DESIGN, DEVELOPMENT AND PERFORMANCE EVALUATION OF TRACTOR DRAWN TIE RIDGER

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Design, Development and Performance Evaluation of Tractor Drawn Tie Ridger

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DECLARATION

I hereby declare that this Master Thesis entitled “Design, Development and Performance Evaluation of Tractor Drawn Tie Ridger” for the partial fulfillment of the requirements for the award of the degree of Master of Science in Agricultural Machinery Engineering is my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Name: Wabi Abdisa Abara Signature__________ Date ____________

RECOMMENDATION

I, Dr. Amana Wako, hereby certify that I have read the revised version of the thesis entitled "Design, Development and Performance Evaluation of Tractor Drawn Tie Ridger" prepared under my guidance by Wabi Abdisa Abara submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Agricultural Machinery Engineering.

Therefore, I recommend the submission of the revised version of the thesis to the department following the applicable procedures.

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APPROVAL SHEET

I, Dr. Amana Wako entitled "Design, Development and Performance Evaluation of Tractor Drawn Tie Ridger" and developed by Wabi Abdisa, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Wabi Abdisa have read and evaluated the thesis entitled "Design, Development and Performance Evaluation of Tractor Drawn Tie Ridger" and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Agricultural Machinery Engineering.

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LIST OF ACRONYMS AND ABBREVIATIONS

ASABE	American Society of Agricultural and Biological Engineering
ASAE	American Society of Agricultural Engineering
CC	Capital cost
DBHP	Drawbar brake horse power
DLW	Daily labor wage
Dp	Depreciation
DTW	Daily tractor wage
FAO	Food and Agriculture Organization
HP	Horse power
I	Interest
kg	Kilo gram
km	Kilo meter
kN	Kilo newton
kP	Kilo pascal
LCC	Life cycle cost
MARC	Melkassa Agricultural Research Center
MS	Mild steel
NAOHT	Number of the annual operational hours of the tie ridger
NP	Nitrogen phosphorous
RCBD	Random complete block design
SVC	Selvage value cost

ABSTRACT

Tie ridging is one of the soil and water conservation practices. It controls runoff, prevents erosion, conserves moisture, and thereby increases crop production. There is a necessity to have an implement that will form a ridge to conserve rainwater in dryland conditions. At present in Ethiopia tie-ridging operation is conducted using human and draft animal power sources. Tie-ridging operation conducted using human and animal draft power is labor-intensive, tedious, and time-consuming. Since the implement was drawn by animals, its field capacity and efficiency were limited. To solve the above problem, this study aimed to design, develop and evaluate the performance of a tractor-drawn tie ridger capable of tie ridging at desired depth and space. The tractor-drawn tie ridger would be developed using locally available materials and consists of the main frame, central driving wheel, tie ridger, furrow opener, and shank. The following activities were carried out, material selection, design of all component parts, fabrication and assembling the component parts, performance evaluation, data collection, data organizing and data analysis to draw meaning full conclusion. The performances of tractor-drawn tie ridger were evaluated in the laboratory and field. In a laboratory test, the machine was checked for its specifications and operations. The average theoretical field capacity, effective field capacity and field efficiency of the machine were 0.94 $ha.hr^{-1}$*, 0.67* $ha.hr^{-1}$ *and 71.24 % respectively. The maximum draft required for the implement is 1,135.23 N. The 40 hp tractor is used to drive this implement. The average depth and width of tie ridge were observed at 22.92 cm and 34.29 cm respectively. The cost of fabrication of the tie ridger was estimated to be approximately about 19,683.45 ETB. Test results in-field evaluation of the tie ridger indicated that it could form tie ridges of 2.78 m × 34.29 cm size. Per hour cost of operation of tie-ridger is 220.12 ETB/hr.*

Keywords: Design, Field efficiency, Field test, Performance evaluation, Soil,Tie ridger

CHAPTER ONE

1. INTRODUCTION

1.1. Background and Justification

Soil moisture and nutrients conservation are the most essential factors for plant growth in Ethiopia. The proper use of soil moisture conservation structures helps to reduce the runoff rate, nutrient losses from the soil and improve the soil moisture and nutrient availability for plant growth which in turn, boosts the productivity of land and plants. In the Ethiopian highland, agricultural productivity is low due to low soil fertility. The problem is directly related to periodic low soil moisture due to erratic and poorly distributed rainfall, severe soil erosion, and runoff loss of water (Heluf and Yohannes, 2002; Zone *et al*., 2019). The estimated total annual actual soil loss at the sub-basin level was 1.01 million tons in 2000 and 1.52 million tons in 2018 with a mean erosion rate of 75.85 t ha^{-1} y^{-1} and 107.07 t ha^{-1} y^{-1}, respectively. The most extensive soil loss rates were estimated in croplands and bare land cover, with a mean soil loss rate of 37.60 t ha^{-1} y^{-1} and 15.78 t ha^{-1} y^{-1}, respectively (Woldemariam & Harka, 2020). The annual rate of soil loss in the country is higher than the annual rate of soil formation rate. Annually, Ethiopia losses over 1.5 billion tons of topsoil from the highlands to erosion which could have added about 1.5 million tons of grain to the country's harvest (Braimoh & Vlek, 2008). This indicates that soil erosion is a very serious threat to the food security of people and requires urgent management intervention.

Agriculture in most parts of Ethiopia depends on the vagaries of the rainy season. The rainfall, in the large areas of it, is insufficient and extremely uncertain. As water is the most important input for crop production, the insufficiency and uncertainty of rainfall often results in partial or complete failure of crops and leads to periodic inadequacies and droughts. Such condition naturally makes the economic life of the cultivators in these regions extremely difficult and insecure. Water is often the most limiting factor in dryland agricultural production. The furrow diking practice is known by many names including tied ridges, furrow damming, basin tillage, basin listing, and micro basin tillage. Furrow diking is a soil and water conservation practice, which is very adaptable to dryland crop production. It is most often used on gently sloping terrain in arid and semi-arid areas where crops are grown under water deficit conditions (Jones and Baumhardt, 2003).

The drylands of Ethiopia consist of a wide range of agro-ecologies including the arid, semi-arid, and dry sub-humid and cover about 75% of the total land mass, whereas the lowland dryland areas in Ethiopia, cover about 55% of the land mass of the country (MoARD, 2000; Ahmed *et al*., 2018). The Ethiopian rift valley, which covers the major portion of the vast dryland areas, is undergoing increasing land-use conversion from pastoral to mixed crop-livestock systems (Biazin and Sterk, 2011; Dessie and Kleman, 2006; Garedew *et al*., 2009; Tsegaye *et al*., 2010). Not only the year-to-year rainfall variability (Tilahun, 2006) but also the non-productive loss of rainfall through soil evaporation and surface runoff limit rainfed agriculture. Up to 40% of the seasonal rainfall may be lost in the form of surface runoff in the rift valley drylands of Ethiopia (Welderufael *et al*., 2008).

In-situ soil and water conservation measures play a great role in alleviating the two extremes of rainfall conditions such as erosion and drought. The loss of water as runoff coupled with periodic drought during the cropping season on degraded lands supporting rain-fed crop production was also equally important (Ahmed *et al*., 2018). The causes of rainfall extremities are due to inadequate efforts and the absence of technologies proved to conserve the soil and water resources, the consequence of which is the need to increase productivity on limited and marginal land and water resources. As rainfall erosivity, soil erodibility, and landform are inherent properties of climate, soil, and land, respectively, only little can be done to modify their effects appreciably. Therefore, moisture conservation practices play a vital role in successful and sustainable crop production in drought-prone areas. Adequate soil moisture is the key to successful crop production in dry land areas. The practice of judicial water conservation undoubtedly plays a significant role in increasing agricultural production in arid, semi-arid and sub-humid areas where agriculture is hampered by periodic droughts and low soil fertility (Zone *et al*., 2019).

