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**SCHOOL OF FOOD TECHNOLOGY, NUTRITION, AND BIOENGINEERING**

**DEPARTMENT OF AGRICULTURAL AND BIO-SYSTEMS ENGINEERING**

**DESIGN AND FABRICATION OF AN APPROPRIATE SEED PLANTER FOR  
SMALLHOLDER FARMERS IN UGANDA**

**BY**

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**JUNE 2026**

## DECLARATION

This thesis is my original work and has not been submitted to any University for any degree

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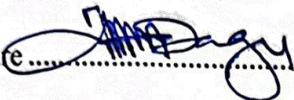
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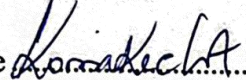
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## **LIST OF ACRONYMS**

|        |                                                               |
|--------|---------------------------------------------------------------|
| AFC    | Actual Field Capacity                                         |
| BCR    | Benefit Cost Ratio                                            |
| FAO    | Food and Agriculture Organization                             |
| FE     | Field Efficiency                                              |
| GDP    | Gross Domestic Product                                        |
| MAAIF  | Ministry of Agriculture, Animal, Industry, and Fisheries      |
| MUARIK | Makerere University Agricultural Research Institute Kabanyolo |
| NARO   | National Agricultural Research Organization                   |
| P/A    | Present Value given Annual Value (worth)                      |
| PV     | Present Value                                                 |
| TFC    | Theoretical Field Capacity                                    |
| UBOS   | Uganda Bureau of Statistics                                   |

## **DEDICATION**

This work is dedicated to my lovely mother, Anna Maria. Her unending love and prayers have enabled me to sail through smoothly.

## **ACKNOWLEDGEMENT**

I would like to express my sincere appreciation to everyone who contributed to the successful completion of this study on the design and fabrication of a seed planter. I am deeply grateful to my course instructors for their valuable guidance, knowledge, and support, which greatly strengthened the academic quality of this work. I extend my special thanks to my supervisors for their professional advice, continuous encouragement, and constructive suggestions throughout the entire research process. Their expertise and dedication played a significant role in shaping the project.

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## **ABSTRACT**

The agriculture sector plays a vital role in the economy of Uganda; it is responsible for about 24% of the GDP and provides employment opportunities to more than 70% of the country's population, but the farmers still have difficulties due to use of rudimentary technologies. manual planting, which involves the use of hand hoes, is one of the major constraints because its physically demanding task that leads to high degree of biomechanical load and musculoskeletal injuries. Mechanized commercial planters, although they provide high precision, are not affordable and do not fit for small plots. This research filled this gap by developing a low-cost seed plater that meets Ugandan farmer's needs. The seed planter has been designed using SolidWorks software and has been fabricated I MUARIK (Makerere University Agricultural Research institute Kabanyolo) using mild steel material. The final device is highly portable, weighing only 3 kg when fully loaded, and due to the vertical position, the mechanism allows an upright operating posture to reduce drudgery. Field testing demonstrated a field efficiency of 75% and successful singulation rates of 80.88% for maize and 82.35% for soya beans. Economically, the planter proved highly viable with a benefit-cost ratio of 2.299 and a payback period of approximately 2.1 years, offering annual labor savings of up to UGX 140,000. The results confirm that this planter is a suitable appropriate technology that enhances planting quality and farmer comfort while supporting Uganda's agricultural modernization goals. Recommendations include the addition of a fertilizer unit and government subsidies to accelerate adoption.

**Keywords:** Drudgery, Seed planter, Mechanization

## **CHAPTER ONE: INTRODUCTION**

### **1.1 Background of the study**

Agriculture is the backbone of the economy of Uganda, contributing approximately 24% of the GDP and supporting more than 70% of the population, mainly by way of stallholder agriculture (UBOS, 2022; MAAIF, 2023). These small scale farmers who farm in plots less than one hectare and fragmented land holdings, play an important role in national food security through the cultivation of crops such as maize, beans and bananas. Nevertheless, structural problems such as climate variations, lack of inputs and primitive technologies limit their productivity as they produced 30-50% below their capacity (FAO, 2021). Seed planting emerges as a foundational yet bottleneck operation in crop establishment, influencing subsequent growth phases, resource use efficiency, and ultimate harvest outcomes. Traditional manual planting techniques, primarily using hand hoes, dominate Ugandan smallholder practices. Beyond high labor demands, they yield suboptimal results such as changing depths (2-10 cm fluctuations), extra seed than the intended, and poor seed to soil contact, leading to germination rates below 70%, uneven crop emergence, competition for resources, and yield penalties (Omara et al., 2016). In women-dominated farming households comprising 53% of Ugandan agriculture, this drudgery exacerbates gender disparities, contributing to musculoskeletal disorders like lower back pain (MAAIF, 2023).

However, despite the claims of uniformity and efficiency offered by mechanical seed planting equipment such as multi-row drills or air-seeding system (for example, singulation 95%), they do not fit the needs of smallholder farmers. The foreign made machines from companies like John Deere or Kubota range from 5 to 50 million, which need tractors not found in micro plots (Khan et al., 2015). Animal-drawn options, though more accessible, are bulky (greater than 20 kg), limited to larger farms, and underutilized due to livestock shortages in highland regions. This mismatch perpetuates a mechanization vacuum, stalling Uganda's progress toward Vision 2040 goals of commercialized smallholder agriculture. The concept of "appropriate technology" advocates for intermediate solutions of low-cost, user-friendly innovation from local materials that empower end-users without external dependencies. In sub-Saharan Africa, successes like jab planters demonstrate 2-3 fold labor savings and yield boosts. In Uganda, specific efforts such as those by NARO and MUARIK have prototyped tools for weeding and harvesting but overlooked

appropriate seed planting equipment which can favor even smallholder farmers, a gap this study addresses.

Building on the approved proposal, this final year project designed, fabricated, and rigorously evaluated a portable (3-4 kg loaded), manually worked seed planter which is optimized for seed such as maize, and beans, it ensures precise drop rates (90-95% accuracy), adjustable depths (3-5 cm), using affordable materials like mild steel which is sourced locally. Field demonstrations at MUARIK confirmed its efficacy, paving the way for dissemination through farmer groups and agro-dealers.

## **1.2 Problem Statement**

Despite advancements in agricultural machinery, Ugandan smallholder farmers are forced to bear the use of conventional implements like hand hoes. Such practices expose them to a great deal of drudgery in the field with resultant inconsistencies in seed distribution and increased risk of back pains. Existing planting machines, although efficient, are too expensive for small-scale farmers. This gap is bridged by developing a lightweight (less or equal to 3 kg loaded), affordable prototype with a horizontal seed metering mechanism for accurate singulation and placement.

## **1.3 Objectives**

### **1.3.1 Main objective**

To design and fabricate an appropriate seed planter for smallholder farmers in Uganda

### **1.3.2 Specific objectives**

- i) To design an appropriate seed planter
- ii) To fabricate a functional prototype of the designed seed planter
- iii) To assess the field performance of the prototype planter in terms of planting effectiveness and efficiency
- iv) To evaluate the cost-effectiveness of adopting the developed planter

## **1.4 Research questions**

- i. What design features and specifications are required to develop a seed planter that is suitable for smallholder farmers in Uganda?
- ii. How can the designed seed planter be fabricated using locally available and affordable materials while maintaining structural integrity and functionality?

