficient of restitution of maize, red gram and cotton seeds at different dropping heights on a 3 mm mild steel and rubber sheets (Jayan and Kumar, 2004).

Table 3.1: Size and shape, sphericity, thousand seed weight and true density of maize, red gram and cotton seeds at 95% confidence limit

Parameters	Kind of seeds		
	maize	Red gram	cotton
Size and shape			
Length (mm)	10.70±0.08	7.35±0.06	9.10±0.09
Breadth (mm)	8.70±0.03	6.35±0.07	5.60±0.05
Area (mm^2)	71.00±0.14	35.80±0.05	37.00±0.08
Roundness	1.14±0.14	1.15±0.10	1.26±0.10
Equivalent diameter (mm)	9.50±0.10	6.74±0.06	6.90±0.07
Sphericity			
Natural rest position	0.621±0.065	0.750±0.016	0.550±0.016
Vertical position	0.551±0.015	0.721±0.032	0.455±0.032
Thousand seed weight (g)	268.30±0.092	102.12±0.060	81.42±0.018
True density (kgm^{-3})	1691.56±0.06	1301.00±0.04	1251.43±0.03

Table 3.2: Coefficient of restitution of maize, red gram and cotton seeds at different dropping heights on a 3 mm mild steel and rubber sheets

Seeds	Impact surface	Coefficient of restitution at different dropping heights					
		50 mm	100 mm	150 mm	200 mm	250 mm	300 mm
Maize	Mild steel sheet	0.707	0.547	0.516	0.500	0.458	0.428
	Rubber sheet	0.529	0.447	0.454	0.435	0.400	0.374
Red gram	Mild steel sheet	0.817	0.632	0.577	0.524	0.489	0.483
	Rubber sheet	0.678	0.500	0.483	0.458	0.428	0.424
Cotton	Mild steel sheet	0.501	0.447	0.417	0.403	0.374	0.365
	Rubber sheet	0.450	0.390	0.355	0.331	0.316	0.305

3.2 Description, Design, and Selection of Materials for the Component Parts

The function of a well-designed seed planter is to meter seeds of different sizes and shapes, place the seed in the acceptable pattern of distribution in the field, place the seed accurately and uniformly at the desired depth in the soil and cover the seed and compact the soil around it to enhance germination and emergence. The recommended row to row spacing, seed rate, seed to seed spacing and depth of seed placement vary from crop to crop and for different agro-climatic conditions to achieve optimum yields.

3.2.1 Main Frame

The main frame is the skeletal structure of the seed planter on which all other components are mounted. The two design factors considered in the determination of the material required for the frame are the weight and strength. In this work, mild steel angle bar of 50.8mm x 50.8mm and 4mm thickness were used to give the required rigidity.

3.2.2 Adjustable Handle

The handle of the seed planter was designed to be adjustable for the different height of individuals thereby reducing drudgery. The handles help the operator to push the planter while in operation. The material used for the handle was a combination of 1 inch mild steel square pipe, ¾ inch mild steel square pipe, and 1 inch mild steel angle bar.

3.2.3 Seed Hopper

The seeds container as the name implies is a device in which the seeds to be planted are kept (transitionally) before their gradual release into the furrowed tunnel. The hopper has the shape of a frustum of a pyramid truncated at the top as shown in Figure 3.1. To ensure free flow of seeds, the slope of the hopper was fixed at 30^o, which is modestly higher than the average angle of repose of the seeds. The seed container also has a lid, with a handle on top to ease opening. The material used for the design was 2mm thick mild steel sheet metal.

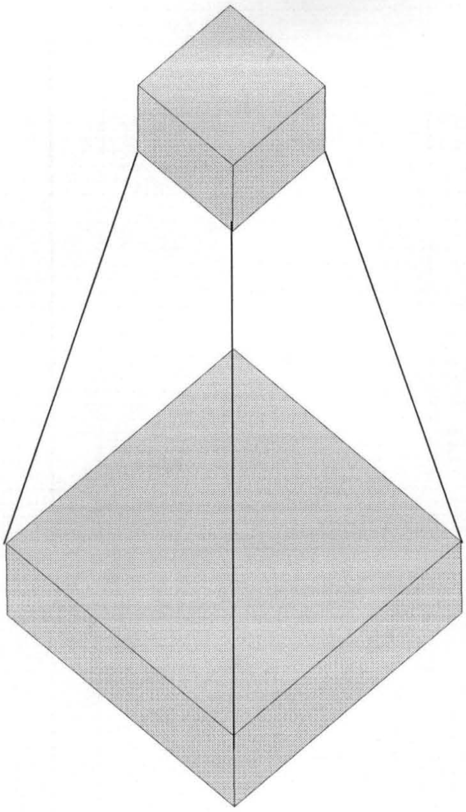

Fig. 3.1: Diagram of the hopper in its inverted form

3.2.4 Seed Metering Mechanism

Metering mechanism is the heart of sowing machine and its function is to distribute seeds uniformly at the desired application rates. In planters it also controls seed spacing in a row. A seed planter may be required to drop the seeds at rates varying across wide range. Proper design of the metering device is an essential element for satisfactory performance of the seed planter. The seed metering device used for this work is the wooden roller type with cells on its periphery. The size and number of cells on the roller depends on the size of seed and desired seed rate. In this design, the wooden roller lifts the seeds in the cells and drops these into the seed funnel which is conveyed to the open furrow through the seed tube. For varying the seed rate and sowing different seeds, three separate rollers were provided. The number of cells on the seed metering device may be obtained from the following expression

$$Number\ of\ cells = \frac{\pi \times Diameter\ of\ the\ planter's\ ground\ wheel}{Intra-row\ spacing\ distance\ of\ seeds} \quad (3.5)$$

3.2.5 Adjustable Furrow Opener

The design of furrow openers of seed planters varies to suit the soil conditions of particular region. Most seed planters are provided with pointed tool to form a narrow slit in the soil for seed deposition. The adjustable furrow opener permits planting at each variety's ideal ground depth. The type used for this work is the pointed bar type. These types of furrow openers are used for forming narrow slit under heavy soils for placement of seeds at medium depths. The material used for the design was 50mm x 5mm mild steel flat bar.

3.2.6 Adjustable Furrow Closer

The furrow closer was also designed to be adjustable. The type used for this design is the shoe type furrow closer. It was designed to allow for proper covering and compaction of the soil over the seeds in the furrows. The material used for the design was 50mm x 5mm mild steel flat bar.

3.2.7 Drive Wheel

The wheels are located at both ends of the frame. They are circular in shape containing 1 inch square pipes which serves as spokes. These spokes are used to support the centre bushing or hub. The spokes are arranged in such a way that it braced the wheels circular circumference and also gives it necessary radial support. Material used for the design was a combination of both 1 inch mild steel square pipes and 3mm thick mild steel flat bars.

3.2.8 Seed Tube

This was the channel through which seeds are conveyed to the furrow. The material used was a conical funnel with a rubber hose. The outlet diameter is 1 inch.

3.2.9 Bearing Selection

Bearings are selected based on their load carrying capacity, life expectancy and reliability (PSG Tech, 1989). Ball bearings are fixed in the bushing provided at the two ends of the frame in other to support the eccentric shaft on which the wheels are attached. They allow the carrying of an impressive load without wear and tear and with reduced friction. This device ensures the smooth operation of the wheels. The material for the bearing is high speed steel.