The erratic rainfall distribution makes cropping to be possible only with the use of water conservation techniques. The use of tied ridge as in-situ moisture conservation techniques should get sufficient attention. It has been effective in reducing surface runoff and increasing soil water storage in different countries as reviewed by Gebreyesus *et al*. (2006). In many parts of Ethiopia, particularly in the eastern Ethiopian highlands, it was reported that proper mechanical soil and water conservation schemes increased maize grain yield by 700-3400 kg/ha (Ahmed *et al.*, 2018). Asfaw *et al*. (1998) also reported maximum maize yield increases of 10, 18, and 23% on Entisols and 54, 35, and 26% on Vertisols of eastern Ethiopia, with crop residue, with residual nitrogen phosphorus (NP) and with both crop residue and residual nitrogen phosphorus (NP), respectively, due to the combinations of tied ridges and furrow planting over flat planting. Thus, the efficiency of the physical soil and water conservation techniques depends on the soil type, climate, the crop grown, and the cropping methods followed.

Moisture conservation at the farm level is the current important issue in the world today for sustainable crop production. Ademe *et al*. (2018) reported in the current on-farm trial, the effect of selected in-situ soil and water conservation measure (tied ridge) was compared with traditional practices in terms of maize productivity parameters like grain yield, biomass production, and soil moisture conservation. The tied ridges showed 35.8 % and 27.8% grain yield and biomass production advantage over traditional practice respectively. The low crop productivity in the country particularly in the study area is directly related to periodic low soil moisture due to erratic and poorly distributed rainfall which could result in low soil fertility. This calls to design effective and efficient in-situ soil moisture conservation strategies that have a better role in sustaining crop production.

The use of tied ridges is very effective in soil water conservation and results in 50-100 percent grain and 80 percent straw yield increase is obtained compared to the traditional method of planting in the flat seedbed in many semi-arid areas of Ethiopia (Georgis, 2015). It is widely adopted in many semi-arid areas. Tie-ridging involves creating ridges that are 20-30 cm high and commonly spaced 75 cm apart, either before, during or after planting. The effectiveness of tie-ridging depends on field conditions. The identification of fields where tie-ridging is likely to be beneficial's is: - slope <7%; sandy loam or finer, soil depth (effective rooting depth) >60 cm, rainfall amount for the growing season <650 mm, or little rainfall during grain filling (Brhane *et al*., 2005).

Despite its laborious and time-consuming nature (Araya and Stroosnijder, 2010), tied ridging is a proven practice to conserve soil moisture in semi-arid areas (Biazin *et al*., 2012). In tied ridging, sometimes called tied-furrows, ridge furrows are blocked with earth ties spaced on fixed intervals to form a series of micro-basins in the field (Biazin *et al*., 2012). Tied-ridging increase soil water in the root zone by 24% and by at least 13% which brought a 44% yield increase of barley (Araya and Stroosnijder, 2010) as compared to traditional tillage in rain season. Besides the adoption of ridging practice for soil moisture under cropping, it is necessary to explore the time of ridging for better crop growth. Tied ridging before or at planting in arid areas of Tigray region, Ethiopia; resulted in optimum soil water status together and improved the performance of a crop compared with tied ridging after planting (Birhane *et al*., 2006). However, Temesgen (2007) studied that in the semi-arid rift valley of Ethiopia, the interval between tied-ridging and sowing has affected water conservation efficiency, and the maize yield negatively under minimum rainfall of the time.

In Ethiopia, extreme weather events have resulted in food shortages and famines in the past (Gray and Mueller, 2012; Cheung *et al*., 2008; Conway and Schipper, 2011; Mersha and Boken, 2005) and they continue to pose a serious threat to the country's development. Hence, small-holder farmers whose economy depends on agriculture have to improve the management of current climate variability.

These days there are several small to medium horsepower tractors owned by farmers, which can be used for farm operations, such as land preparation. Besides, there are several two-wheel and medium horsepower tractors disseminated, to rural youths and common interest groups, by governmental business companies, non-governmental organizations, private limited share companies and governmental projects. Developing an efficient and affordable tractor-drawn tie ridger has paramount importance to farmers living in water-stressed areas.

Soil moisture is the foremost factor that limits the productivity of rainfed cereal crops. However, rainwater harvesting is an important factor for crop production, the use of a tied-ridger for on-farm rainwater harvesting for crop production is very important. To maintain required soil moisture in rainfed lands, strategies should be focused on conserving much amount of rainwater by using tie ridger is important. Therefore, the present study was aimed to design, develop and evaluate the performance of tractor-drawn tie ridger for dryland areas.

1.2. Statement of the Problem

In Ethiopia tie-ridging operation is conducted using human and draft animal power sources. Tie-ridging operation conducted using human power is labor-intensive, tedious, and time-consuming. There was usually a labor shortage during tie-ridging before or during planting, as most of the laborers are involved in other routine field operations.

Animal-drawn tie-ridger for water stresses areas was developed and disseminated for small-scale farmers by the Agricultural Engineering Research Directorate. However, the implement requires high draft power and in one pass of the operation, it makes only one ridge. The tie-ridger had to be lifted every few meters over the accumulated soil to obtain the tied ridge. This was hard work for the farmer and animals. Since the implement was drawn by animals, its field capacity and efficiency were limited. It would be most desirable to have tractor-drawn implements for constructing tie-ridges at a faster rate and a low cost. Therefore, developing a more efficient, technically compatible, simple to use and transport tractor-drawn tie ridger is important.

1.3. Objectives

1.3.1. General Objective

The general objective of this research was to design, develop and evaluate the performance of tractor-drawn tie ridger.

1.3.2. Specific Objectives

- To design tractor-drawn tie ridger.
- To develop tractor-drawn tie ridger.
- To evaluate the performance of developed tractor-drawn tie ridger.

1.4. Significance of the Study

This study was tried to avail a medium horsepower operated tie-ridger that alleviates the problem of our farmers faced in moisture stress areas to make tied-ridge. The tractor-drawn tie-ridger that has been developed was to help farmers for preparing tied-ridge using available tractors. Tie- ridger will control runoff, prevents erosion, conserves moisture, and thereby increases crop production. There is a necessity to have an implement which was form a basin to conserve rainwater in Ethiopian dryland conditions. Generally, it can solve the problems of the farmers across the wide range of Ethiopia's drylands, the areas that are prone to drought including the highland and mid-altitude areas, where the farming systems are mixed and both crop and livestock production.

1.5. Scope of the Study

The scope of this research was limited to the design, development and performance evaluation of tractor-drawn tie ridger. The development of tie- ridger would be considered different soil parameters (soil type, soil moisture content (% d.b.), bulk density (kg/m^3), as well as machine parameters (fuel consumption ($l\ h^{-1}$), wheel slippage,(%), draft and power requirement, effective working width (mm), depth of tie ridge (mm), width of tie ridge (mm), length of tie ridges (mm), effective field capacity ($ha.h^{-1}$), theoretical field capacity ($ha.h^{-1}$), field efficiency (%). After the prototype construction would be accomplished basic performance evaluation of tie ridging would be done in the field.