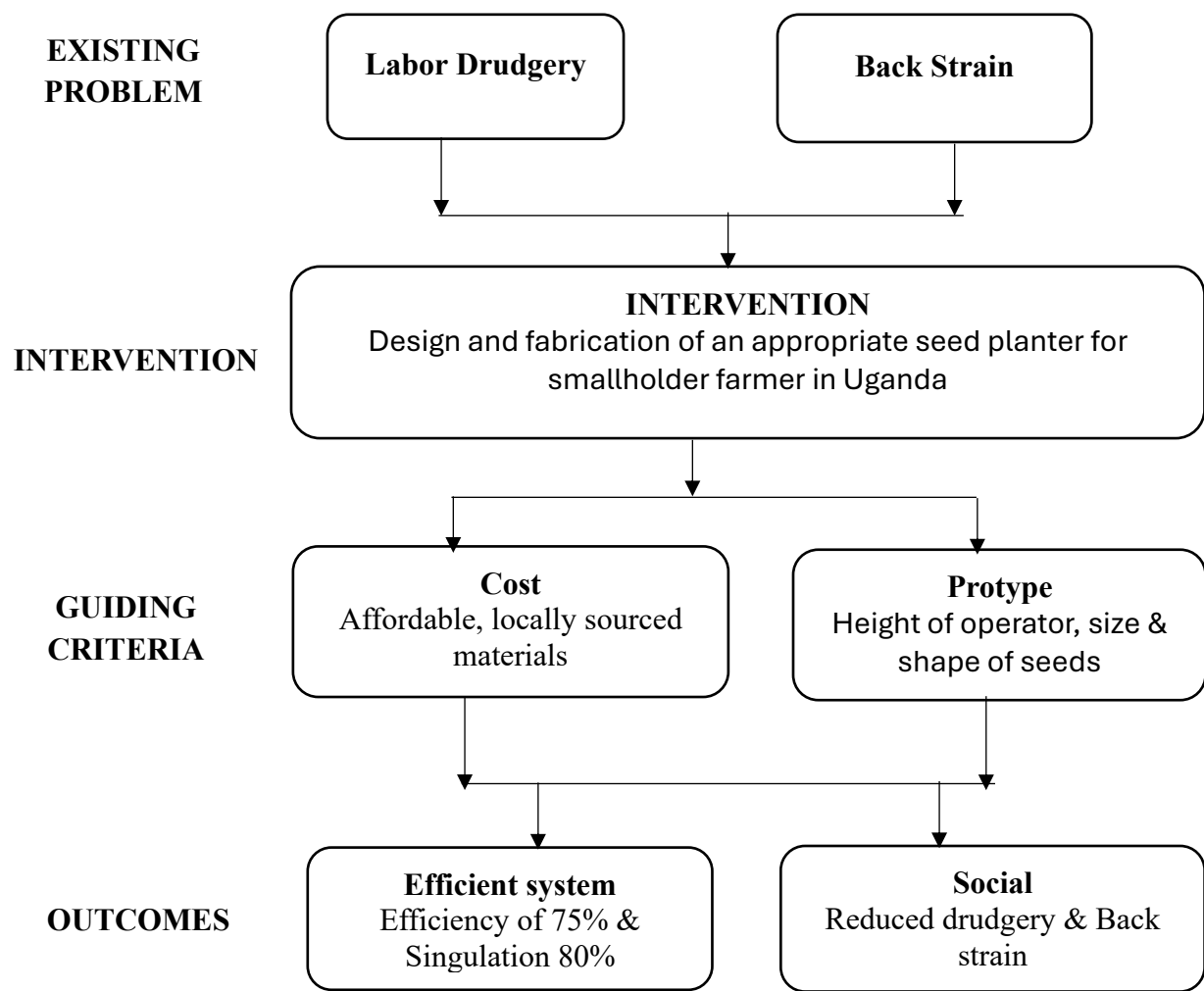
- iii. How does the fabricated seed planter perform in terms of planting depth uniformity, seed metering, and field efficiency under typical smallholder farm conditions?
- iv. What payback period and return on investment are possible for farmers adopting this technology?

### **1.5 Justification**

The continued reliance on traditional planting methods, such as hand hoeing and manual seed placement, has limited productivity among smallholder farmers. These methods are not only time-consuming but also result in occupational strain as well as uneven planting depth, leading to poor germination and low yields among farmers (Alhassan et al., 2018). On the other hand, existing mechanized and animal-drawn planters have demonstrated improved planting precision and efficiency elsewhere, but their high costs, large size, and maintenance challenges make them inaccessible to Uganda's small-scale farmers, who typically cultivate less than one hectare (Obura et al., 2020). Consequently, there is a technological gap for an affordable, simple, and portable planting device that can meet the needs of low-income farmers.

There is therefore a need to develop a manually operated, cost-effective, and portable precision seed planter that enhances planting accuracy, reduces drudgery, and improves field efficiency. Through the use of local materials and construction methods, the proposed design will encourage local innovation and sustainable development in agriculture. Also, through the results, engineering solution that will assist in maintaining the objectives of agricultural modernization and sustainable development goal 2 (zero hunger) will be attained.

## 1.5 Conceptual Framework



*Figure 1: Conceptual framework*

## CHAPTER TWO: LITERATURE REVIEW

### 2.1 Review of the Application of Planter Technology in Farming

The use of the planter in agriculture is driven by the urgent need to resolve the problems of the existing conventional techniques to make the process more efficient, productive, and to reduce the physical labor of people (Alhassan et al., 2018). All over the world, the available space for agriculture becomes less in connection with the growing population, making the take of improving the use of resources and food production much more important (Chen et al., 2024). Planting with the help of conventional methods can be described as slow and tedious, laborious, and expensive (Omara et al., 2016). In case of crops like maize, beans and groundnuts, manual planting requires bending position from the person who plants them (figure 2), causing significant biomechanical strain and fatigue thus reducing work capabilities (Khan et al., 2015).



*Figure 2: Hand hoeing, source; Daily monitor 2021*

Manual techniques lead to inconsistencies in seed planting depth and positioning (Deogirikar Amit Ashokrao, 2024). Such inconsistency affects the productivity level through making plants compete for resources such as water, sunlight and nutrients (Alhassan et al., 2018). Inconsistent planting makes mechanization process including weed removal harder to achieve (Deogirikar Amit Ashokrao, 2024). Consequently, the introduction of planter technology aims to improve planting precision, reduce labor drudgery, and increase overall field efficiency (Alhassan et al., 2018).

## 2.2 Review of the Nature and Design of Planter Technology

Planter technology encompasses a wide variety of designs aimed at ensuring precision and efficiency, addressing needs ranging from small-scale subsistence farming to high-speed commercial agriculture (Chen et al., 2024).

### 2.2.1 Classification and Operational Context

Planters are categorized based on their operational mechanism (e.g., mechanical, pneumatic) and the type of material they handle. For small land holdings, simple, low-cost, manually operated or animal-drawn planters are crucial for increasing efficiency without large capital investment (Olufemi et al., 2020). For example, jab planters (Figure 3) are often approximately 100% cheaper than using a traditional cutlass for maize planting (Omae et al., 2015). The hand planter developed by Oklahoma State University (OSU) achieves greater than 80% singulation and plants seeds to a depth of 5 cm (Omara et al., 2016).



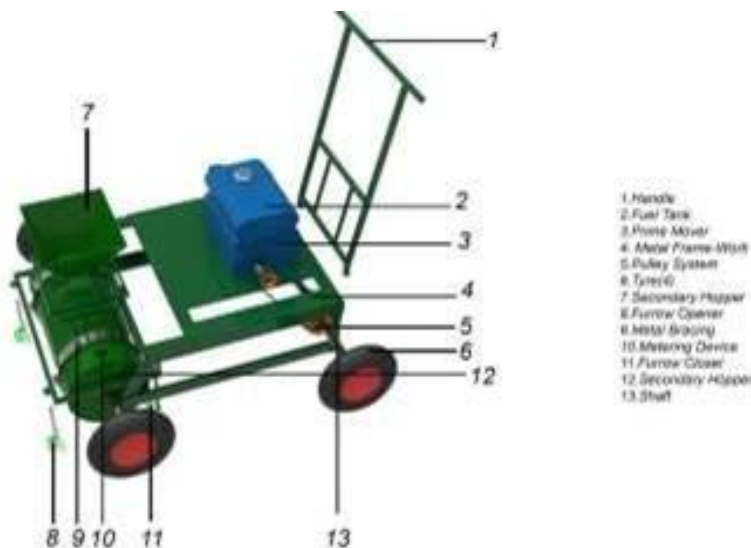
*Figure 3: Jab planter, source; eden-equip-online.co.za*

In Uganda, an ox-drawn tool combining a plough, planter, and cultivator (Figure 4) achieved a field efficiency of 87.3% (Obura et al., 2020). Although animal-drawn planters are easily accessible, they are underutilized due to livestock shortages in some areas, especially highland regions.