3.3 Determination of the Weight of the Hopper Material

From Figure 3.2, using Pythagoras theorem, the length EK is obtained as follows

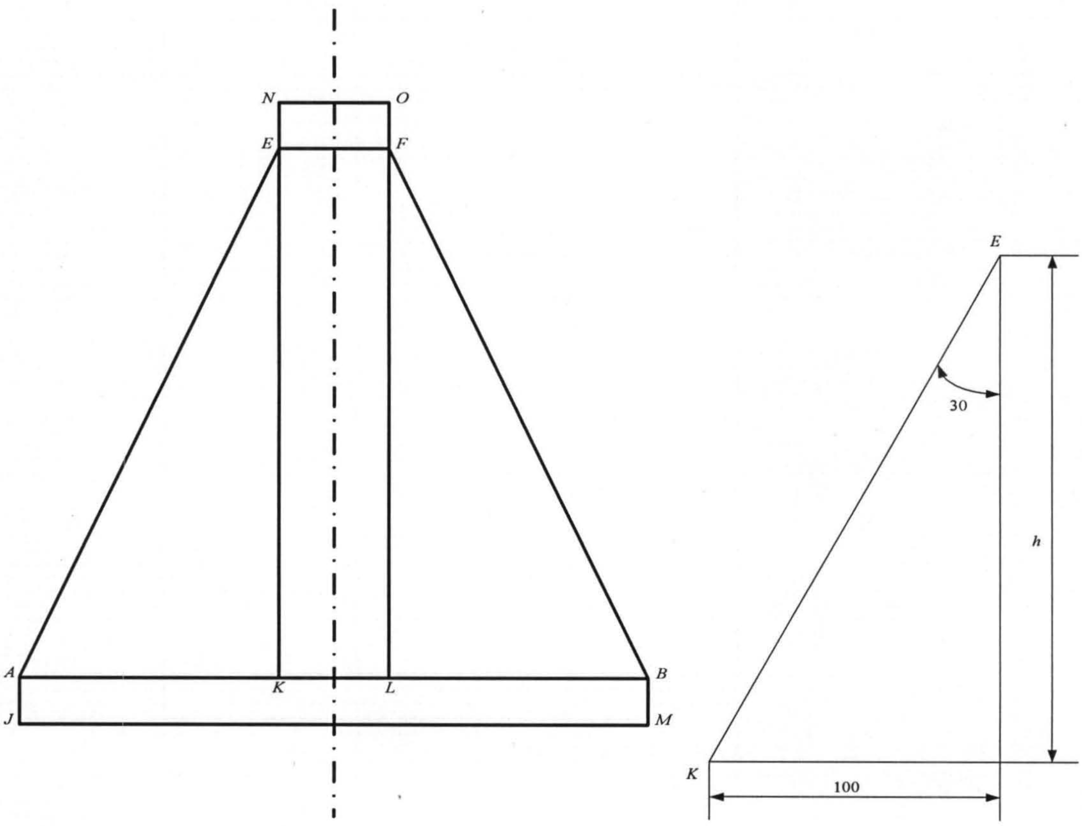

Fig. 3.2: Diagram showing one part of the hopper in its inverted form

$$EK^2 = FL^2 = 0.1^2 + h^2 \quad (3.6)$$

$$EK = FL = \sqrt{0.1^2 + h^2} \quad (3.7)$$

$$Area\ EAK = Area\ FBL = \frac{1}{2} \times AK \times FL \tag{3.8}$$

$$Area\ EKLF = KL \times FL \tag{3.9}$$

$$Area\ EFON = EF \times EN \tag{3.10}$$

$$Area\ ABMJ = AB \times BM \tag{3.11}$$

$$A_{HM}\ for\ one\ side\ of\ hopper\ material = 2 \times \frac{1}{2} \times AK \times FL + KL \times FL + EF \times EN + AB \times BM \tag{3.12}$$

$$A_{HM} = 4 \times A_{HM}\ for\ one\ side\ of\ hopper\ material \tag{3.13}$$

$$V_{HM} = A_{HM} \times t_{HM} \tag{3.14}$$

$$M_{HM} = V_{HM} \times \rho_{HM} \tag{3.15}$$

$$W_{HM} = M_{HM} \times Acceleration\ due\ to\ gravity \tag{3.16}$$

Where,

A_{HM} = *Surface area of the hopper material*

V_{HM} = *Volume of the hopper material*

t_{HM} = *Thickness of the hopper material*

M_{HM} = *Mass of the hopper material*

ρ_{HM} = *Density of the hopper material*

W_{HM} = *Weight of the hopper material*

3.4 Determination of the Weight of the Main Frame Material

From Figure 3.3, the weight of the main frame material may be obtained from the following expressions

$$A_{MFM} = [w_{MFM} + (w_{MFM} - t_{MFM})](6 \times L + 4 \times l) \tag{3.17}$$

$$V_{MFM} = A_{MFM} \times t_{MFM} \tag{3.18}$$

$$M_{MFM} = V_{MFM} \times \rho_{MFM} \tag{3.19}$$

$$W_{MFM} = M_{MFM} \times Acceleration\ due\ to\ gravity \tag{3.20}$$

Where,

A_{MFM} = *Surface area of the main frame material*

w_{MFM} = *Width of the main frame material*

V_{MFM} = *Volume of the main frame material*

t_{MFM} = *Thickness of the main frame material*

M_{MFM} = *Mass of the main frame material*

ρ_{MFM} = *Density of the main frame material*

W_{MFM} = *Weight of the main frame material*

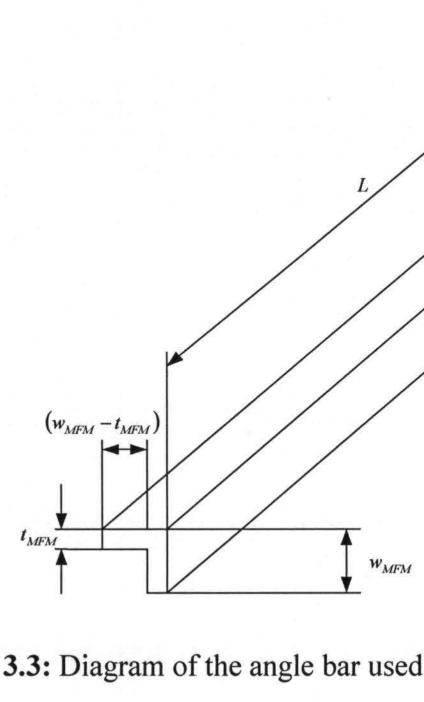

Fig. 3.3: Diagram of the angle bar used for the main frame

3.5 Determination of the Weight of Grain

From Figure 3.4, using Pythagoras theorem, the lengths QG *and* AC are determined as follows

$$EG^2 = EF^2 + FG^2 \tag{3.21}$$

$$EG = \sqrt{EF^2 + FG^2} \tag{3.22}$$

$$QG = \frac{1}{2}EG = \frac{1}{2} \times \sqrt{EF^2 + FG^2} \tag{3.23}$$

$$AC^2 = AB^2 + BC^2 \tag{3.24}$$

$$AC = \sqrt{AB^2 + BC^2} \tag{3.25}$$

$$RC = \frac{1}{2}AC = \frac{1}{2} \times \sqrt{AB^2 + BC^2} \tag{3.26}$$

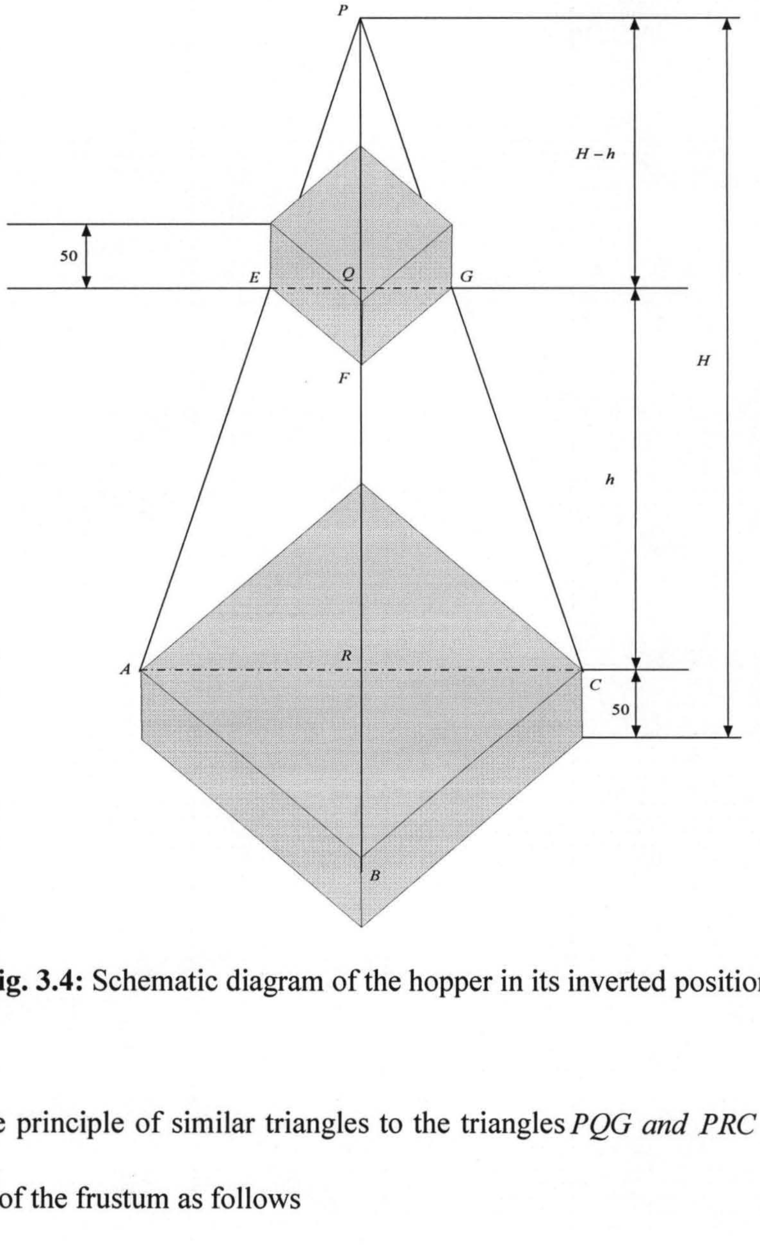

Fig. 3.4: Schematic diagram of the hopper in its inverted position

Application of the principle of similar triangles to the triangles PQG *and* PRC, one obtains the overall height H of the frustum as follows