CHAPTER TWO

2. REVIEW OF LITERATURE

Ridging and tied ridging involves making ridges and furrows, then tying or damming furrows with small mounds to increase the surface water storage and avoid a runoff. The tie act as a barrier for the rainwater movement and increases contact time available for infiltration thus enhances the availability of soil moisture to the crops (Rana, 2007).

2.1. Tie Ridging Technology

The check basin forming technology has great potential for use in arid and semi-arid regions (Miller, 2000). This study was conducted at Domboshawa in South Africa to measure the effect of tie ridging on surface runoff and soil loss. The high wing ridger is of French design but it was manufactured locally. The ridger has two adjustable discs angled to form a wide V shape. Although the unit was heavy, the draft requirement was less than that required for the conventional moldboard plows.

Micro-basins created by tillage can reduce runoff and increase infiltration and thereby water is available for crop production (Gebreyesus *et al*., 2006; Gebreyesus *et al*., 2008). Tied-ridging is a form of micro-basin tillage that consists of ridging the soil typically to heights of 0.20 to 0.30 m and is blocked with earth ties spaced considering the slope of the land. Planting of the crop can be either in the furrow or on the ridge based on the expected soil moisture required for a particular crop (Tewodros *et al*., 2009).

The beneficial effects of tillage such as tied-ridging on crop yield vary due to differences in amount and distribution of rainfall, soil type, slope, landscape position, crop type, time of ridging, and the condition where rainfall events result in significant runoff. Tied-ridging increased sorghum grain yield by more than 40% and soil water by more than 25% compared to the traditional tillage practice in northern Ethiopia (Gebreyesus *et al*., 2006).

Asfaw *et al*. (1998) reported maximum maize yield increases of 10, 18, and 23% on entisols and 54, 35, and 26% on vertisols of eastern Ethiopia, with crop residue, with both crop residue and residual nitrogen phosphorus (NP), respectively, due to the combinations of tied ridges and furrow planting over flat planting. Thus, the efficiency of the physical soil and water conservation techniques depends on the soil type, climate, the crop grown, and the cropping methods followed. However, despite the significance of the problems of soil erosion and drought in the Ethiopian highlands, research aimed at generating soil and water conservation techniques and farming practices that reduce soil erosion and harvest rainwater for use by plants, on cultivated lands in the country, is inadequate.

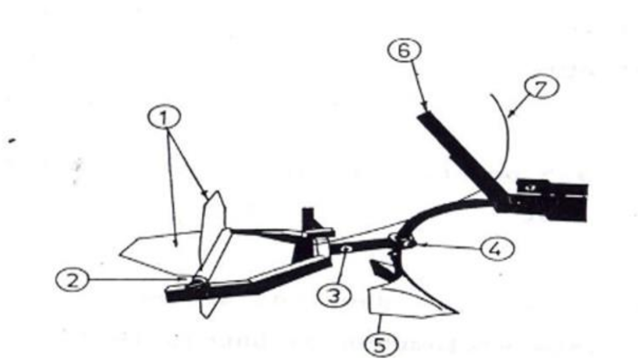
Tied-ridging has been effective in reducing surface runoff and increasing soil water storage in different countries as reviewed by Gebreyesus *et al.* (2006). Soil and water resources are usually conserved together by methods of soil and water conservation, this is true of all regions including arid and semi-arid regions. Common conservation measures direct either to the soil, water, or both. The use of physical structures or improved land management systems that can reduce surface run-off will also help to reduce erosion. In the same manner, reducing erosion will usually prevent the splashing of soil particles by raindrop impact, surface crust formation, or breakdown of structural aggregates, which in combination improve infiltration of water and contribute to water conservation (Gebreyesus *et al.*, 2006).

With the current change in global climate, adaptation methods like the use of conservation approaches are to be implemented in the agriculture sector is to continue to meet the ever-increasing food demand especially in developing countries like Ethiopia (Solomon, 2015).

Within the furrows, the closed-end tied ridge is more efficient than the open-end tied ridge as indicated by increased yield, and the relative effectiveness of the tied ridges and planting methods in increasing crop yields increased with increasing level of soil fertility. In general, the results indicated that in the Ethiopian highlands where the rainfall is low and erratic and the soils are degraded, low total rainfall or its uneven distribution during the cropping season is one of the principal factors limiting the yield of crops. Hence, regardless of the water holding capacity and fertility levels of the soils, soil, and water conservation and particularly, in situ water harvesting practices are indispensable agricultural operations (Demoz, 2016).

2.2. Development of Tie Ridging Devices

Nagy *et al.*(1988) tested an animal-drawn safeguard mechanical ridge tier to evaluate its technical viability in the field, its profitability, and farmer’s acceptance in the cereal farming system on the Massi Plateau of Burkina Faso, West Africa. Previous field research had shown that the water retention technique of tie ridge construction in combination with the fertilizer use was technically viable in the field and profitable. Manual tie ridge construction, however, required a large amount of labor (Fig. 2.1). Labor data indicated that it required up to 100 man-$h.ha^{-1}$to construct the tie ridges by hand. The mechanical ridge tier with donkey traction required only 1 $h.ha^{-1}$.



1. Shovel
2. Axel bearing
3. Shovel angle adjustment bolt
4. Coupler
5. Ridger that allows the soil to flow over the top
6. Handle
7. Bicycle cable to the brake lever

Figure 2. 1. Safegard mechanical ridge tire

Durairaj *et al*. (1992) developed a basin lister actuated by a tractor hydraulic system. The basin listing operation was accomplished by lifting the mounted ridger through the hydraulic control of the tractor at a regular interval.

Gajakos (2000) conducted a study at Aspen Research Institute, Bhiwadi, and District Thane on the design and development of check basin former. The mechanism of cam and follower was used to get the desired up and down motion necessary for the effective formation of basins by scoops. The field efficiency of bullock drawn implement was obtained 66.4 %.

Anonymous (2000) stated that to avoid having too many operation ties could be coupled manually operated check basin former. Ties were made by scrapping the tie maker along the furrow between the ridges until enough soil has been collected. It was found from 70 % acceptability by the farmers that ridge and tie makers did not require any special skill to operate or maintain.

(Gebregziabher *et al*., 2016) stated that Ethiopian farmers have been using an ox-drawn and plow known as ‘Maresha’ for thousands of years (Fig.2.2). Although simple and cheap this implement was inefficient and several researchers and organizations have been trying to introduce new implements from other countries as early as 1939. The main reason for the rejection has been the fact that little attention was given to the nature of the traditional implements and the farmers. They conducted simple experiments comparing the new animal-drawn implements with the traditional ones. Results indicated a reduction in labor and time requirements for land preparation, row planting, and weeding along with improvements in soil moisture conservation using simple techniques like tie-ridging and improved tillage.

Figure 2. 2. Maresha

In Humbo, south region of Ethiopia, open and tied ridge on cotton variety 'Sele' was used' to revealed that there was a significant ($p<1\%$) seed cotton yield record in open ridge planting method followed by tied ridge planting 1619 kg/ha but flatbed planting method gave significantly the lowest seed cotton yield 1273 kg/ha (Demoz, 2016).