*Figure 4: Ox-drawn planter, (source; Obura et al., 2020)*

More advanced systems, such as self-propelled multi-crop precision planters (Figure 5), have achieved effective field capacities (EFC) of 0.1 ha/hr (Alhassan et al., 2018). Although these plant various seeds like maize, soybeans, and cowpeas, their functionality and performance depend on the speed of operation, with lower engine speed, a high number of seeds being discharged, and percentage damage also being high



*Figure 5: Multi-crop precision planter, (source; Alhassan et al., 2018)*

Robotic systems utilizing sensors and custom algorithms can provide nearly perfect accuracy, with one robotic maize planter (Figure 6), achieving a seed placement accuracy of 98.6% (Ayanniran et al., 2024). Although these planters have an accuracy of 98.6%, they require real-time mapping and monitoring of the field to help the robot navigate the field more efficiently and accurately, which is not economical for a smallholder farmer in Uganda, since it is expensive and requires some skilled labor.



*Figure 6: Robotic seed planter, (source; Ayanniran et al., 2024)*

### **2.2.2 Core Design Components and Principles**

The seed metering is the central functional component responsible for achieving uniform distribution and specific seed spacing (Kumar et al., 2024). Mechanical metering mechanisms, such as horizontal plates, are often adapted for specific crops like maize. (Kumar & Karmakar, 2025). For example, a manual two – maize planter was built using a simple horizontal plate metering system (Abubakar et al., 2020).

The contemporary designs can use pneumatic metering or flexible orifice seed metering plates to compensate for the differences in the shape of seeds and prevent their injuries (Liu et al., 2025; (Mahapatra et al., 2024). The other key elements include the frame that has been chosen according to the strength and weight criteria and the furrow openers capable of dealing with soil resistance

(Kumar et al., 2024; (Alhassan et al., 2018). The transmission system that consists of shafts and sprockets defines seed placement (Olufemi et al., 2020).

### **2.3 Review of the Design Requirements for the Planters**

The design of the planter to be considered appropriate, it would have considered agronomic and engineering criteria in relation to socio-economic limitations.

#### **2.3.1 Criteria for an Appropriate Planter Design**

For the planter to be considered appropriate, it must be easy to operate and maintain by smallholder farmers who cannot afford imported equipment (Olufemi et al., 2020). The machine must be easy to make from locally available material at affordable cost (Omae et al., 2015). In addition to this, ergonomics is important as well because the design must limit bending and squatting to minimize biomechanical stress (Abubakar et al., 2020). Finally, manual planters make it possible to handle the seedlings without touching them directly (Omae et al., 2015).

#### **2.3.2 Functional and Performance Requirements**

The design must ensure accurate seed placement to minimize resource competition (Alhassan et al., 2018). For maize and Beans, seeds should ideally be placed at a depth between 3 cm and 5 cm to ensure uniform emergence (Omara et al., 2016). The metering device must reliably deliver the desired number of seeds (singulation) while keeping seed damage below 5% to maintain viability (Mahapatra et al., 2024).

#### **2.3.3 Context-Specific Design Requirements**

Small-scale needs favor lightweight designs, such as the OSU hand planter, which is only 1.9 kg empty (Omara et al., 2016). Conversely, high-precision pneumatic systems are designed for high operational performance at speeds up to 14.2 km/h (Mahapatra et al., 2024).

## **2.4 Review of the Performance of Planters**

Performance is evaluated through technical metrics like field effectiveness and economic indicators like cost savings. Mechanized systems typically report higher efficiency, with a self-propelled multi-crop precision planter achieving a field efficiency (FE) of 81.2% (Alhassan et al., 2018). In contrast, a manually operated maize planter attained an average FE of 72.73% (Abubakar et al., 2020). Integrated ox-drawn tools in Uganda have registered high efficiencies of 87.3%.

In terms of accuracy, a robotic maize planter reached 98.6% accuracy, while a manually operated single-row planter achieved a 90.38% rate for single seed drops (Ansar et al., 2023). Seed damage varies significantly by design, ranging from 2.53% in some mechanized systems to as high as 13.3% in some manually operated two-row prototypes (Alhassan et al., 2018).

## **2.5 Review of the cost-effectiveness of planters**

Technologies highlights that mechanization lowers the operational cost, saves seeds and reduces labor needs relative to manual techniques and some studies have shown great cost saving using engineered planting technology such as; the manual Low-Cost Maize seeder with operating cost of 410 Tk/ha as opposed to the 5250 Tk/ha from manual seeding which is a 92% decrease in cost for seeding and jab planters which showed to be approximately 100% more cost effective than cutlass method.

## **2.6 Research Gaps and the Proposed Seed Planter**

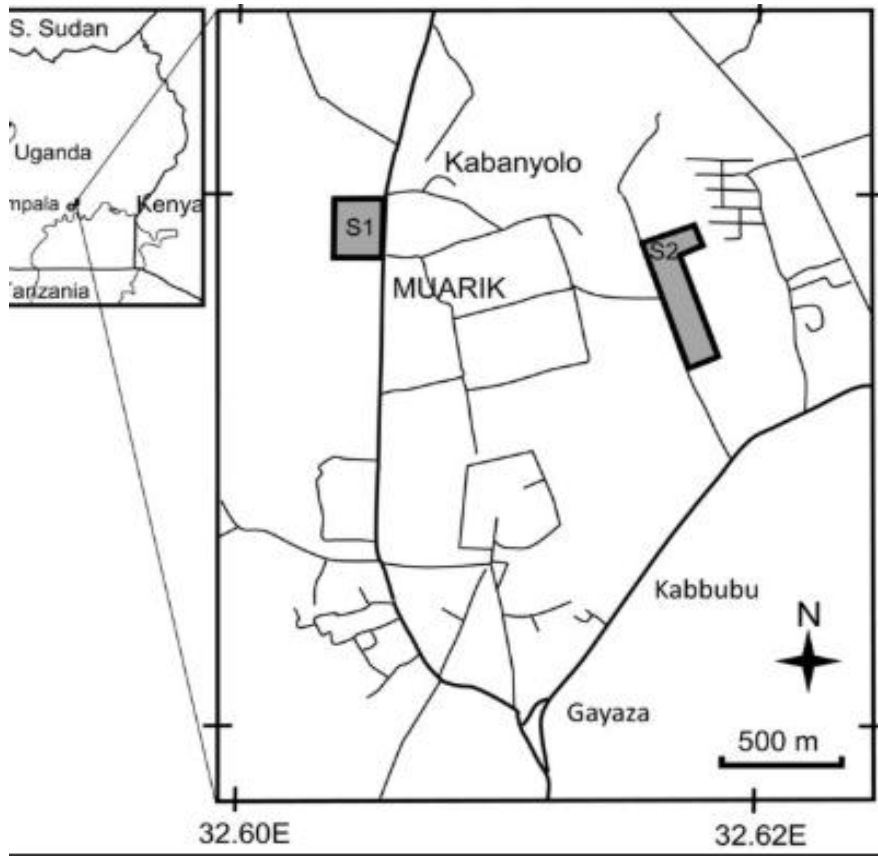
Though different advancement has been made, there are still gaps regarding cost, field adaptability, and ergonomics. Many existing prototypes are either too bulky or lack precision under variable field conditions. Crucially, there is limited research on locally fabricated planters optimized for Ugandan soil and seed characteristics. This study seeks to fill this gap by designing a portable, cost-effective precision planter using locally available materials.