$$\frac{PQ}{QG} = \frac{PR}{RC} \tag{3.27}$$

$$PQ = QG \times \frac{PR}{RC} \tag{3.28}$$

$$H - h = QG \times \frac{H}{RC} \tag{3.29}$$

$$H - \frac{QG}{RC} H = h \tag{3.30}$$

$$H\left(1 - \frac{QG}{RC}\right) = h \tag{3.31}$$

$$H = \frac{h}{\left(1 - \dfrac{QG}{RC}\right)} \tag{3.32}$$

The volume of the hopper may be obtained from the following expression

$$\begin{aligned} V_H &= \frac{1}{3}[(area\ of\ frustum\ base) \times overall\ height\ of\ frustum] \\ &\quad - \frac{1}{3}[(area\ of\ truncated\ frustum\ base) \times height\ of\ truncated\ frustum] \\ &\qquad + volume\ of\ the\ square\ extension\ at\ the\ top\ and\ bottom\ of\ hopper \\ &= \frac{1}{3}[(AB \times BC)H - (EF \times FG)(H - h)] + [(AB \times BC) + (EF \times FG)] \times 0.05 \end{aligned} \tag{3.33}$$

$$M_G = V_H \times \rho_G \tag{3.34}$$

$$W_G = M_G \times Acceleration\ due\ to\ gravity \tag{3.35}$$

Where,

V_H = *Volume of hopper*

M_G = *Mass of grain*

ρ_G = *Density of grain*

W_G = *Weight of grain*

3.6 Determination of the Shaft Diameter

Shaft design consists primarily of the determination of the correct shaft diameter to ensure satisfactory strength and rigidity when the shaft is transmitting power under various operating and loading conditions. Design of shafts of ductile material based on strength is controlled by maximum shear theory. The material for the shaft is mild steel rod. For a shaft having little or no axial loading, the diameter may be obtained using the ASME code equation (Khurmi and Gupta, 2005) given as

$$d^3 = \frac{16}{\pi S_a}\sqrt{(k_b M_b)^2 + (k_t M_t)^2} \quad (3.36)$$

Where,

$d = Diameter\ of\ the\ shaft$

$M_b = Bending\ moment$

$M_t = Torsional\ moment$

$k_b = Combined\ shock\ and\ fatigue\ factor\ applied\ to\ bending\ moment$

$k_t = Combined\ shock\ and\ fatigue\ factor\ applied\ to\ torsional\ moment$

$S_a = Allowable\ stress$

For rotating shafts, when load is suddenly applied (minor shock) (Khurmi and Gupta, 2005):

$$k_b = 1.5\ to\ 2.0 \qquad k_t = 1.0\ to\ 1.5 \quad (3.37)$$

For shaft without key way, allowable stress $S_a = 55MN/m^2$

For shaft with key way, allowable stress $S_a = 40MN/m^2$

3.7 Determination of the Maximum Bending Moment

Figure 3.5 shows the load distribution on the shaft. The maximum bending moment may the obtained from the following expressions

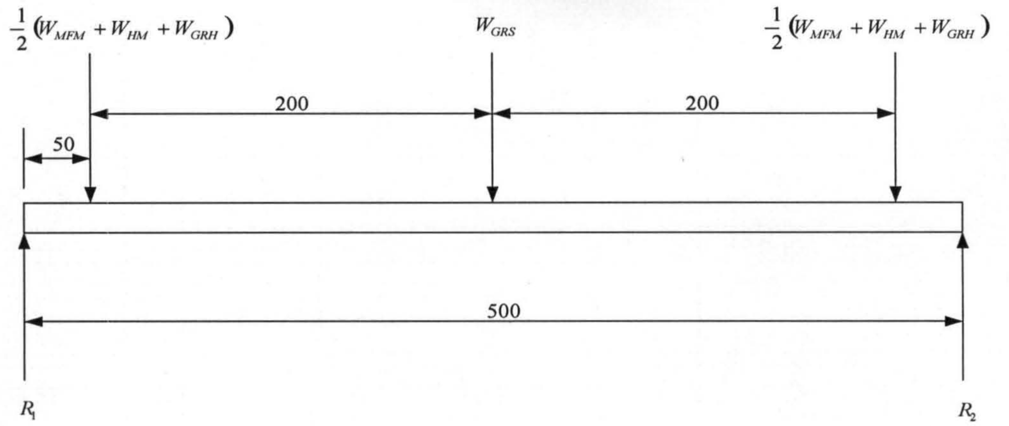

Fig. 3.5: Load distribution on shaft

The following expressions may be used to calculate the reactions at the support

$$R_1 + R_2 = 2 \times \frac{1}{2}\left(W_{MFM} + W_{HM} + W_{GRH}\right) + W_{GRS} \tag{3.38}$$

$$R_1 = \frac{1}{0.5}\left[\frac{1}{2}\left(W_{MFM} + W_{HM} + W_{GRH}\right) \times 0.45 + W_{GRS} \times 0.25 + \frac{1}{2}\left(W_{MFM} + W_{HM} + W_{GRH}\right) \times 0.05\right] \tag{3.39}$$

Where,

$R_1, R_2 = \text{Reactions at the support}$

$W_{GRH} = \text{Weight of grain resting on the hopper}$

$W_{GRS} = \text{Weight of grain resting on the shaft}$

Using the method of sectioning, the following expressions were obtained for the bending moment

$$M_{b1} = R_1 \times 0.05 \tag{3.40}$$

$$M_{b2} = R_1 \times 0.25 - \frac{1}{2}\left(W_{MFM} + W_{HM} + W_{GRH}\right) \times 0.20 \tag{3.41}$$

$$M_{b3} = R_1 \times 0.45 - \frac{1}{2}\left(W_{MFM} + W_{HM} + W_{GRH}\right) \times 0.4 - W_{GRS} \times 0.2 \tag{3.42}$$

The maximum value in equation (3.40), (3.41), and (3.42) is taken as the maximum bending moment M_b for the shaft.

$$V_{GRS} = 0.45 \times \left(EF \times FG\right) \tag{3.43}$$

$$M_{GRS} = V_{GRS} \times \rho_G \tag{3.44}$$

$$W_{GRS} = M_{GRS} \times Acceleration\ due\ to\ gravity \tag{3.45}$$

$$W_{GRH} = W_G - W_{GRS} \tag{3.46}$$

Where,

$V_{GRS} = Volume\ of\ grain\ resting\ on\ the\ shaft$

$M_{GRS} = Mass\ of\ grain\ resting\ on\ the\ shaft$

3.8 Determination of the Force Required to Push the Planter

Figure 3.6 gives the free body diagram showing all the forces acting on the planter. the force required to push the planter may be obtained from the following expressions

$$\sum F_x = F_P \cos\theta - R_S \cos\phi - F_R = 0 \tag{3.47}$$

$$\sum F_y = R_S \sin\phi - F_P \sin\theta - W_P = 0 \tag{3.48}$$

Where,

$F_P = Planter\ push\ force$

$F_R = Horizontal\ soil\ resistance\ force$

$R_S = Soil\ frictional\ resistance\ force$

$\phi = Angle\ of\ friction$

$\theta = Angle\ between\ planter\ handle\ and\ the\ horizontal\ plane$

$W_P = Weight\ of\ planter$

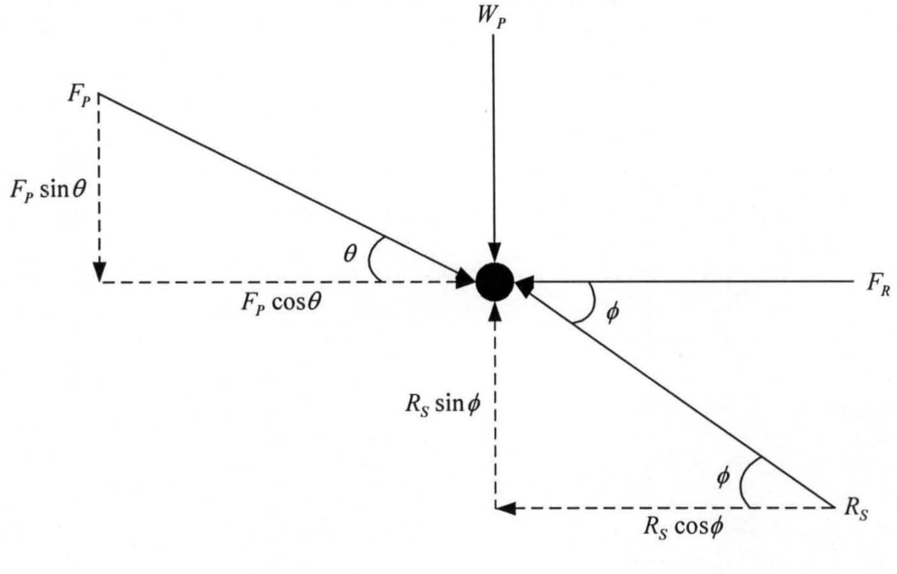

Fig. 3.6: Free body diagram showing all the forces acting on the planter

From equation (3.47)

$$F_P = \frac{R_S \cos\phi + F_R}{\cos\theta} \tag{3.49}$$

Substituting equation (3.49) into equation (3.48), one obtains

$$R_S = \frac{F_R \tan\theta + W_P}{(\sin\phi - \cos\phi \tan\theta)} \tag{3.50}$$

The maximum draft on the planter is a function of the soils resistance on the machine and the area of contact of the furrow opener with the soil. Data for the different soil resistance is presented in table 3.3 (Gbabo, 1988). The maximum draft on the planter is the horizontal component of push parallel to the line of motion in order to overcome the soil resistance on the planter (Gbabo, 1988). The maximum draft may therefore be obtained from the following expression

$$D_{FM} = R_S \times A_{FO} \times Acceleration\ due\ to\ gravity \tag{3.51}$$

D_{FM}=Maximum draft

A_{FO} = Surface area of furrow opener in contact with soil

$$A_{FO} = \text{Re}commended\ depth\ of\ cut \times Thickness\ of\ furrow\ opener \tag{3.52}$$