Sawant (2015) reported that the rack and pinion mechanism was used to stop the rotation of the blade during field operation and the main ridger creating the main ridges on both sides. The 55 hp tractor is used to drive this implement. The maximum field efficiency of the implement was observed as 75.94 %. The maximum draft required for the implement is 3336.22 N. Test result in-field evaluation of the tie ridger indicated that it could form tie ridges of 6.02×2.01m size. The per-hour cost of operation of a tie-ridger is 479.26 ETB. This implement is found suitable to form the basin in well-prepared land.

With the current change in global climate, adaptation methods like the use of conservation approaches are to be implemented if the agriculture sector is to continue to meet the ever-increasing food demand especially in developing countries like Ethiopia. The magnitude of yield response to water conservation and the relative effectiveness of the different tied ridges and planting methods tend to vary with soil type, level of soil fertility and distribution, and the total rainfall during the crop season. Regardless of the type of the tied ridge, furrow planting proved to be more effective in conserving water and increasing the yield of sorghum with relatively consistent effects in most seasons than the ridge and flat bed methods on both soils and soil fertility levels (Demoz, 2016).

2.3. Performance Evaluation of Tie Ridging Machine

Deshpande (1994) designed developed and field evaluated tractor operated tie-ridger. This machine worked on the principle of tripping mechanism which regulated the rotation of tie-ridging blades for maintaining an interval of tie ridges. Test result in-field evaluation of the tie-ridger indicated that it could form the tie ridges of 6.07 x 3.02 m size (Fig. 2.3). A tractor driver alone could operate this machine and cover 0.86 $ha.h^{-1}$. The cost of preparation of tie ridges using this machine was observed to be 54.49 ETB per ha. Thus, the machine was found suitable to form the tie ridges in well-prepared land.

Figure 2. 3. Tie-ridger (Deshpande, 1994)

Nalawade *et al*. (2008) reported the research experiment on testing of tractor-operated tie-ridger for evaluation of its performance. The tractor-operated tie-ridger was tested in the laboratory as well as in the field. In laboratory testing, checking for the material of construction and adjustment was done. Tie-ridger was operated in the field with different field conditions to collect data viz. working width, effective field capacity, and field efficiency which was found to be 2.94 m, 0.545 $ha.h^{-1}$ and 54.6 % respectively at a corresponding average speed of 3.5 km.h^{-1}. The basin formation required well-pulverized soil with a leveled field. Despite some limitations and drawbacks, it was observed that tie-ridger could be used for basic formation (6m × 3m) with some modification.

Dhoble (2012) developed and field evaluated tractor operated check basin former which consisted of mainframe, bund former, power transmission unit, and cam and follower arrangement and cross bund former (Fig. 2.4). The mechanism of cam and follower was used to get the desired up and down motion necessary for the effective formation of basins. The 55 hp tractor was used to drive this implement. The cost of the machine was 24395.58 ETB and the cost of operation of this check basin former was observed to be 398.14 ETB per hour. Thus the implement was found suitable to form the check basin is well-prepared land.

Figure 2. 4. Check basin former (Dhoble, 2012)

Melesse *et al*. (2001) studied the tie ridger mounted Maresha, an ox-driven plow used in South Africa. They found that its draft power requirement was reduced to 77.8 % of that of Maresha alone. The on-farm test revealed that the use of tie ridger increased the grain yield of maize by 22.5 % compared to the farmer's practice of flat planting.

On-farm tests revealed that the use of the tie ridger increased the grain yield of maize by 22.3% compared to the farmers' practice of flat planting although this is a one-season result. However, the most important point here is that farmers are now provided with an implement to make tied ridges and it is the performance of the implement that is more important as the practice of tie ridging is advantageous by previous investigators (Temesgen *et al*., 2001).

2.4. Summary of Literature Review

From the literature review made, it was noted that the use of effective moisture conservation practices is the most important issue in areas where the availability of soil moisture is the most limiting factor for crop production in general. As research findings indicate tied ridges had brought a significant yield improved over the other moisture conservation practices in general and the farmer's practice in particular.

On the basis of reviews studied and need for farmers a tractor drawn tie ridger was developed with the following features; centeral driving wheel, depth and length of tie controler, shank, furrow openers and tie ridging bottoms. Beside this suitable hitching system, the frame to with standy the various loads accuring during operation of the tie ridging.

CHAPTER THREE

3. MATERIAL AND METHODS

3.1. The Study Area Description

The study site was located near the town of Awash-Melkassa, Adama Woreda, East Shewa Zone, Oromia Regional State, 117 km east of Addis Ababa and 17 km southeast of Adama city

at Melkassa Agricultural Research Center (MARC). It's found at an elevation of 1560 m above sea level and lies between 8° 24' 0" to 8° 30' 12" N, 39° 21' 0" to 39° 35' 14" E. The average annual rainfall in the area is 768 mm, which is erratic and uneven in distribution. The agro-ecology is termed as Kolla (Warm, semi-arid lowlands). The dominant soil type in the area is sandy loam. Fabrication of prototype and any adjustment or maintenance also conducted in Agricultural Engineering Research workshop, which was found in Melkasa Agricultural Research center.

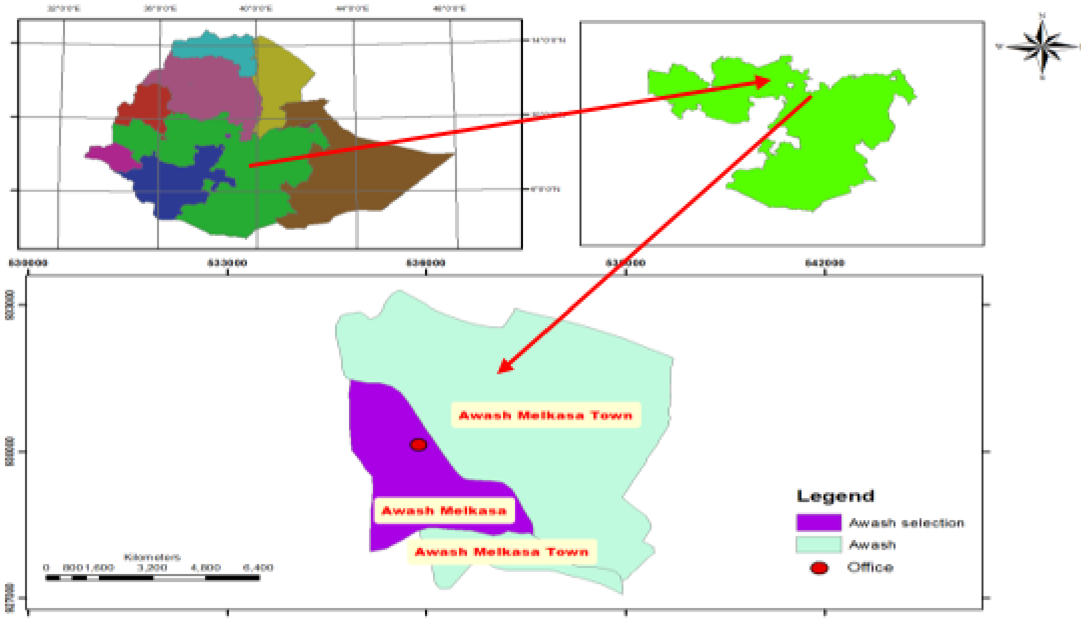


Figure 3. 1. Study area description map

3.2. Material Selection

The selection of proper materials for manufacturing various components of tie ridger is very important. The farm machinery has to work under severe hazardous and heterogeneous environmental conditions.