## CHAPTER THREE: METHODOLOGY

### 3.1 Area of study

The appropriate seed planter was designed and constructed to ensure simple operating characteristics such as safety of operations, ease of maintenance and repair, ease of handling, quick assembly, portability, affordability, and these design considerations were done following the specific objectives as stated.

The fabrication and testing were conducted at Makerere University Agricultural Research Institute, Kabanyolo (MUARIK), located in Nangabo Sub-County, Wakiso District, Central Uganda. MUARIK provided an ideal representative smallholder farming environment with moderate topography and accessible infrastructure (Figure 7).



*Figure 7: Location of MUARIK*

### 3.2 Design of an appropriate seed planter

The planter was conceptualized as a lightweight (approximately 3 kg when fully loaded), single-row, manually operated precision seed planter optimized for maize and soya beans. The vertical orientation and trigger mechanism enable upright operation, significantly reducing drudgery compared to traditional hand-hoe planting, and the figure below shows the exploded view of machine components

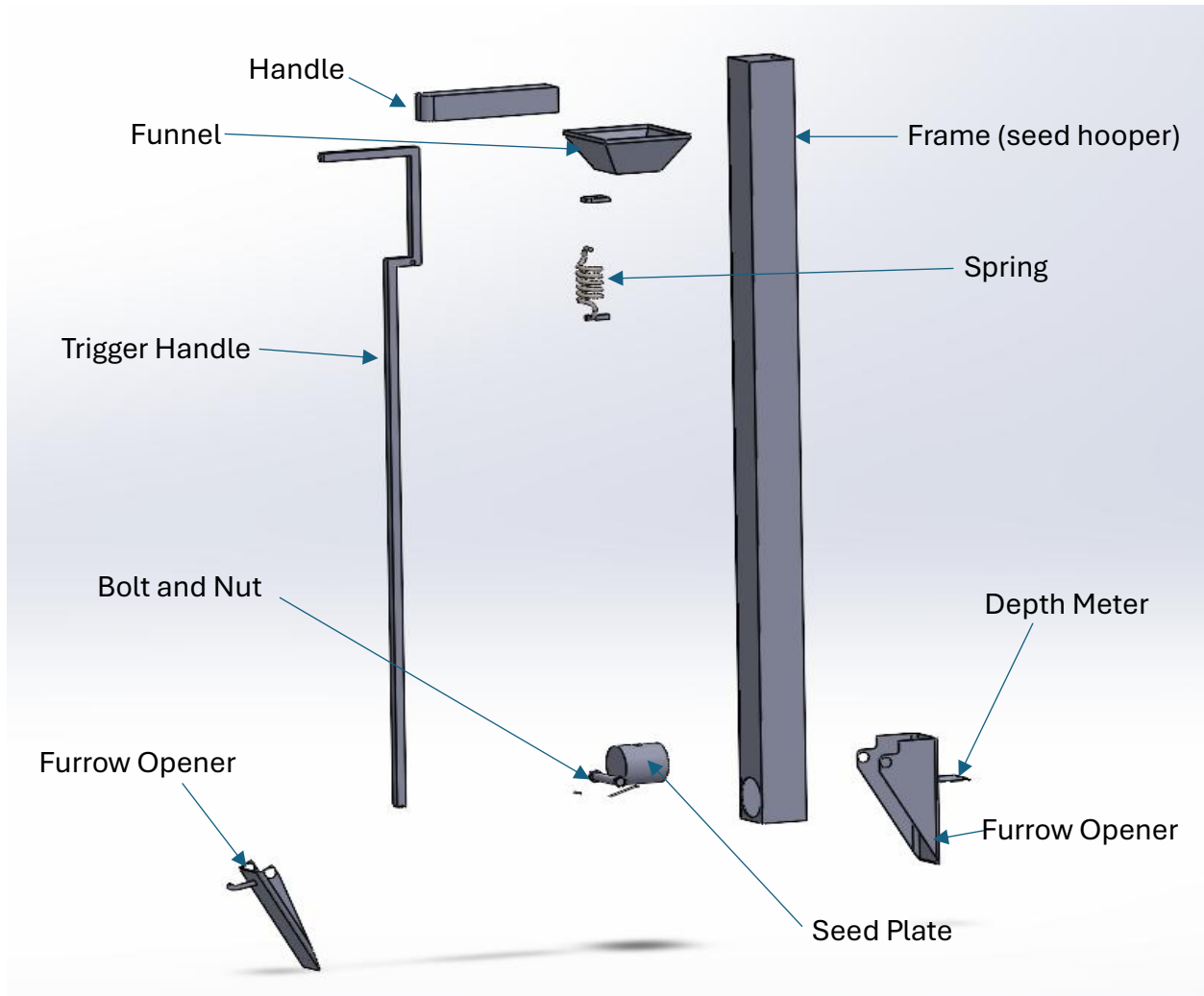


Figure 8: Exploded view of the seed planter

## Design Considerations

### 3.2.1 Ergonomics and Safety

- **Drudgery Reduction:** A primary goal is to allow the operator to work in an upright standing posture, avoiding the biomechanical strain and fatigue associated with traditional stooping or bending methods.
- **Operating Speed:** Manual planter is typically designed for forward speeds manageable by a human operator, often ranging from 0.3 to 1.0 km/h (Deogirikar Amit Ashokrao, 2024), to minimize missed plantings.

### 3.2.2 Field and Environmental Factors

- **Soil Type and Moisture:** Design considered sandy loam soils and with moderate moisture content, as high moisture can lead to soil sticking or clogging the planter tip
- **Actual Soil Resistance:** For a manual furrow opener working in light soil with a trapezoidal cross-section, the calculated actual soil resistance is 1.62 kgf (approximately 15.9 N (Deogirikar Amit Ashokrao, 2024)).

### 3.2.3 Component Specific Design

#### 3.2.3.1 Design of Frame (seed hooper)

The planter handle length was geometrically calculated based on anthropometric data of East African adult populations. The operating structural length (L) was designed using the following relation (equation 1)

$$L = H_{elbow} - \Delta h_{soil} \dots \dots \dots \text{Equation 1}$$

Where  $H_{elbow}$  is the average standing elbow height of the operator 105cm and  $\Delta h_{soil}$  represents the depth of the opened soil furrow approximately 5 cm

This model, with volume according to equation 2, is designed to ensure it does not cause excessive fatigue for the operator. It is designed for a capacity to hold 1 kg of seeds, and to meet that requirement, a diameter of less than or equal to 5.8 cm and a total length of less than or equal to 1.4 m is recommended (Omara et al., 2016).

$$\text{Volume of the seed hopper/ frame } V = l \times w \times h \dots \dots \dots \text{Equation 2}$$

Inside the seed hopper, there is a device placed at an angle of repose of  $30^\circ$ , which is recommended for easy seed flow according to (Deogirikar Amit Ashokrao, 2024).

### **3.2.3.2 Seed metering mechanism**

The metering unit is the "heart" of the planter, responsible for uniform distribution, and we are to use a reciprocating Internal Drum as shown in Appendix 2. This system uses a rotating drum with a prefabricated cavity, and as the drum rotates, the cavity captures a seed.

- **Geometry:** The Drum was tested with the recommended cavity angles of  $20^\circ$  and  $25^\circ$  (Omara et al., 2016). This specific profile ensures that only a single seed enters the cavity at a time, preventing double-seeding
- **Interchangeability:** To accommodate multiple crop varieties, the assembly features an easy-disassemble architecture. The operator can unscrew the primary movable mechanical poker, allowing the internal seed disc to be rotated or replaced with plates containing specialized hole shapes optimized for maize or soybeans.

### **3.2.3.3 Furrow opener**

This consisted of two sharp metal plates of 1.2 mm thick and of 15 cm in length, with the first part fixed to the frame, while the second part attached to the first part through a bolt and nut passing through it, making it movable to close and open a furrow.