Table 3.3: Soil Resistance Table

Type of Soil	Resistance in PSI	Resistance in g/cm^2
Sandy	3	210
Sandy Moist	3-4	210-280
Sandy Loam Dry	4-6	280-350
Silt Loam Moist	5-6	350-420
Silt Loam Dry	6-7	420-490
Clay Loam Moist	6-7	420-490
Clay Loam Dry	7-8	490-560
Heavy Clay Dry	9-10	630-700
Heavy Clay Sod	10-11	700-770

3.9 Determination of the Capacity of the Planter

The capacity of the planter may be determined in terms of the area of land covered per time during planting or the number of seeds planted per time of planting. The capacity of the planter in terms of the area of land covered per time may be obtained from the following expression

$$C_{PA} = \frac{Area\ \text{covered}\ by\ planter}{10000m^2}\ (hectare/time) \quad (3.53)$$

C_{PA} = Capacity of planter in hectare/time

$$Area\ \text{covered}\ by\ planter = (Inter-row\ spacing)\times(Distance\ \text{covered}\ by\ planter)\ (m^2/time) \quad (3.54)$$

$$Distance\ \text{covered}\ by\ planter = (Speed\ of\ planter)\times(Time\ of\ planting)\ (m/time) \quad (3.55)$$

The speed of the planter may be obtained from raw experiment. The capacity of the planter in terms of number of seeds planted per time may be obtained from the following expression

$$C_{PN} = \frac{Distance\ \text{covered}\ by\ planter\ per\ time}{Intra-row\ spacing}\times Number\ of\ seeds\ per\ hole\ (seeds/time) \quad (3.56)$$

C_{PN} = Capacity of planter in terms of number of seeds/time

3.10 Design Calculations

Weight of the hopper material

The weight of the hopper material is obtained as follows

From equation (3.7)

$EK = FL = \sqrt{0.1^2 + h^2} = \sqrt{0.1^2 + 0.35^2} = 0.364m$

From equation (3.8)

$$Area\ EAK = Area\ FBL = \frac{1}{2} \times AK \times FL = \frac{1}{2} \times 0.1 \times 0.364 = 1.82 \times 10^{-2} m^2$$

From equation (3.9)

$$Area\ EKLF = KL \times FL = 0.05 \times 0.364 = 1.82 \times 10^{-2} m^2$$

From equation (3.10)

$$Area\ EFON = EF \times EN = 0.05 \times 0.05 = 2.50 \times 10^{-3} m^2$$

From equation (3.11)

$$Area\ ABMJ = AB \times BM = 0.25 \times 0.05 = 1.25 \times 10^{-2} m^2$$

From equation (3.12)

$$A_{HM}\ for\ one\ side\ of\ hopper\ material = 2 \times \frac{1}{2} \times AK \times FL + KL \times FL + EF \times EN + AB \times BM$$
$$= 2 \times 1.820 \times 10^{-2} + 1.820 \times 10^{-2} + 2.50 \times 10^{-3} + 1.250 \times 10^{-2} = 0.1821 m^2$$

From equation (3.13)

$$A_{HM} = 4 \times A_{HM}\ for\ one\ side\ of\ hopper\ material = 4 \times 0.1821 = 0.7284 m^2$$

From equation (3.14)

$$V_{HM} = A_{HM} \times t_{HM} = 0.7284 \times 0.002 = 1.457 \times 10^{-3} m^3$$

From equation (3.15)

$$M_{HM} = V_{HM} \times \rho_{HM} = 1.457 \times 10^{-3} \times 7840 = 11.42 kg$$

From equation (3.16)

$$W_{HM} = M_{HM} \times Acceleration\ due\ to\ gravity = 11.42 \times 9.81 = 112N$$

Where,

A_{HM} = *Surface area of the hopper material*

V_{HM} = *Volume of the hopper material*

t_{HM} = *Thickness of the hopper material*

M_{HM} = *Mass of the hopper material*

ρ_{HM} = *Density of the hopper material*

W_{HM} = *Weight of the hopper material*

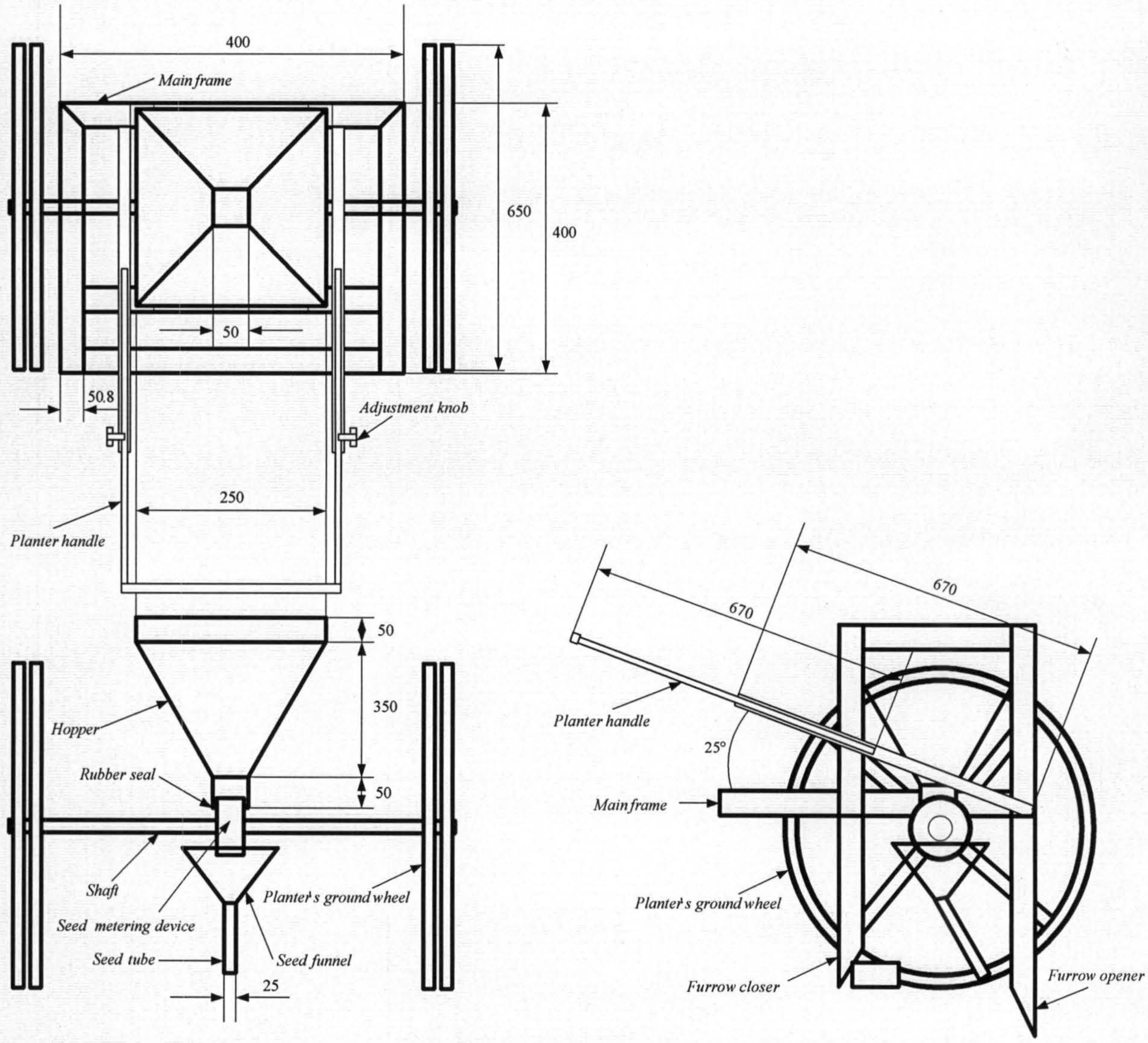

Fig. 3.7: Diagram of the seed planter showing all the necessary dimensions

Weight of the main frame material

The weight of the main frame material is obtained as follows

From equation (3.17)

$$A_{MFM} = [w_{MFM} + (w_{MFM} - t_{MFM})](6 \times L + 4 \times l)$$
$$= [0.0508 + (0.0508 - 0.004)](6 \times 0.4 + 4 \times 0.45) = 0.4099 m^2$$

From equation (3.18)

$$V_{MFM} = A_{MFM} \times t_{MFM} = 0.4099 \times 0.004 = 1.640 \times 10^{-3} m^3$$

From equation (3.19)

$$M_{MFM} = V_{MFM} \times \rho_{MFM} = 1.640 \times 10^{-3} \times 7840 = 12.86 kg$$

From equation (3.20)

$$W_{MFM} = M_{MFM} \times Acceleration\ due\ to\ gravity = 12.86 \times 9.81 = 126.1 N$$