The selection of these materials was based on durability, cost, and availability, strength and rigidity, weight, and friction. It should be adequately strong, stiff, and wear-resistant and serves the purpose and operating requirements of the tie ridger parts.

It should be readily shaped, welded, and easily machine-able. The materials for the construction of different components should be easily and locally available. The structure of the power unit should be simple and this makes the operation, maintenance and repair easy. Before starting the construction of the tie ridger, the following factors were considered for the appropriate selection of materials. The selection of metal must be such that it can be formed into the desired shape. It is based on the ductility characteristics of the metal. The materials for fabrication of various components were selected considering their function and strength requirements as given in Table: 3.1. The economic consideration and ease of availability of materials are also taken into account.

Table 3. 1. Tools, materials and machine needed for the fabrication of the tie ridger

Sr. No.	**Machine /tool name**	**Purpose**
1	Drills machine	Hole/cell making
2	Lathe machine	Threading /cutting /finishing /shaping /machining.
3	Grinding machine	Grinding /cutting tool
4	Cutting blade	Cut flat bar
5	Electric welding machine	Welding
6	Steel tape	Measurement of linear distance
7	Vernier calipers	Measurement of outer diameter and inner diameter
8	Center punch	Hole marking
9	Choke	Marking
10	Hammer	Used to strike an object
11	Chisel	Cutting
12	Spanner	Tighten nut and bolt
13	Screwdriver	Tighten screw

Table 3. 2. Different components part, functions, and material.

Sr.No	**Components**	**Specification**	**Material**
1	Ground wheel	Wheel diameter 680 mm and 6 mm thick	Mild steel flat
2	Frame	Total length and width were 2,160 mm and 1,550 mm respectively	MS square pipe 70x50x3 mm
3	Shaft for central driving wheel	30 mm dia and 1000 mm length	Round mild steel
4	Tyne type of furrow opener	Adjustable row to row spacing, 40 x150x10 mm	Flat Iron
5	Tie Ridger	MS. flat 250 mm having depth, 300 top widths,100 bottom width and 6mm thick	Mild steel flat bar
6	Three-point hitch system		Mild steel bar
7	Ball-bearing	Diameter 30 mm	

Table 3.3. Tractor specifications

Machine parameters	Specification
Tractor capacity	40 hp
Model	YTO - 404
Make	YTO group corporation
Origin	China
Over all dimension (lxwxh) (mm)	3727x1630x2400
Wheel base (mm)	1965
Minimum ground clearance (mm)	270
Minimum operating weight (Kg)	1990
Tyre specfication	7.5 -16/ 11.2 – 28
Wheel track (mm)	1250/ 1300 -1600
Number of transmission gears	8/4
Speed range (Km/h)	2.49 – 32.59/ 3.69 – 11.25
Lifting force 610mm (KN)	≥6.62

Lifting force articulated point (KN)	8.52

3.3. Design Considerations

During designing and developing the tie ridger; the selection of materials was based on durability, cost and availability, strength and rigidity, weight and friction. CATIA V5 was considered to design and construct the machine and its different parts.

The overall cost of the machine was considered based on the Life Cycle Cost (LCC) of the machine throughout the design stage, material selection stage, and the fabrication stage which in the long run would be affordable to users of the machine, especially local farmers. The machine was constructed with the use of the availability of local materials to ensure the need for possible replacement of damaged parts that are easily available and affordable in the local market. The machine was designed by considering the model of the tractor, hp of the tractor, soil type, and moisture content, and weight of the machine (tie ridge).

Development consideration of tractor drawn tie ridger is undertaken to keep in view the following points.

- The machine was constructed with the use of the available of local materials to ensure the need for possible replacement of damaged parts that are not expensive.
- The tie-ridger should uniformly scrap and collect the soil from an area of a given plot size
- It should distribute the collected soil proportionately to form the main ridges and tie-ridges.
- The overall cost of the machine was considered based on the LCC of the machine throughout the design stage.
- It should be easy to operate and to move from one place to another.
- It should be simple in design and construction.
- The tie ridger developed should be simple in design and construction, involve minimum, maintenance and repair and should be capable, of high-speed trouble-free operation.

3.4. Design Analysis of Major Components of the Tie Ridger

The fabrication of the machine was accomplished on the basis of the design specification predetermined dimensions for each component. Design of the parts of the tie ridge machine was presented using CATIA software.

The tractor-drawn tie-ridger was developed basically to cope up with the problems of low moisture stress in drought-prone areas. The functional components of the machine were consist of the mainframe, shaft, shank, furrow wing, bearing, hub, spoke and wheel. The selection of materials for the construction depends on - strength, availability, durability, weight, resistance to corrosion, etc.

This assumption was on the basis of literature reviews essential for the design that the three-bottom
tie ridger. The power source was a tractor which has 40 hp.

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

Soil type = Sandy loam

Gear level: 3rd gear of tractor

The slope of the land, i<7%

Drawbar horse power (DBHP): 60 % of BHP of tractor (Sharma and Mukesh, 2010)

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

Therefore, DBHP = 40 hp × 0.6 = 24 hp

= 17.90 KW

The tractor drawbar horse power (DBHP), draught available (Df) and the number of the row (n)
was calculated by equations (3.1), (3.2) and (3.3) (Sharma and Mukesh, 2010).

$$\text{DBHP} = \frac{D_f \times V}{270} \quad \text{……… (3.1)}$$

Where: Df = Draft force, (kg)

V = Speed, (km. hr-1)

Generally, the speed of tie ridging was done in the range of 3 to 5 km. hr^{-1}. (ASABE, 2011). Let the forward speed of the tie ridger be 4 km. hr^{-1}.

Putting the values in the equation (3.1), Draught available for ridging = $\dfrac{24 \text{ hp x } 270}{4 \text{ km/hr}}$ = 1620 kgf