The wedge angle of about  $35^\circ$  (Deogirikar Amit Ashokrao, 2024) is recommended for effectiveness

### **3.2.3.4 Depth meter**

To maintain a strict and stable furrow depth 5 cm across uneven, tilted micro-plots, a specialized depth control gauge is integrated. This component is fabricated from a 1.2 mm thick mild steel sheet, bent into a stable, rigid L-like structural flange. It is attached directly to the fixed side of the furrow opener through an adjustable vertical slot mechanism. When the operator strikes the planter into the soil, the L-shaped plate establishes a flat datum line against the soil surface thus resisting further penetration beyond the preset 5 cm depth.

### 3.2.3.5 Spring

This spring functions as a mechanical automatic return device that forcefully snaps the open poker aw shut immediately after seed discharge. The spring stiffness K is calibrated using the standard deflection formulation (equation 3).

$$K = \frac{Force}{\delta (deflection)} \dots\dots\dots \text{Equation 3}$$

Where; F - represents the activation force supplied by the operator's arm

$\delta$  – represents the maximum linear displacement required to open the seed plate cavity and the furrow

The spring is therefore calibrated relative to a 1 kg tool when unloaded to prevent accidental spring compression especially when carrying the planter across the field. At the same time, it also allows effortless triggering under physical light squeeze.

### 3.2.3.6 Handle and Trigger Handle

- **The Primary Handle:** This is made of a mild steel pipe with length 15cm and a diameter of 3cm that is welded at one end to the top section of the frame. These dimensions were engineered to match standard human hand grip thus minimizing palm fatigue during field operations.
- **The Trigger Mechanism:** This is constructed from a rigid mild steel round bar with 15mm diameter. This rod runs parallel along the frame and links directly to the dynamic, pivoting jaw of the furrow opener at the base. Actuation relies on a clean mechanical pull-trigger stroke that simultaneously opens the soil tip and lines up the internal drum seed cavity to drop a single seed into the soil

## 3.3 Material selection

The criteria for Material selection were based on local availability, affordability, mechanical strength, corrosion/wear resistance, ease of fabrication/repair, and low weight to reduce operator fatigue.

*Table 1: Material selection of each component*

| <b>Component part</b>          | <b>Material</b>                     |
|--------------------------------|-------------------------------------|
| Frame (Seed hopper) and Funnel | 1.2 mm thick Mild steel square pipe |
| Seed plate                     | 3 mm thick mild steel sheet         |
| Furrow opener                  | 1.5 mm thick mild steel square pipe |
| Spring                         | Stainless steel                     |
| Handle and trigger handle      | Mild steel round bar                |
| Depth meter                    | 1.2 mm thick mild steel sheet       |
| Bolt and Nuts                  | Alloy steel                         |

### **3.4 Fabrication of a prototype of the designed seed planter**

The fabrication process (Figure 9 - Figure12) occurred in the MUARIK Agricultural Engineering workshop under the guidance and help of a technician, and the following operations and tools (Table 2) were employed to fabricate the seed planter according to the design specifications.

*Table 2: Fabrication tools and operation employed*

| <b>Operation</b> | <b>Tools/equipment</b>                        |
|------------------|-----------------------------------------------|
| Measuring        | Measuring tape & square                       |
| Marking          | Center punch<br>Mark pen                      |
| Cutting          | Hack saw<br>Angle grinder with a cutting disc |
| Welding          | Welding machine with a welding torch & rod    |
| Grinding         | Angle grinder with a grinding disc            |
| Drilling         | Power drilling machine<br>Drilling bit        |
| Painting         | Compressor<br>Lead oxide mixed with petrol    |
| Protective gear  | Welding glasses<br>Safety boots               |

### 3.4.1 Step by step fabrication procedures

#### i) Measuring and marking

This involved using a precision steel rule, digital vernier calipers, a combination square set, and a high-carbon steel scribe were used to scratch clear layout lines onto the metal. Center punches were struck at all planned intersecting coordinates to guide subsequent drill bits and prevent tool slipping

#### ii) Cutting and sizing operations

- **Frame and Handles:** An angle grinder with the cutting disc was used to make clean linear cuts of 15cm in length of a round pipe with 3cm diameter and with frame of 100 cm in length out of 40mm by 40mm by 1.2 mm thick square pipe.
- **Plates and Brackets:** The furrow opener jaws, and L-shaped depth gauge, were sliced out of 1.2 mm sheet metal using an electric grinder equipped with a grinding disc.

#### iii) Machining and drilling Reciprocating seed Metering Disc

The disc was chucked into a lathe machine to face the surfaces flat and turn down the outer perimeter to match the internal diameter of the hopper housing shell precisely, leaving a critical running clearance of just 0.5 mm to prevent seed binding or dust jamming

Specific seed pocket cell depressions 11.5mm length, 7.5mm width, 5mm thick for maize and 10mm in length, width and thickness for soyabeans, were carved into the perimeter using an end-mill cutter on a vertical milling machine, maintaining smooth 20° exit ramps to facilitate gravity dropping.

#### iv) Assembly and Mechanical Integration

- **Execution:** The stationary furrow jaw was completely welded to the terminal end of the square frame tube. The top handle grip was horizontally centered and welded onto the upper frame end. Slag deposits were continually cleaned off after each pass using a chipping hammer and wire brush to inspect for weld porosity, undercut defects, or incomplete root fusion
- **Poker Jaw Pivoting:** The dynamic, movable jaw was mounted to the permanent frame base using a bolt and locknut, tightened just enough to eliminate lateral wobble while allowing totally unrestricted rotational opening

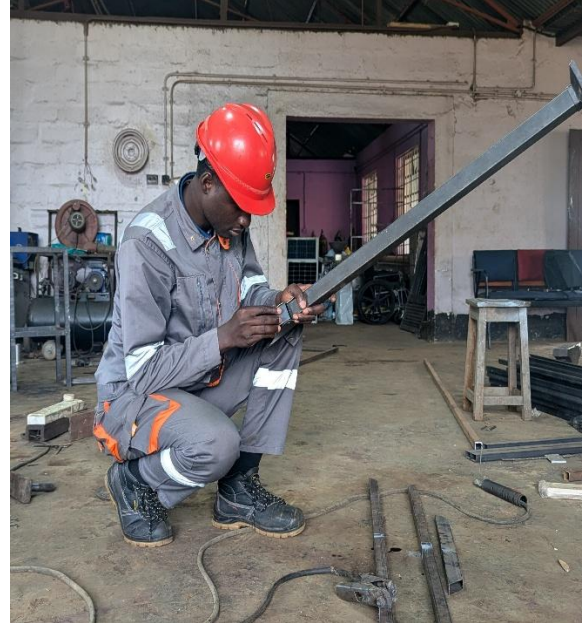
- **Spring Calibration:** The calibrated stainless steel helical compression spring wrapping round trigger rod, was pre-tensioned by 10mm to supply a continuous mechanical restoring force, ensuring that the instant the user releases the hand trigger, the poker jaw forcefully shuts the moveable poker jaw.