Where,

A_{MFM} = *Surface area of the main frame material*

w_{MFM} = *Width of the main frame material*

V_{MFM} = *Volume of the main frame material*

t_{MFM} = *Thickness of the main frame material*

M_{MFM} = *Mass of the main frame material*

ρ_{MFM} = *Density of the main frame material*

W_{MFM} = *Weight of the main frame material*

Weight of the grain

The weight of the grain is obtained as follows

From equation (3.23)

$$QG = \frac{1}{2} EG = \frac{1}{2} \times \sqrt{EF^2 + FG^2} = \frac{1}{2} \times \sqrt{0.05^2 + 0.05^2} = 3.536 \times 10^{-2} m$$

From equation (3.26)

$$RC = \frac{1}{2} AC = \frac{1}{2} \times \sqrt{AB^2 + BC^2} = \frac{1}{2} \times \sqrt{0.25^2 + 0.25^2} = 0.1768 m$$

From equation (3.32)

$$H = \frac{h}{\left(1 - \frac{QG}{RC}\right)} = \frac{0.35}{\left(1 - \frac{3.536 \times 10^{-2}}{0.1768}\right)} = 0.4375m$$

From equation (3.33)

$$V_H = \frac{1}{3}\left[(area\ of\ frustum\ base) \times overall\ height\ of\ frustum\right]$$

$$-\frac{1}{3}\left[(area\ of\ truncated\ frustum\ base) \times height\ of\ truncated\ frustum\right]$$

$$+ volume\ of\ the\ square\ extension\ at\ the\ top\ and\ bottom\ of\ hopper$$

$$= \frac{1}{3}\left[(AB \times BC)H - (EF \times FG)(H - h)\right] + \left[(AB \times BC) + (EF \times FG)\right] \times 0.05$$

$$= \frac{1}{3}\left[(0.25 \times 0.25)0.4375 - (0.05 \times 0.05)(0.4375 - 0.35)\right] + \left[(0.25 \times 0.25) + (0.05 \times 0.05)\right] \times 0.05$$

$$= 1.229 \times 10^{-2} m^3$$

From equation (3.34)

$$M_G = V_H \times \rho_G = 1.229 \times 10^{-2} \times 1691.56 = 20.79kg$$

From equation (3.35)

$$W_G = M_G \times Acceleration\ due\ to\ gravity = 20.79 \times 9.81 = 204N$$

Where,

V_H = *Volume of hopper*

M_G = *Mass of grain*

ρ_G = *Density of grain*

W_G = *Weight of grain*

The weight of the grains resting on the shaft is obtained as follows

From equation (3.43)

$$V_{GRS} = 0.45 \times (EF \times FG) = 0.45 \times (0.05 \times 0.05) = 1.125 \times 10^{-3} m^3$$

From equation (3.44)

$$M_{GRS} = V_{GRS} \times \rho_G = 1.125 \times 10^{-3} \times 1691.56 = 1.903kg$$

From equation (3.45)

$W_{GRS} = M_{GRS} \times Acceleration\ due\ to\ gravity = 1.903 \times 9.81 = 18.67N$

The weight of the grains resting on the hopper is obtained as follows

From equation (3.46)

$W_{GRH} = W_G - W_{GRS} = 204 - 18.67 = 185.3N$

Reactions R_1 *and* R_2 at the supports

The reactions R_1 *and* R_2 at the supports are obtained as follows

$(W_{MFM} + W_{HM} + W_{GRH}) = 126.1 + 112 + 185.3 = 423.4N$

From equation (3.39)

$$R_1 = R_2 = \frac{1}{0.5}\left[\frac{1}{2}(W_{MFM} + W_{HM} + W_{GRH}) \times 0.45 + W_{GRS} \times 0.25 + \frac{1}{2}(W_{MFM} + W_{HM} + W_{GRH}) \times 0.05\right]$$

$$= \frac{1}{0.4}\left[\frac{1}{2} \times 423.4 \times 0.45 + 18.67 \times 0.25 + \frac{1}{2} \times 423.4 \times 0.05\right] = 221N$$

Bending moments along the span of the shaft

The bending moments along the span of the shaft are obtained as follows

From equation (3.40)

$M_{b1} = R_1 \times 0.05 = 221 \times 0.05 = 11.05Nm$

From equation (3.41)

$$M_{b2} = R_1 \times 0.25 - \frac{1}{2}(W_{MFM} + W_{HM} + W_{GRH}) \times 0.2 = 221 \times 0.25 - \frac{1}{2} \times 423.4 \times 0.2 = 12.91Nm$$

From equation (3.42)

$$M_{b3} = R_1 \times 0.45 - \frac{1}{2}(W_{MFM} + W_{HM} + W_{GRH}) \times 0.4 - W_{GRS} \times 0.2$$

$$= 221 \times 0.45 - \frac{1}{2} \times 423.4 \times 0.4 - 18.64 \times 0.2 = 11.05Nm$$

Diameter of the shaft

The diameter of the shaft is obtained as follows

From equation (3.36)

$$d^3 = \frac{16}{\pi S_a}\sqrt{(k_b M_b)^2 + (k_t M_t)^2}$$

$$S_a = 40MN/m^2 \ \ for \ \ shaft \ \ with \ \ key-way$$

$$k_b = 2$$

$$k_t M_t = 0, \ for \ a \ case \ of \ \ pure \ bending$$

$$M_b = Maximum \ bending \ moment = M_{b2} = 12.91Nm$$

$$d = \left(\frac{16}{\pi S_a}\sqrt{(k_b M_b)^2 + (k_t M_t)^2}\right)^{\frac{1}{3}} = \left(\frac{16}{\pi \times 40 \times 10^6}\sqrt{(2 \times 12.91)^2 + (0)^2}\right)^{\frac{1}{3}} = 14.87mm$$

Number of cells on the seed metering device

The number of cells on the seed metering device is obtained as follows

From equation (3.5)

$$Number \ of \ cells = \frac{\pi \times Diameter \ of \ the \ planter's \ ground \ wheel}{Intra-row \ spacing \ distance \ of \ seeds}$$

Diameter of the planter's ground wheel $= 0.65m$

Recommended intra-row spacing of maize are $0.2, 0.25, \ and \ 0.3m$ (Gbabo, 1988)

Recommended intra-row spacing of cowpea are $0.2 \ and \ 0.3m$ (Gbabo, 1988)

Recommended intra-row spacing of soya beans is $0.2m$

For $0.2m$ $intra-row \ spacing, \ Number \ of \ cells = \frac{\pi \times 0.65m}{0.2m} = 10.210 \approx 10$

For $0.25m$ $intra-row \ spacing, \ Number \ of \ cells = \frac{\pi \times 0.65m}{0.25m} = 8.168 \approx 8$

For $0.3m$ $intra-row \ spacing, \ Number \ of \ cells = \frac{\pi \times 0.65m}{0.3m} = 6.807 \approx 7$

In most of the cases with the same intra-row spacing, the number of cells is the same. The only difference is the sizes of the cells.

Maximum draft on the planter

The maximum draft on the planter is obtained as follows for the different types of soil.

From equation (3.51)

$D_{FM} = R_S \times A_{FO} \times Acceleration\ due\ to\ gravity$

Recommended depth of cut for maize is 3 to 4cm. The average value was used for computation

From equation (3.52)

$A_{FO} = \text{Re}commended\ depth\ of\ cut \times Thickness\ of\ furrow\ opener = 3.5cm \times 1.5cm = 5.250cm^2$

For sandy soil, $D_{FM} = 0.210kg/cm^2 \times 5.250cm^2 \times 9.81m/s^2 = 10.816N$

For sandy moist soil, $D_{FM} = 0.245kg/cm^2 \times 5.250cm^2 \times 9.81m/s^2 = 12.618N$

For sandy loam dry soil, $D_{FM} = 0.315kg/cm^2 \times 5.250cm^2 \times 9.81m/s^2 = 16.223N$

For silt loam moist soil, $D_{FM} = 0.385kg/cm^2 \times 5.250cm^2 \times 9.81m/s^2 = 19.828N$

For silt loam dry soil, $D_{FM} = 0.455kg/cm^2 \times 5.250cm^2 \times 9.81m/s^2 = 23.434N$

For clay loam moist soil, $D_{FM} = 0.455kg/cm^2 \times 5.250cm^2 \times 9.81m/s^2 = 23.434N$

For clay loam dry soil, $D_{FM} = 0.525kg/cm^2 \times 5.250cm^2 \times 9.81m/s^2 = 27.039N$

For heavy clay dry soil, $D_{FM} = 0.665kg/cm^2 \times 5.250cm^2 \times 9.81m/s^2 = 34.249N$

For heavy clay sod soil, $D_{FM} = 0.735kg/cm^2 \times 5.250cm^2 \times 9.81m/s^2 = 37.854N$

Capacity of the planter in terms of the area of land covered per time

The capacity of the planter in terms of the area of land covered per time is obtained as follows.

The speed of the planter from raw experiment was obtained as 0.15m/s. This means that in 1s the planter covers a distance of 0.15m.