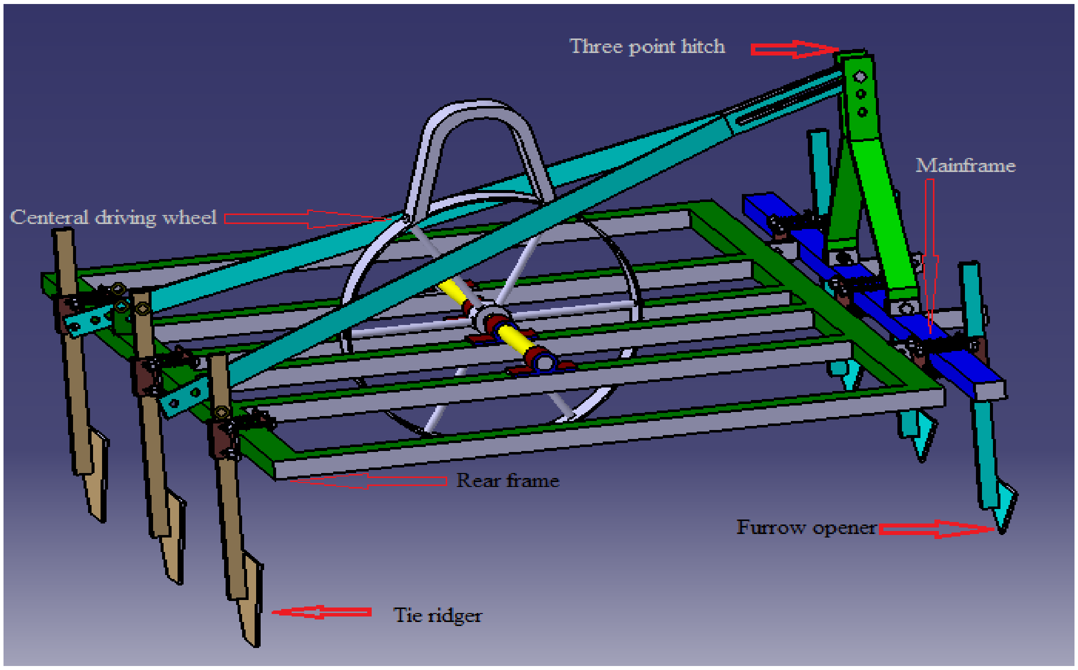


Figure 3. 2. Diagram of the prototype tie ridger

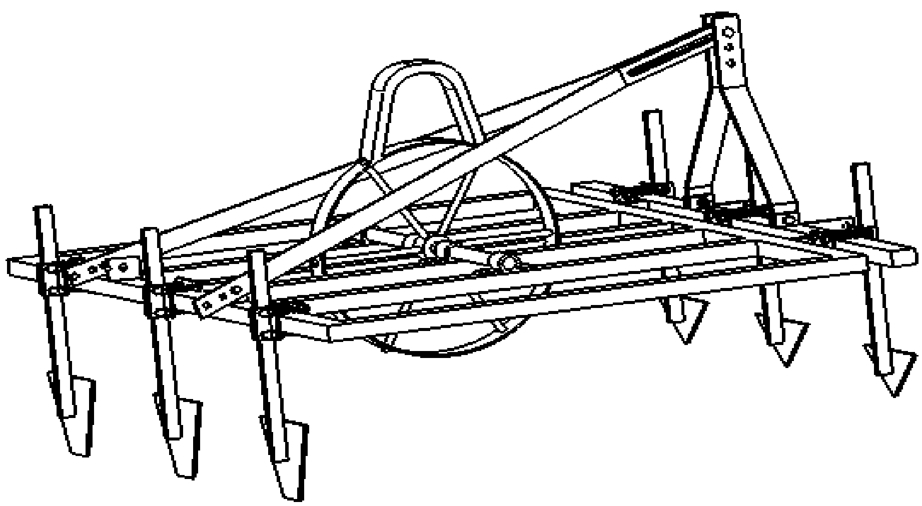


Figure 3. 3. 3D view of the prototype tie ridger machine

3.4.1. Mainframe

The mainframe, with low weight, strength, and reliability, was made from square pipe material. Other parts of the ridge, like the central driving wheel, furrow wing, bearings, etc. were attached to the mainframe. Besides, three-point linkage attachments were provided to the mainframe for attaching to the power source. The consideration has been given that the frame to be light in weight and strong enough to withstand the imposed load during field operation with appropriate materials.

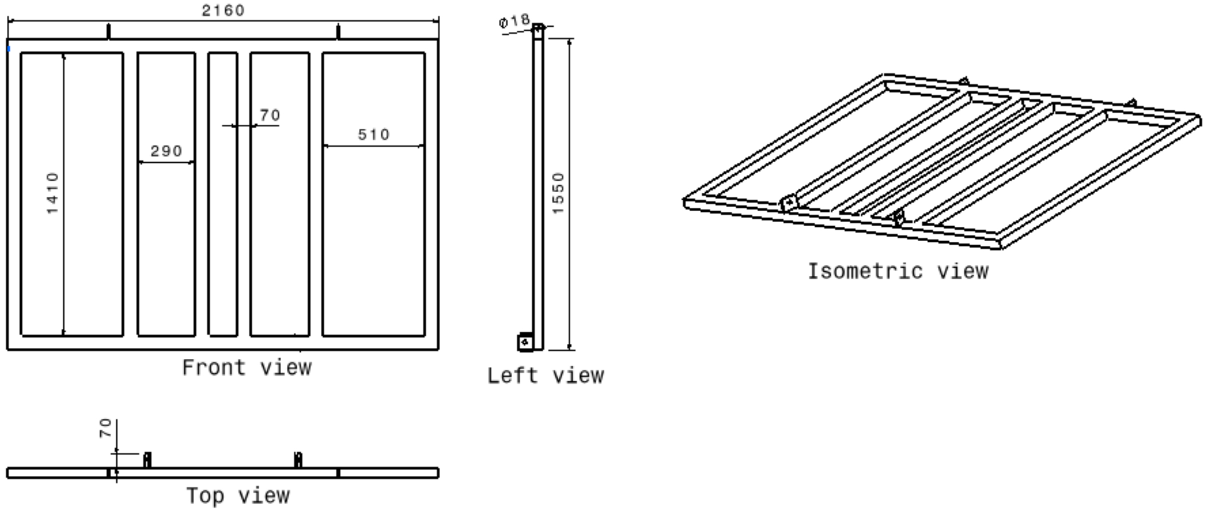


Figure 3. 4. Isometric view of the mainframe (all dimensions are in mm)

The main frame is subjected to torsion and bending due to induced draught. The design was based on the stresses produced in the frame. The design should be based on the stress produced in the toolbar.

In addition to torque, the bending moment (M) is also produced in the toolbar. The toolbar can be assumed as a simply supported frame. The maximum bending moment was at the center.

The working width of the tie ridger was estimated using equation (3.2) (Sharma and Mukesh, 2010)

$L = 2(S + F)$…………………………………………………………………….. (3.2)

$L = 2 \times 72 \text{ cm} + 2 \times 36 \text{ cm}$

$= 216 \text{ cm}$

Where:

L= Total length of the beam

S= Uniform distance between furrows

F= Distance from the edge of the beam to the first furrow opener.

Let take a unit draft for sandy loam soils = 0.3 $^{\text{kg}}/_{\text{cm}^2}$

Depth of operation (a) = 15 cm

Theoretical draft on one front furrow opener (D_o)

D_o = unit draft cross − sectional area of front furrow opener

3.4.2. Design of a Tine

It is assumed that the draught force on the furrow opener is 50 to 100 kgf/tyne and acting and a

height of h/3 from the bottom of the furrow opener where the h is the total length of the furrow opener and tyne. Standard will be in bending so, it will design for easy operation and proper balancing of the machine, the maximum height of furrow opener tyne is taken as 20 cm (Bosai *et al.*, 1987). Considering the available draft of kgf from a tractor as exerted on the tip of the furrow openers of 42 cm length by equation (3.4) (Bosai *et al*., 1987).

Draft on tine was estimated using :

Draft on one tine, kg = cross-sectional area of furrow × soil resistance force × FOS(Sharma and Mukesh, 2010)

$D_e = A \times S_r \times FOS$ ……………………………………………………………….…….. (3.3)

Where:

A = Cross-sectional area of the furrow, cm^2

S_r= Soil resistance, N or kg

D_e= Theoretical draft on one tine × factor of safety, D × FOS, kg/cm^2

B_o= Width of furrow opener, cm

a_{max}= Maximum depth of operation, cm

FOS = Factor of safety

D_e= ½(34 ×15) × 0.3 × 2 = 153 kg

Moment on the tine

Bending moment on tine can be estimated using equation (3.4).