#### **v) Finishing and Surface Protective Coatings**

- **Surface Preparation:** All welded seams were ground flush using a handheld angle grinder fitted with an abrasive flap disc to remove sharp burrs, spatter particles, and slag remnants
- **Primer Application:** A uniform coat of red oxide primer was applied using a spray gun connected to the compressor to seal the micro-porous steel surfaces and after allowing a 12-hour curing window for the primer, finish paint (army green paint) was applied to shield the fabricated seed planter from moisture penetration during field testing



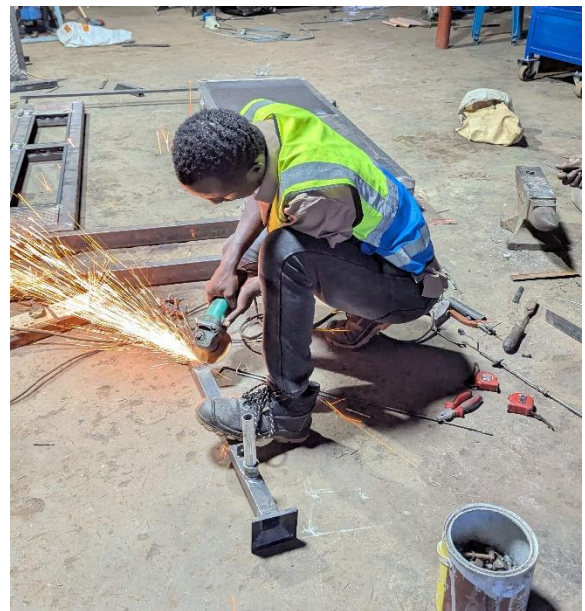
*Figure 9: Measuring of the frame*



*Figure 10: Attaching of the poker onto the frame*



*Figure 11: Welding of the planter*



*Figure 12: Grinding of the planter*

### 3.5 Field performance of the prototype seed planter

#### 3.5.1 Experimental Site Characterization and Preparation

Field testing at the workshop (Figure 13) and in the field (Figure 14) was conducted at the Makerere University Agricultural Research Institute, Kabanyolo (MUARIK). The testing plot was characterized as a uniform sandy loam texture, a typical representation of agricultural land profiles managed by Ugandan smallholder farming populations. Prior to testing, the plot was subject to secondary tillage operations, specifically harrowing and tilting, to produce a weed-free seedbed with fine soil tilth. Soil moisture content was logged to ensure realistic field working conditions that avoid soil-clogging intervals within the dynamic poker jaws.

Plot of land measuring 10 m in length by 1 m in width were marked, certified seeds of Maize with intra-row spacing of 75cm, plant to plat spacing of 30cm and Soybeans with intra-row spacing and plant to plat spacing of 15cm, were used as the test and two distinct operators (Operator A and Operator B) with varying physical heights and walking paces conducted independent passes to eliminate operator bias from the operational data and the following were analyzed;

- Singulation of the seed in the field
- Ability to change the seed plate for different seeds
- Field efficiency
- Ergonomics of the seed planter



*Figure 13: Workshop testing the planter*



*Figure 14: Field testing of the planter*

### 3.5.2 Core Performance Evaluation Metrics

#### 3.5.2.1 Testing the singulation of seeds by the prototype

Seed singulation defines the precision capability of the reciprocating internal drum metering mechanism to deliver exactly one seed per drop command into the opened soil furrow without creating multiples (doubles) or misses (skips).

The seed hopper was loaded with half a kilogram of seeds. The operator walked along the 10m plot, executing exactly 34 potential drop strikes based on the 30cm spacing interval marker for maize and about 68 potential drop strikes based on the 15cm spacing for soyabeans

The dropped seeds were physically exposed and verified. The quantitative Singulation Percentage was computed by equation 4:

$$\text{Singulation percentage} = \frac{\text{Total number of single seeds successfully sown}}{\text{potential seed drops}} \times 100\% \dots \text{equation 4}$$

#### 3.5.2.2 Testing the ability to change the seed plate and spacing adjustments

- **Seed Plate Changeability:** This was tested by the ability to easily disassemble the metering system and change the seed plate. The seed plate can be accessed by unscrewing the moveable poker and rotating the seed plate for various seeds with different holes.
- **Spacing Flexibility:** Visual inspections verified the alignment of the plant-to-plant adjustment indicators (Figure 14) to confirm that operators could modify mechanical indexing without seed damage

#### 3.5.2.3 Field efficiency

Time-motion studies were determined using digital stopwatches to break down total operating times (t) across four consecutive replicating passes per operator A & B. The following parameters were calculated to establish field capacity

- **Operating Speed (S):** Calculated by dividing the fixed runway distance traveled (D = 10m) by the average recorded travel time (t) in seconds as shown in the equation 5 below;

$$S(\text{speed}) = \frac{D}{t} \times 3.6 \text{ (km/h)} \dots \text{equation 5}$$

- **Theoretical Field Capacity (TFC):** The maximum possible area coverage rate per hour if the tool operated at 100% capacity without stopping, calculated using equation 6

$$TFC = \frac{S \times W}{10} \text{ (ha/h)} \dots\dots\dots \text{equation 6}$$

Where S is the operating forward speed (km/h) and W is the structural configuration working width of the single-row planter, equivalent to the inter-row spacing (0.75m for maize and 0.15m for soyabeans)

- **Actual Field Capacity (AFC):** The actual average rate of field coverage represented by equation 7, accomplished by the operator, factoring in turning times, adjustments, and loading intervals.

$$AFC = \frac{A}{t_{total}} \text{ (ha/h)} \dots\dots\dots \text{equation 7}$$

Where A is the area of the test plot ( $10\text{m} \times 1\text{m}$ ) =  $10\text{m}^2 = 0.001\text{ha}$  and  $t_{total}$  is the average operational time

- **Field Efficiency (FE):** The ultimate performance percentage mapping the tool's field utilization ratio, expressed mathematically using equation 8

$$FE = \frac{AFC}{TFC} \times 100\% \dots\dots\dots \text{equation 8}$$

#### 3.5.2.4 Ergonomic and Fatigue Qualitative Assessment

- **Posture Evaluation:** Operators were monitored to ensure they fully maintained an upright, vertically neutral biomechanical spine posture without needing to bend during planting.
- **Mass Payload Strain:** Total loaded mass combinations were tracked from an empty dead weight of 2.0kg to a maximum seed load capacity weight of 3.0 kg. This helped determine whether the physical weight profile caused palm or arm muscle fatigue across continuous operational run

### 3.6 Evaluate the cost-effectiveness of adopting the seed planter

To justify the engineering deployment of the fabricated prototype within smallholder farming systems, an engineering financial evaluation was conducted. The cost-effectiveness of adopting the manual precision seed planter was modeled against traditional hand hoeing practices and existing commercial imported machinery configurations. The analysis used the bill of materials (Table 3), workshop fabrication records, and current local prices/wage rates in Uganda.

*Table 3: Bill of materials*

| Materials              | Quantity  | Total Amount (UGX) |
|------------------------|-----------|--------------------|
| 1.2mm square pipe      | ½ a pipe  | 22,000             |
| Cutting disc           | 1         | 5,000              |
| Grinding disc          | 1         | 5,000              |
| Paint                  | ½ a liter | 6,000              |
| Bolts and nuts         | A pair    | 4,000              |
| Spring                 | 1         | 3,000              |
| Round bar              | ½ a bar   | 5,000              |
| Miscellaneous features |           | 20,000             |
| Labor                  |           | 50,000             |
| <b>Grand Total</b>     |           | <b>120,000</b>     |

#### 3.6.1 Financial Baseline Assumptions and Boundary Conditions

- **Asset Life Cycles:** The physical economic operating lifespan (N) of the manual seed planter was estimated at 5 years, assuming normal operational wear in abrasive sandy loam condition
- **Discount Factor:** A constant annual discount rate (i) of 10% was applied to compute present values (PV) for future cash streams, matching the opportunity cost of capital for micro-agricultural investments in East Africa
- **Operational Boundary:** The baseline smallholder plot cultivation size was standardized at 0.6hectares (1.5acres), which represents the average smallholder landholding fraction in Uganda (UBOS, 2022).