Recommended inter-row spacing of maize is $0.9m$ (Gbabo, 1988)

Recommended inter-row spacing of cowpea is $0.75m$ (Gbabo, 1988)

Recommended inter-row spacing of soya beans is $0.5m$

From equation (3.55)

$$\begin{aligned} Dis\tan ce\ covered\ by\ planter &= (Speed\ of\ planter) \times (Time\ of\ planting)\ (m/time) \\ &= 0.15m/s \times 3600s = 540m/hr \end{aligned}$$

From equation (3.54)

$$Area\ covered\ by\ planter\ for\ maize =$$

$$(Inter - row\ spacing\ of\ maize) \times (Distance\ covered\ by\ planter)\ (m^2/time)$$

$$= 0.9m \times 540m/hr = 486m^2/hr$$

$$Area\ covered\ by\ planter\ for\ cowpea =$$

$$(Inter - row\ spacing\ of\ cowpea) \times (Distance\ covered\ by\ planter)\ (m^2/time)$$

$$= 0.75m \times 540m/hr = 405m^2/hr$$

$$Area\ covered\ by\ planter\ for\ soya\ beans =$$

$$(Inter - row\ spacing\ of\ soya\ beans) \times (Distance\ covered\ by\ planter)\ (m^2/time)$$

$$= 0.5m \times 540m/hr = 270m^2/hr$$

From equation (3.53)

$$C_{PA}\ for\ maize = \frac{Area\ covered\ by\ planter\ for\ maize\ in\ m^2/time}{10000m^2/hectare}\ (hectare/time)$$

$$= \frac{486m^2/hr}{10000m^2/hectare} = 0.0486hectare/hr$$

$$C_{PA}\ for\ cowpea = \frac{Area\ covered\ by\ planter\ for\ cowpea\ in\ m^2/time}{10000m^2/hectare}\ (hectare/time)$$

$$= \frac{405m^2/hr}{10000m^2/hectare} = 0.0405hectare/hr$$

$$C_{PA}\ for\ soya\ beans = \frac{Area\ covered\ by\ planter\ for\ soya\ beans\ in\ m^2/time}{10000m^2/hectare}\ (hectare/time)$$

$$= \frac{270m^2/hr}{10000m^2/hectare} = 0.0270hectare/hr$$

Capacity of the planter in terms of number of seeds planted per time

The capacity of the planter in terms of number of seeds planted per time is obtained as follows

From equation (3.56)

$$C_{PN}\ for\ maize =$$

$$\frac{Distance\ covered\ by\ planter}{Intra - row\ spacing\ of\ maize} \times Number\ of\ seeds\ per\ hole\ (seeds/time)$$

$$C_{PN}\ for\ cowpea =$$

$$\frac{Distance\ covered\ by\ planter}{Intra - row\ spacing\ of\ cowpea} \times Number\ of\ seeds\ per\ hole\ (seeds/time)$$

C_{PN} *for soya beans* =

$$\frac{Distance\ covered\ by\ planter}{Intra-row\ spacing\ of\ soya\ beans} \times Number\ of\ seeds\ per\ hole\ (seeds/time)$$

For $0.2m$ $intra-row\ spacing,\quad C_{PN} = \frac{540m/hr}{0.2m} \times 2seeds = 5400seeds/hr$

For $0.25m$ $intra-row\ spacing,\quad C_{PN} = \frac{540m/hr}{0.25m} \times 2seeds = 4320seeds/hr$

For $0.2m$ $intra-row\ spacing,\quad C_{PN} = \frac{540m/hr}{0.3m} \times 2seeds = 3600seeds/hr$

Time required to cultivate 1 hectare of land

The time required to cultivate 1 hectare of land is therefore obtained as follows

$$Time\ required\ for\ maize = \frac{1}{0.0486} = 20.576hrs$$

$$Time\ required\ for\ cowpea = \frac{1}{0.0405} = 24.691hrs$$

$$Time\ required\ for\ soya\ beans = \frac{1}{0.0270} = 37.037hrs$$

Number of days required to plant 1 hectare of land

Assuming 8hrs is used per day for planting, the number of days required to plant 1 hectare of land is obtained as follows

$$For\ maize,\ the\ number\ of\ days\ required = \frac{20.576hrs}{8hrs/day} = 2.572\ days \approx 2.6\ days$$

$$For\ maize,\ the\ number\ of\ days\ required = \frac{24.691hrs}{8hrs/day} = 3.086\ days \approx 3.1\ days$$

$$For\ maize,\ the\ number\ of\ days\ required = \frac{37.037hrs}{8hrs/day} = 4.630\ days \approx 4.6\ days$$

3.11 Shear Force and Bending Moment Diagram

Figure 3.8 shows the shear force and bending moment diagram, the maximum bending moment was obtained from the bending moment diagram.

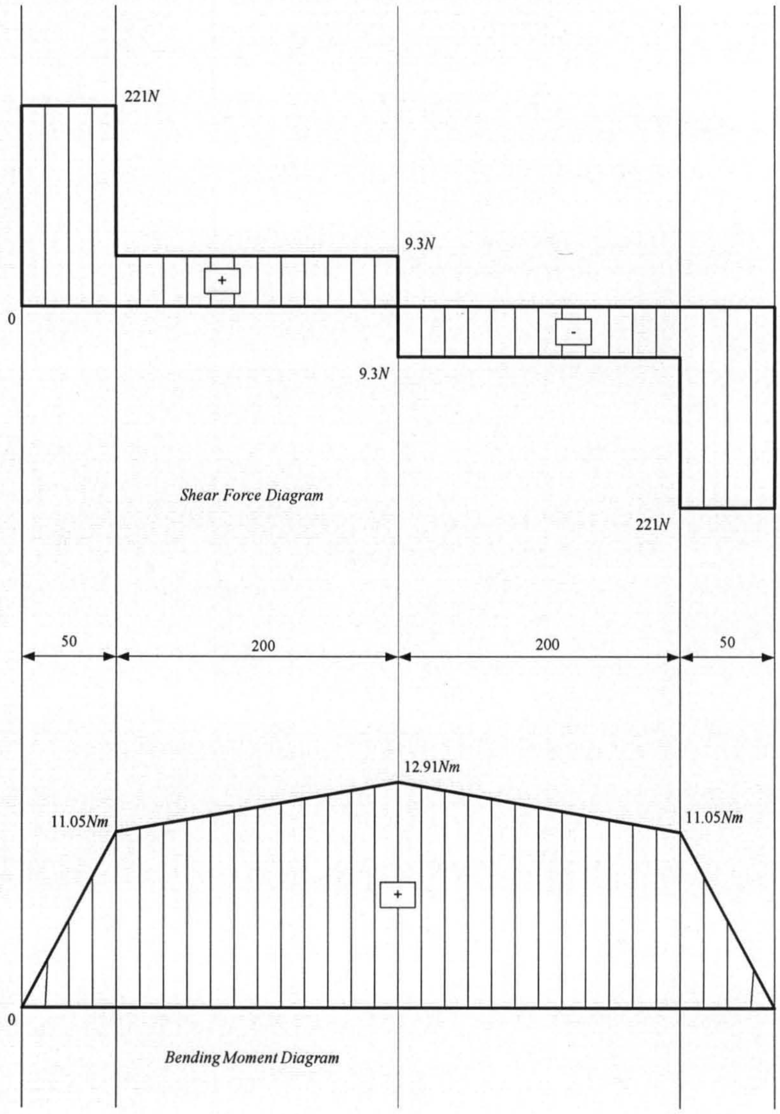

Fig. 3.8: Shear force and bending moment diagram

3.11 Criteria for Material Selection

The preceding has shown that almost ninety eight percent of the planter's components are made up of metallic material, while the remaining two percent are non metallic material (wood and rubber). The decision to use these particular materials as components in the production of the seed planter was based on the following factors

1. Service requirement
2. Strength
3. Economic factor

4. Environmental factor

- Service requirement: - All the materials are suitable to meet the requirement of the working condition to which the component parts will be subjected to.
- Strength: - The material has the ability to support dead-load and with-stand shock as well as enduring repetitive usage.
- Economic factors: - The materials are readily available and are obtained at a lower cost.
- Environmental Factors: - This includes the climatic condition in which the machine will be used.

CHAPTER FOUR

FABRICATION, TESTING AND COST ANALYSIS

4.1 Fabrication

As shown in Figure 4.1, all the parts of the multi-crop planter were fabricated from mild steel material, except for the metering mechanism which was fabricated from good quality wood (mahogany), the seed funnel which was made from rubber material, and the seed tube which was also made from rubber material. The choice of rubber material for the seed funnel and seed tube was because the coefficient of restitution for rubber material is lower than that of a mild steel sheet of the same thickness. The rubber material will go a long way in minimizing seed bouncing, thereby protecting the seeds from damage due to impact.