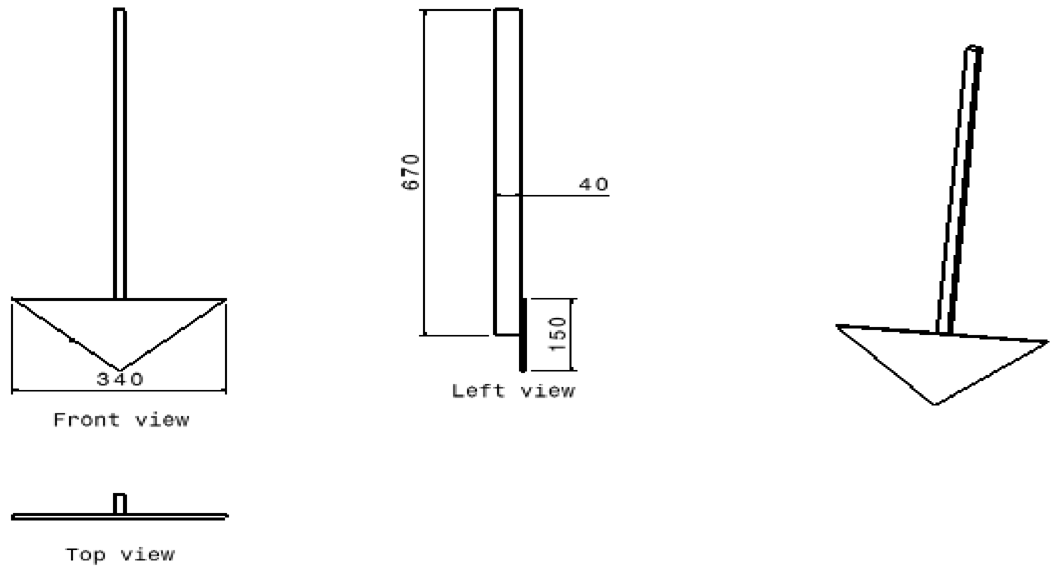


Figure 3. 5. Isometric view of furrow opener (all dimensions are in mm)

B_M = Draft on one tine × moment arm length (Sharma and Mukesh, 2010)

$B_M = D_e \times H'$ …………………………………………………………………………. (3.4)

B_M = 153 kg × 670 mm = 102,510 kg-mm

Where:

B_M = Bending moment on tine

D_e = Draft on one tine, kg

H' = Moment arm length

To estimate bending stress, section modulus and width of the shank by equation (3.6,3.7,3.8 and
3.9) (Bosai *et al.*, 1987).

$f = \frac{M \times C}{I}$ …………………………………………………………………………..………. 3.5

Where:

f = Bending stress, (kg. m^{-2})

I = Moment of inertia, (m^4)

M = Bending moment, (kg-cm)

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

The section modulus axis was computed by using the formula

$Z = \frac{M}{f}$

……………………………………………………………………………………..…..3.6

Bending stress (56 N/ mm^2 for mild steel)

$Z = \frac{102{,}510}{5.7} = 17{,}984.21\ mm^3$

Section modulus of the furrow

$z = \frac{bh^2}{6}$ ………………………………………………………………………………………. 3.7

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

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

……………………………………………………………………………………….3.8

$17{,}984.21 = \frac{16b^3}{6}$

b = 1.9 cm = 19 mm

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

The width of the shank furrow opener was selected =40 mm

3.4.3. Design of Toolbar or Frame for Tie Ridger

i). Total draft on front frame, N or kg (Sharma and Mukesh, 2010)

soil resistance × cross sectional area of the furrow × number of tine

$$= 0.3 \times \frac{34 \times 15}{2} \times 3 = 229.5 \text{ kg}$$

$229.5 \text{ kg} \times \text{FOS}(2) = 459$ kg, total draft on front toolbar or frame.

ii). Draft on one tine, N or kg can be estimated using equation (3.10).

$= \frac{\text{total draft}}{\text{number of tines}}$ ……………………………………………………….………… 3.9

Theoretical draft on one tine, N or kg

$D_e = \text{draft on one tine} \times \text{factor of safety}$

$D_e = D \times FOS$ = 153 kg

iii). Bending momentum acts about the central axis of the frame

M_{max} = W x I………………………………………….…………………….…….. (3.10)

Where:

W = Total draft (total weight on frame) = 1012.5 kg

I = Total length of frame = 216 cm

M_{max} = Maximum bending moment

M_{max} =1012.5 kg × 216 cm = 218,700 kg-cm

iv). Torsion moment acting on the frame

M_T = draft on one tine (D_e) × height of the draft from frame hitch point × number of tines

$M_T = 153 \times 67 \times 3 = 30{,}753$ kg_cm

M_B = 218,700 kg-cm

v). Equivalent moment acting on the frame

$$T_{eq} = \sqrt{{M_B}^2 + {M_T}^2} \quad \text{(3.11)}$$

$$T_{eq} = \sqrt{(218{,}700)^2 + (30{,}753)^2}$$

$= 220{,}851.6$ kg_cm

vi). Allowable stress

$$S_t = \frac{T_{eq}}{Q_i} \quad \text{(3.12)}$$

The polar moment of inertia for the square section is given by:

$Q_i = 2t(a - t)^2$

Where:

S_t = Allowable stress of materials i.e. for mild steel 1050 $\mathrm{kg}/\mathrm{cm}^2$

T_{eq} = Equivalent stress

Q_i = Polar moment inertia of the section

$$S_t = \frac{T_{eq}}{Q_i}$$

$$1050 = \frac{220{,}851.6}{2t(6t - t)^2}$$

t = 1.6 cm

a = 9.6 cm

Calculation of size and draft of the rear frame

Size of furrow opened by tie ridge bottom would be

Top width 30 cm

Bottom width 10 cm

Depth of the furrow 25 cm

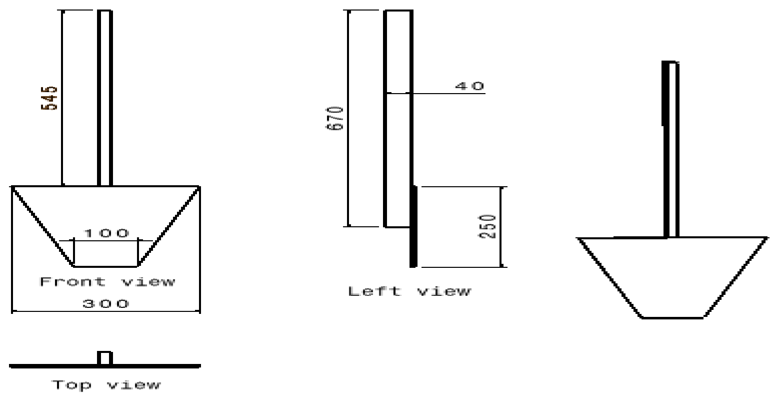


Figure 3. 6. Isometric view of tie ridger (all dimensions are in mm)

Therefore, area of cross section of furrow = (top width + bottom width)/2 × depth

$= ((30\text{ cm} + 10\text{ cm}))\ /\ 2 \times 25\text{ cm}$

$= 500\text{ cm}^2$

The total area of cross-section of furrow = number of bottoms × area of one furrow

$3 \times 500\text{ cm}^2 = 1500\text{ cm}^2$

So, the unit draft of sandy loam soil would be 0.3 $^{\text{kg}}/_{\text{cm}^2}$

Therefore draft of three tie ridger bottoms = area × unit draft

$= 1500\text{ cm}^2 \times\ 0.3\ ^{\text{kg}}/_{\text{cm}^2}$

$= 450\text{ kg}$

$= 450\text{ kg} \times \text{FOS} = 450 \times 2(\text{Factor of safety for M.S.} =\ 2) = 900\text{ kg}$

Torque on the square bar = draft x ground clearance

Ground clearance = 50 cm

T = 900 x 50 = 45,000 kg-cm

In addition to the torque, the bending moment would also be produced. The bar was considered as simply supported beam on the frame in between the two furrow openers. To estimate maximum the bending moment was given by equation (3.11) (Bosai *et al.*, 1987).