- **Labor Cost Base:** Seasonal agricultural planting labor wages in Uganda were benchmarked at UGX 15,000 to UGX 25,000 per person-day, depending on the proximity to urban market zones (Daily Monitor 2026).
- **Initial retail investment ( $I_o$ ):** To absorb market overheads, the plant was evaluated at the market value of UGX 170,000

### 3.6.2 Seasonal Labor cost savings

Traditional manual planting requires a labor density of 6 to 8 energetic workers to complete an acre within a single operational day. By utilizing the fabricated single-row precision planter, the task transitions to a "Do-It-Yourself" (DIY) model or requires only one hired laborer. The net seasonal cash saving realized by eliminating high human labor inputs was formulated using equation 9.

$$\Delta C = (L_{hoe} \times W_{hoe} \times A_{farm}) - C_{planter\_ops} \dots \dots \dots \text{Equation 9}$$

Where;

$L_{hoe}$  = Labor density required for manual hand hoeing (6 to 8 persons/acre)

$W_{hoe}$  = Prevailing daily agricultural wage rate (UGX/person-day)

$A_{farm}$  = Reference farm plot size area (1.5 acres)

$C_{planter\_ops}$  = Operating cost using the prototype, modeled under two scenarios: UGX 0 for self-operated DIY and UGX 30,000 to UGX 50,000 per day if a single worker is hired for a 2-day period

### 3.6.3 Payback period

The payback period given by equation 10, identifies the exact temporal cross-over point (expressed in years) required for cumulative net seasonal cash flows resulting from labor savings to break even with the initial retail investment ( $I_o$ )

$$PBP = Y_{last\_negative} + \frac{|Unrecovered\ Cost\ at\ Start\ of\ Year|}{Net\ Cash\ Flow\ During\ Year} \dots \dots \dots \text{Equation 10}$$

Where;

$Y_{\text{last\_negative}}$  = The last year in the scheduling timeline where cumulative net cash flow remains below the initial expenditure hurdle

Net Cash Flow = Net annual cash inflows ( $S_n$ ) generated from continuous labor savings minus recurring maintenance overheads ( $M_n$  = UGX 20,000 to 30,000 per year)

### 3.6.3 Benefit-cost ratio

To account for the time-value of money over the 5-year operating lifecycle, the Benefit-Cost Ratio was modeled by dividing the sum of the Present Value (PV) of all future annual benefits by the Present Value of all initial and recurring costs as shown in equation 11 below.

$$BCR = \frac{\sum_{n=1}^N \frac{B_n}{(1+i)^n}}{I_0 + \sum_{n=1}^N \frac{M_n}{(1+i)^n}} \dots \dots \dots \text{Equation 11}$$

Where;

$B_n$  – represents the annual benefits (cash inflows derived from continuous labor savings, evaluated under the 80,000UGX/year baseline

$M_n$  – represents the recurring annual operational maintenance cost (UGX 20,00 per year)

$I_0$  – represents the initial investment capital injection (UGX 170,000)

$i\%$  - represents the discount rate (10%)

$n$  = Year identifier index (1, 2, 3, 4, 5)

The present value calculation leverages standard uniform series present worth factors ( $P/A$ ,  $i\%$ ,  $n$ ) to convert future cash variations into present-day value equivalents.

If the resulting  $BCR > 1.0$ , the capital adoption path for the technology is designated as economically efficient and superior to traditional methods.

## CHAPTER FOUR: RESULTS AND DISCUSSION

### 4.0 RESULTS

#### 4.1 Design of the seed planter

The different components were then combined in SolidWorks to form a complete design of the seed planter, as shown in the diagram below

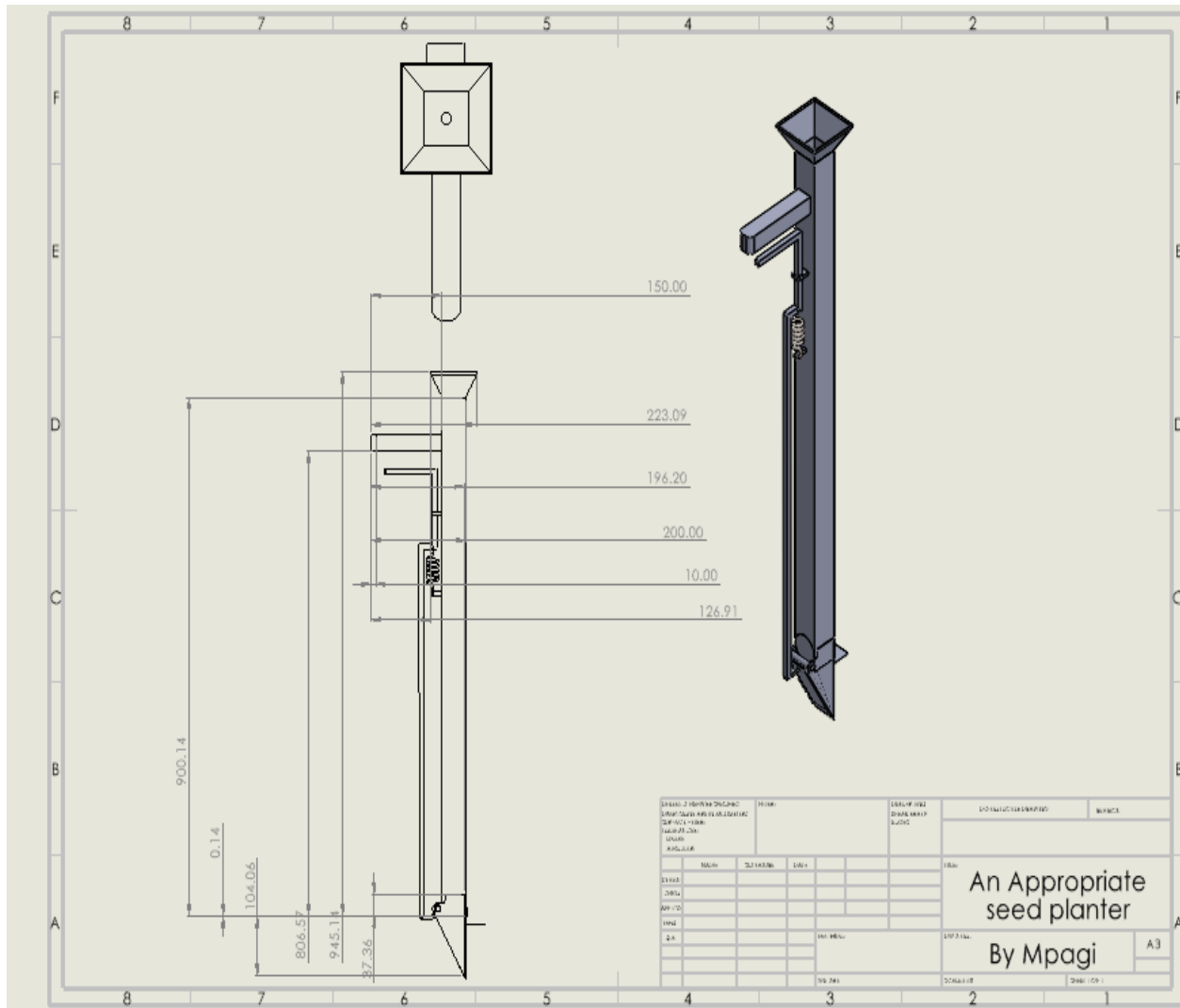


Figure 15: SolidWorks 3D Design of the Seed Planter

## 4.2 Fabrication of a functional prototype of the designed seed planter

The figure below shows the fully fabricated and assembled seed planter that was fabricated at the MUARIK workshop



*Figure 16: Fabricated planter*

### 4.3 Field performance of the prototype seed planter

The results obtained from the field performance of the seed planter included

#### 4.3.1 Efficiency of the planter

The following were the results obtained from testing the seed planter;

Number of rows per pass = 1

Inter row spacing = 75 cm

Plant to plant spacing = 30cm for maize and 15cm for soyabeans

Distance travelled (D) = 10m

Planting depth = 5cm

Number of seeds per hole = 1 seed

*Table 4: Time taken per pass during testing*

| Pass<br>number  | Time taken (seconds) |            |             |             |
|-----------------|----------------------|------------|-------------|-------------|
|                 | Maize seed           |            | Soya beans  |             |
|                 | Operator A           | Operator B | Operator A  | Operator B  |
| 1 <sup>st</sup> | 55                   | 62         | 48          | 58          |
| 2 <sup>nd</sup> | 50                   | 60         | 47          | 53          |
| 3 <sup>rd</sup> | 48                   | 55         | 45          | 60          |
| 4 <sup>th</sup> | 48                   | 59         | 50          | 63          |
| <b>Average</b>  | <b>50.25</b>         | <b>59</b>  | <b>47.5</b> | <b>58.5</b> |