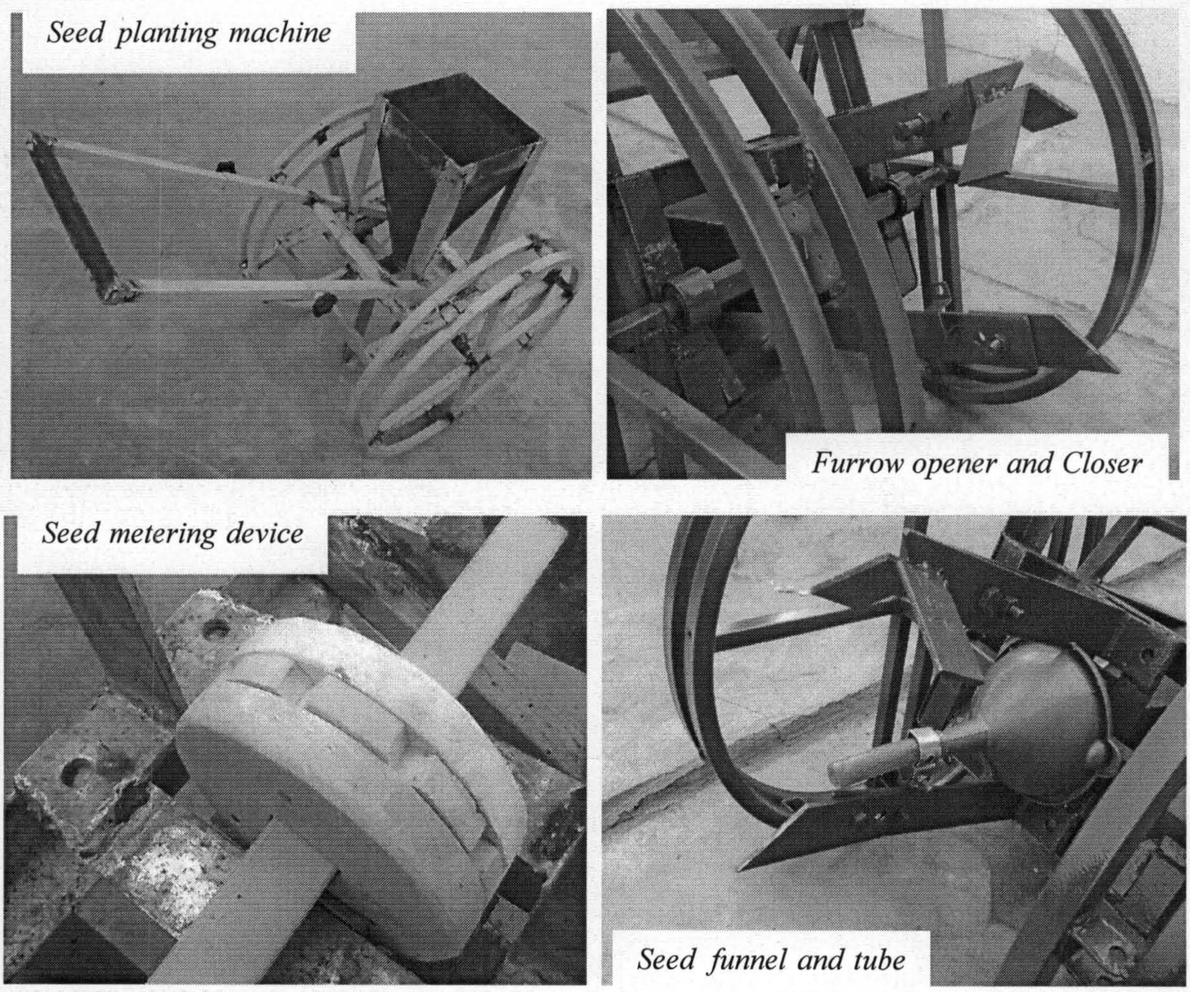

Fig. 4.1: Photograph of component parts of the fabricated seed planter

The **hopper** was fabricated using 2mm thick mild steel metal sheet. The **metering mechanism** was fabricated from good quality wood material (mahogany). The **main frame** which supports every other component of the multi-crop planter was fabricated using 2 inch angle bar of 4mm thickness. The **adjustable handle** for the planter was fabricated using a combination of 1 inch mild steel square pipe, ¾ inch mild steel square pipe, and 1 inch mild steel angle bar. The **adjustable furrow opener** and **furrow closer** were both fabricated using a 50mm x 5mm mild steel flat bar. The **planter's ground wheels** were fabricated using a combination of both 1 inch mild steel square pipes and 3mm thick mild steel flat bars. Furrow opener and closer were designed to be interchangeable. For this design, the drive shaft directly controls the seed metering mechanism which eliminates completely attachments such as pulleys, belt systems, and gears thereby eliminating complexities which increase cost, and increasing efficiency at a highly reduced cost which is the major focus of this project work.

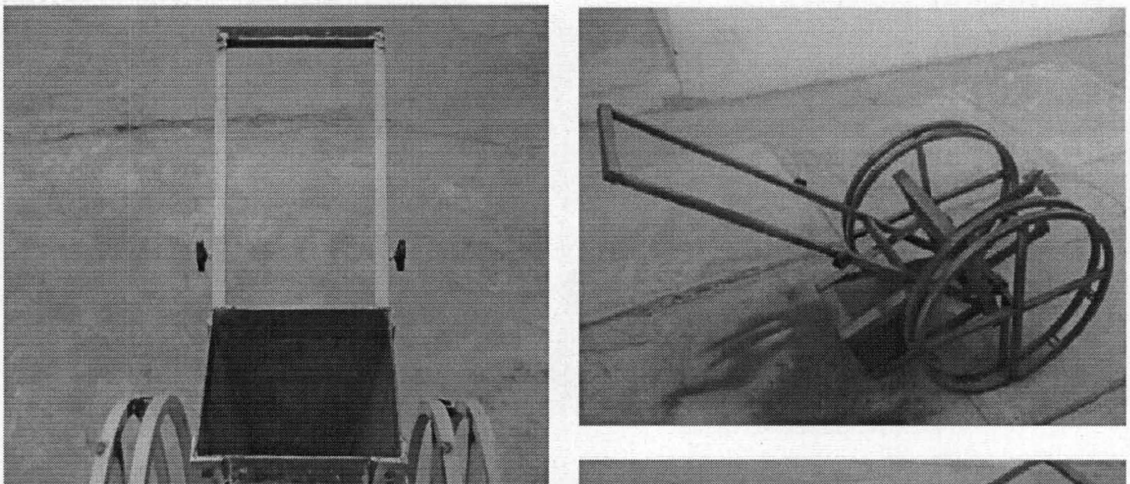

Fig. 4.2: Photograph of the fabricated multi-crop planter

4.2 Testing

Trial tests were conducted to see if the seed metering mechanism, furrow opener, and furrow closer are functioning properly. The results show that they are functioning properly as expected. For a furrow opener, the ability to place the seed at a given sowing depth in the soil is an important factor in evaluating its performance. For the planter operation, the hopper was filled with seeds. The filling of the hopper depends on how much area of the field to be covered. As the multi-crop planter was pushed forward in the direction of travel at an average speed of 0.15m/s, the pointed bar type furrow opener penetrated the soil creating a furrow for seeds to be placed. The planter's ground wheel is connected directly to the seed metering device, and as the ground wheel rotates, the seed metering device placed at the bottom of the hopper also rotates, thereby releasing two or three seeds depending upon the size of the cells or the size of the seeds. These seeds are then conveyed to the furrow through the seed tube. The furrow was then closed by the shoe type furrow closer. A close visual inspection of the seeds that were released from the planter's metering mechanism shows no visible sign of damage.

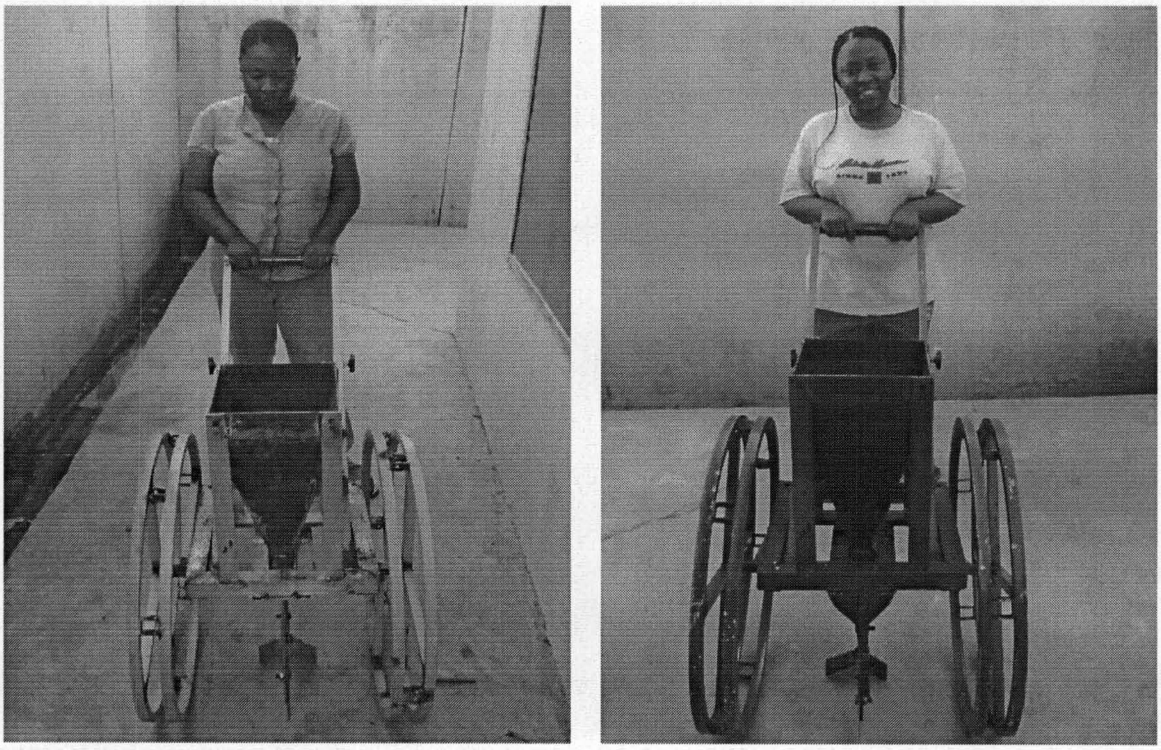

Fig. 4.3: Photograph of the fabricated seed planter during the trial test

4.3 Cost Analysis

In any engineering design, the economic benefit has to be put into consideration through the selection of materials which are very cheap and at the same time meet the specific purpose for which the machine was designed. The essence of costing the design and fabrication is better appreciated when considerations are given to the fact that a product is incomplete unless the cost of designing and fabricating the product are evaluated. The cost of designing and fabricating the manually operated single-row multi-crop planter is classified as follows:

i. Material cost

ii. Labour cost

iii. Overhead cost

iv. Total cost

4.3.1 Material Cost

This is the cost of all the materials used in the fabrication of the multi-crop planter. For simplicity and clarity, table 4.1 gives the summary of the cost of materials used in fabrication.