*Table 5: Field test results summary*

| Operator | Seed      | Ave. Time | Speed = D/t | TFC    | AFC    | FE (%) |
|----------|-----------|-----------|-------------|--------|--------|--------|
|          |           | (t) (s)   | (km/h)      | (ha/h) | (ha/h) |        |
| <b>A</b> | Maize     | 50.3      | 0.7164      | 0.0537 | 0.0716 | 75.0   |
|          | Soyabeans | 47.5      | 0.7596      | 0.0569 | 0.0757 | 75.2   |
| <b>B</b> | Maize     | 59.0      | 0.6102      | 0.0457 | 0.0610 | 74.9   |
|          | Soyabeans | 58.5      | 0.6154      | 0.0462 | 0.0615 | 75.1   |

#### 4.3.2 Singulation of the seeds

Using a plant-to-plant spacing of 30cm for maize and 15cm for soyabeans, singulation was determined by

$$\text{Singulation percentage} = \frac{\text{Total number of single seeds successfully sown}}{\text{potential seed drops}} \times 100\%$$

Table 6: Table showing singulation results

| Pass Number            | Successful drops every in a 10m length |            |
|------------------------|----------------------------------------|------------|
|                        | Maize                                  | Soya beans |
| 1 <sup>st</sup>        | 27                                     | 58         |
| 2 <sup>nd</sup>        | 28                                     | 56         |
| 3 <sup>rd</sup>        | 29                                     | 50         |
| 4 <sup>th</sup>        | 27                                     | 60         |
| <b>Average</b>         | <b>27.25</b>                           | <b>56</b>  |
| <b>Potential drops</b> | <b>34</b>                              | <b>68</b>  |

$$\text{Singulation percentage for maize} = \frac{27.5}{34} \times 100\% = 80.88\%$$

$$\text{Singulation percentage for Beans} = \frac{56}{68} \times 100\% = 82.35\%$$

For engineering and design purposes, such as the development of the OSU hand planter, a target of 80% singulation is often set to ensure the tool is effective for smallholder farmers (Omara et al., 2016), and since the seed planters' singulation falls in the range, it is therefore viable

#### 4.3.4 Ergonomics results

The seed planter weighed 2 kg when empty, with a capacity of 1kg, making it 3kg when full, making it light for the operator. Also, the planter has adjustments for plant-to-plant and inter-row spacing, making it easier for the operator to control plant spacing as shown in the image below



*Figure 17: Plant spacing adjustments*

#### **4.4 Evaluate the cost-effectiveness of adopting the seed planter**

**Initial investment** = Shs170,000

##### **Assumptions made**

Wage of shs15,000 – 25000 per person per acre, with farmers owning 0.6ha (1.5acres) on average

*Table 7: Costs and savings variations*

| <b>Method</b>        | <b>Labor cost per (1.5 acre) (Shs) in a season</b> | <b>Time to complete</b> | <b>Savings (Shs) per year</b> |
|----------------------|----------------------------------------------------|-------------------------|-------------------------------|
| Manual (hand hoeing) | 180,000 - 240,000                                  | 1 day (6-8 workers)     | -                             |
| Seed planter         | 0 (Do it yourself)                                 | 2 days                  | 20,000 – 140,000              |
| Seed planter         | 30,000 – 50,000 (hired labor)                      | 2 days (1 worker)       | 10,000 – 50,000               |

Assuming an economic life of 5 years, discount rate of 10%, with a constant annual savings of 80,000 shillings, and when hired labor is used, a constant annual saving of 40,000 is assumed, with the cost of maintenance of 20,000 per year, and  $(P/A, 10\%, 5) = 0.909, 1.736, 2.487, 3.170, 3.191$

*Table 8: Table showing present value (PV)*

| Year            | P/A factor | Annual savings (Shs) | PV of savings (Shs) | Annual savings (hired) | PV saving (hired) (Shs) |
|-----------------|------------|----------------------|---------------------|------------------------|-------------------------|
| 1               | 0.909      | 80,000               | 72720               | 40,000                 | 36360                   |
| 2               | 1.736      | 80,000               | 138880              | 40,000                 | 69440                   |
| 3               | 2.487      | 80,000               | 198960              | 40,000                 | 99480                   |
| 4               | 3.170      | 80,000               | 253600              | 40,000                 | 126800                  |
| 5               | 3.191      | 80,000               | 255280              | 40,000                 | 127640                  |
| <b>Total PV</b> |            |                      | <b>Shs 919440</b>   |                        | <b>Shs 459720</b>       |

#### 4.4.1 Payback period

Cash flows in yr1= Shs80,000 and in yr 2 = Shs80,000 and yr 3 = 80,000

Payback period = 2 years (160,000) +  $\frac{10,000}{80,000}$  (balance) = 2.125 yrs

Therefore, in about 2 years and 1 month, the initial investment of 170,000 shillings is recovered, making the planter viable

#### 4.4.2 Benefit-Cost Ratio

##### With the farmer doing the planting himself

Annual benefits of Shs 919,440 and assuming maintenance cost of 20,000 Shs per year

Total costs = 170,000 + (20,000×0.909) +(20,000×1.736) +(20,000×2.487) +(20,000×3.170) + (20,000×3.191)

$$B/C = \frac{919440}{170,000+229860} = \frac{919440}{399860} = 2.299$$

Since the B/C ratio is greater than 1, the planter is economically viable

##### With hired labor

$B/C = \frac{459,720}{170,000+344,790} = \frac{459,720}{399,860} = 1.15$ , Since the B/C ratio is greater than 1 even with hired labor, the planter is economically viable

#### **4.5 Deductions**

The results clearly indicate that the designed and fabricated seed planter successfully meets the project objectives. The seed planter achieves the right balance of precision, cost effectiveness, mobility and simplicity of use. Therefore; it qualifies to be an appropriate technology for smallholder agriculture in Uganda. Although it may need some improvements particularly on singulation precision, it has achieved considerable progress compared to traditional manual planting techniques.

## **CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS**

### **5.1 Conclusion**

The fabricated prototype weighed 3kg when completely loaded and performed well in the fields showing an average field efficiency of 75.0%, and achieving seed singulation of 80.9% for maize and 82.4% for soya beans. This is an indication that the planter is much better at uniform planting than the conventional hand hoe broadcasting technique. This planter is also friendly to use because of its depth adjustment of up to 5cm, spacing capability, and upright working position. The planter is also very economical since it saves labor costs amounting between 20,00 to 140,00 per year on an average farm size of 1.5 acres and this with an initial investment of only 170,000 Uganda shillings.

This study contributed to bridging a critical gap in Uganda's agricultural mechanization by developing an affordable, locally manufacturable seed planter using readily available materials. The prototype aligns well with the principles of appropriate technology and contributes toward the national goal of commercializing smallholder agriculture under Vision 2040.

### **5.2 Limitations of the planter**

- i. Optimized mainly for maize and soyabeans however the seed mechanism can be changed for other seeds like beans
- ii. Tested on the prepared sandy loam soils of MUARIK with moderate moisture, however performance may degrade in heavy clay, very wet/dry and unprepared soils
- iii. The planter is limited to single row with the operating speed limited to human walking pace (0.6-0.76 km/hr)
- iv. Lacks automation found in commercial models

### **5.3 Recommendations**

In order to improve the performance of the prototype planter, the following modifications are recommended;

- i. Further Improvements to optimize the seed metering mechanism to increase singulation above 90% and also test the planter on a wider range of crops and soil types across different agro-ecological zones.
- ii. There should be further improvement to include the fertilizer unit in the design

- iii. The government and NGOs should subsidize or provide credit for such appropriate technologies to accelerate adoption among smallholders.
- iv. Conduct a full-scale socio-economic impact assessment after one or two planting seasons to quantify yield improvements and long-term benefits.

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## APPENDIX

### Appendix 1: Images during the fabrication process



**Appendix 2: Image showing seed metering mechanism**



### Appendix 3: Images during field evaluation



**Appendix 4: Image showing MUARIK Workshop**