4.3.2 Labour Cost

Taking a direct labour cost of 25% of the material cost (Olarewaju, 2005)

$$Labour\,Cost = \frac{25}{100} \times Material\,Cost = 0.25 \times 12370 = \text{₦}3092.50$$

4.3.3 Overhead Cost

This includes all other expenses incurred apart from material and labour cost. Taking an overhead cost of 20% of the material cost (Olarewaju, 2005)

$$Overhead\,Cost = \frac{20}{100} \times Material\,Cost = 0.20 \times 12370 = \text{₦}2474.00$$

4.3.4 Total Cost

The total cost of fabricating the manually operated seed planter is the sum of the material cost, labour cost, and overhead cost.

$$Total\,Cost = Material\,Cost + Labour\,Cost + Overhead\,Cost = 12370 + 3092.5 + 2474 = ₦17936.50$$

Table 4.1: Summary of Material Cost

S/N	Component Description	Specification	Number Required	Unit Cost ₦	Amount ₦
1	Main Frame which supports every other component parts of the planter	Mild steel angle bar (1½ inch)	1	4000.00	4000.00
2	Adjustable Handle to accommodate variable heights of planter operators	Mild steel square pipe (1 inch)	1	1000.00	1000.00
		Mild steel angle bar (1 inch)	1	300.00	300.00
3	Seed hopper (shape of a frustum of a pyramid truncated at the top) which usually contains the seeds for planting.	Mild steel sheet metal (2mm thick)	1	2000.00	2000.00
4	Seed metering device (wooden roller type with cells on its periphery)	Wood (450mm x 150mm x 60mm)	1	500.00	500.00
5	Adjustable furrow opener (pointed bar type) which permits planting at each variety's ideal ground depth.	Mild steel flat bar (50mm x 5mm)	1	300.00	300.00
6	Adjustable Furrow Closer (shoe type) which pushes the soil to cover the furrow and then compact it.	Mild steel flat bar (50mm x 5mm)	1	400.00	400.00
7	Drive Wheel which also rotates the planter's seed metering device.	Mild steel square pipe (1 inch)	1	2000.00	2000.00
8	Seed funnel and tube (conveys the seeds into the furrow)	Conical funnel with a rubber hose (outlet diameter of 1 inch)	1	50.00	50.00
9	Bearings (for easy rotation of the planter's ground wheels)	Ball bearing (high speed steel) internal diameter 2cm	4	300.00	1200.00
10	Paint (to prevent corrosion of the component parts of the planter)	Green colour	1	500.00	500.00
11	Bolts and Nuts (to allow for the easy adjustment of the furrow opener and closer)		4	30.00	120.00
	TOTAL				**12370.00**

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This work focused on the design and fabrication of a manually operated single-row multi-crop planter that is cheap, easily affordable by the rural farmers, easy to maintain and less laborious to use. The multi-crop planter will go a long way in making farming more attractive to the youths, reducing the problem of urban migration by youths in search of white collar job, saving tremendous amount of time during farming, ensuring capacity utilization of available farmland, and finally increasing agricultural output. All parts of the planter were fabricated from mild steel material, except for the metering mechanism which was made from good quality wood (mahogany) and the seed funnel and tube, which were made from rubber material. The seed metering mechanism used for this work was the wooden roller type with cells on its periphery. It was designed to be interchangeable to allow for the different varieties and types of seeds. For this design, the drive shaft directly controls the seed metering mechanism which eliminates completely attachments such as pulleys, belt systems, and gears thereby eliminating complexities which increase cost, and increasing efficiency at a highly reduced cost which is the major focus of this project work. The results obtained from the trial tests showed that the planter functioned properly as expected with a planting capacity of 0.0486 hectare/hr for maize, 0.0405 hectare/hr for cowpea, and 0.0270 hectare/hr for soya beans. Visual inspection of the seeds that were released from the planter's metering mechanism showed no visible signs of damage to the seeds.

5.2 Recommendation

The planter's metering mechanism should de designed to accommodate a maximum of four cells for better performance. The clearance between the metering mechanism and the hopper should be large enough to prevent damage to the seeds. A smaller wheel size should be selected to reduce the time of travel of the seeds into the furrow.

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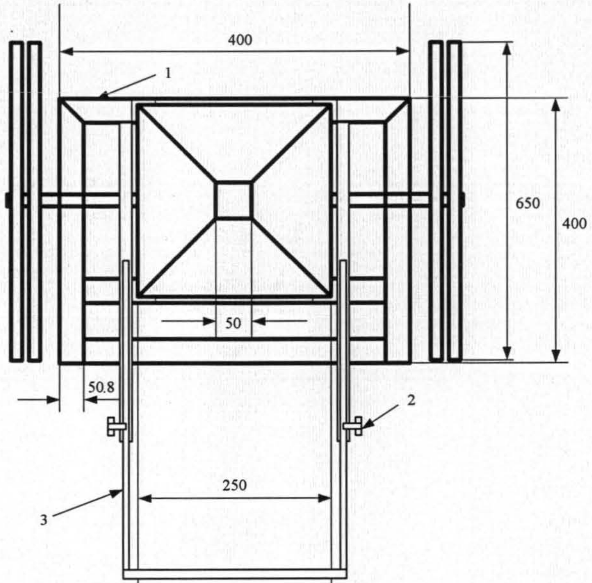
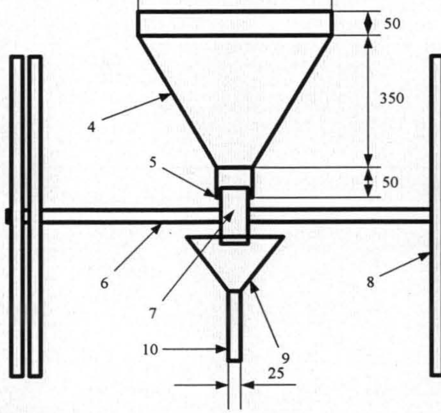
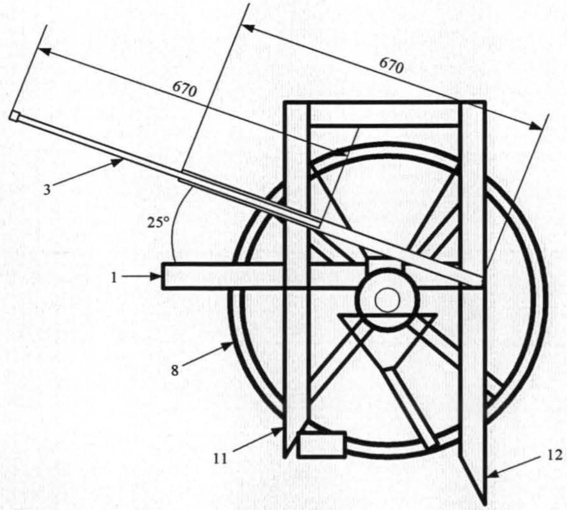
PLAN VIEW





FRONT VIEW



SIDE VIEW

PART NO	DESCRIPTION	MATERIAL
1	Main frame	Mild Steel
2	Adjustment knob	Plastic
3	AdjustablePlanter handle	Mild Steel
4	Hopper	Mild Steel
5	Rubber seal	Rubber
6	Shaft	Mild Steel
7	Seed metering device	Wood
8	Planter's groundwheel	Mild Steel
9	Seed funnel	Rubber
10	Seed tube	Rubber
11	AdjustableFurrow closer	Mild Steel
12	AdjustableFurrow opener	Mild Steel

FEDERALUNIVERSITY OF TECHNOLOGY, MINNA
DEPARTMENTOF AGRICULTURAL AND BIORESOURCES ENGINEERING

PROJECT TITLE
DESIGN, FABRICATION AND TESTINGOF A MANUALLY OPERATEDSINGLE - ROW MULTI - CROP PLANTER

DESIGNED AND DRAWN BY: OMOLAYO - JIMOH, IBUKUN BLESSING
MAT. NO.: 2004/18407EA

SUPERVISED AND CHECKED BY: ENGR. DR. GBABO AGIDI

DATE: FEBRUARY, 2010