M_{max} = W x I

Where:

W = Total draft (total weig ht on frame) = 900 kg

I = Total length of frame = 216 cm

M_{max} = Maximum bending moment

M_{max} =900 kg × 216 cm = 194,400 kg-cm

Equivalent torque due to torsion and bending moment is given by equation (3.14) (Khurmi and Gupta, 2003).

$$T_e = (M_{max}2 + T^2)^{\frac{1}{2}} \ldots\ldots (3.13)$$

Where:

T_e= Equivalent torque, kg-cm = $(194{,}400\ ^2 + 45{,}000\ ^2\ )^{\frac{1}{2}}$ = 199,540.37 kg-cm

T = Torque on the bar, kg-cm = 45,000 kg-cm

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

The maximum shear stress and polar moment of inertia developed at the center of the tool frame

was obtained by equations (3.15 and 3.16) (Khurmi and Gupta, 2003).

$$\frac{1}{4}\frac{fs \times R}{d} = \frac{T_e}{I} \ldots\ldots (3.14)$$

Where:

fs = Shear stress at any section

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

Te = Torque produced

I = Polar moment of inertia, t = 9.6

The maximum working stress of 1120 kg. cm^{-1} has occurred at the Centre of the frame. For square section having each side measuring d,

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

The factor of safety was taken as 2, Fs is 1120 kg. cm^{-1}.

$$\frac{1120 \times 10}{d \times 4} = \frac{=\ 199{,}540.37\ \ \times 9.6}{d^4}$$

$d^3 = \frac{=\ 199{,}540.37\ \times 2\ \ \times 9.6}{1120 \times 10}$ = 6.99 cm, take width of the section = 70 mm

Therefore, considering the availability of the next higher section the square bar section 70 x 50 x 3 mm was selected to made the frame of the tie ridger.

Draft of furrow opener of front toolbar attachment would be

Total draft of tie ridger = draft of tie ridging + draft of furrow openers

$$1620\ \text{kg} = 900\ \text{kg}\ + \text{draft of furrow opener}$$

$$\text{draft of furrow opener} = 1620\ \text{kg} - 900\ \text{kg}$$

$$= 720\ \text{kg}$$

$$\text{Total draft (kg)} = \text{unit draft}\left({}^{\text{kg}}/_{\text{cm}^2}\right) \times \text{width of the implement (cm)} \times \text{depth(cm)}$$

$$\text{widthof the implement} = \frac{\text{total draft (kg)}}{\text{unit draft} \times \text{depth}}$$

$$= \frac{1620\ \text{kg}}{0.3\ {}^{\text{kg}}/_{\text{cm}^2} \times 25\ \text{cm}}$$

$$= 216\ \text{cm}$$

3.4.4. Weight Determination of Components of the Tie ridger

3.4.4.1. Weight of the Mainframe

A rectangular hollow pipe was used in the construction of the tie ridger frame. The weight of the frame was calculated as follows. The cross-sectional area of the hollow material can be calculated from the following equations (Math, 2012);

$$A_{\text{cross-section}} = A_{\text{outer}} - A_{\text{inner}} \quad \text{(3.16)}$$

$$= (70 \times 50) - (67 \times 47) = 351\text{mm}^2$$

The length of frame material is:

$$L_{\text{FM}} = (3 \times 216) + (4 \times 141) = 1{,}212\ \text{cm} = 12{,}120\ \text{mm}$$

The volume of frame material can be computed using the following equations (ITSI-SU, 2011);

$$V_{\text{FM}} = A_{\text{cross-section}} \times L \quad \text{(3.17)}$$

$$= 351\text{mm}^2 \times 12{,}120\ \ \text{mm} = 4{,}254{,}120\ \text{mm}^3 = 0.00425412\ \text{m}^3$$

Mass of frame material is can be computed using the following equations (ITSI-SU, 2011);

$M_{FM} = V_{FM} \times \rho_{FM}$……………………………………………………………………..…….
(3.18)

$$= 0.00425412 \text{ m}^3 \times 7850 \text{ kg}/\text{m}^3 = 33.3948 \text{ kg}$$

The density of mild steel is approximately 7.85 g/cm^3 (7850 kg/m^3 or 0.284 lb/in^3) and Young's modulus is 200 GPa (29,000 ksi).

The weight of frame material can be computed using the following equations (Gat and Uri, 1988);

$W_{FM} = M_{FM} \times g$…………………………………………………………………..…….(3.19)

$W_{FM} = 33.39 \text{ kg} \times 9.81 \text{ m}/\text{s}^2 = 327.6029 \text{ N}$

Where:

$A_{Cross\ section}$= Cross-sectional area of frame material

V_{FM} = Volume of frame material

L_{FM} = Length of frame material

M_{FM} = Mass of frame material

ρ_M = Density of frame material

W_{FM} = Weight of frame material

3.4.4.2. Weight of Tie Ridging

The volume of the tie ridging device used was estimated using the following equations (ITSI-SU, 2011);

$V_{TR} = A_{TR} \times$ thickness of tie ridging.. (3.20)

$$= 562.5 \text{ cm}^2 \times 1\text{cm} = 562.5 \text{ cm}^3$$

The Mass of the tie ridging was determined by the equation (ITSI-SU, 2011);

$M_{TR} = V_{TR} \times \rho_{TR}$ ....(3.21)

$M_{TR} = 562.5 \text{ cm}^3 \times 7850 \text{ kg}/\text{m}^3 = 0.0005625 \text{ m}^3 \times 7850 \text{ kg}/\text{m}^3 = 4.4156 \text{ kg}$

The weight of the tie ridging was calculated by using the following equation (Gat and Uri, 1988);

$W_{TR} = M_{TR} \times g$ ………………………………………………………………….…(3.22)

$$= 4.4156 \text{ kg} \times 9.81 \text{ m}/\text{s}^2 = 43.3172 \text{ N}$$

The total Weight of three bottoms of tie ridging $= 43.3172 \text{ N} \times 3 = 129.9516 \text{ N}$

Where:

A_{TR}= Area of tie ridging

V_{TR} = Volume of tie ridging

M_{TR} = Mass of tie ridging

ρ_{TR} = Density of tie ridging

W_{TR} = Weight of tie ridging

3.4.4.3. Weight of Furrow Opener

The volume of the furrow opener device used was estimated using the following equations (ITSI-SU, 2011);

$V_{FO} = A_{FO} \times \text{thickness of furrow opener}$ ....(3.23)

$= 255 \text{ cm}^2 \times 1\text{cm} = 255 \text{ cm}^3$

The Mass of the furrow opener was determined by the equation (ITSI-SU, 2011);

$M_{FO} = V_{FO} \times \rho_{FO}$ ....(3.24)

$M_{FO} = 255 \text{ cm}^3 \times 7850 \,{}^{\text{kg}}/_{\text{m}^3} = 0.000255 \text{ m}^3 \times 7850 \,{}^{\text{kg}}/_{\text{m}^3} = 2.0017 \text{ kg}$

The weight of the furrow opener was calculated by using the following equation (Gat and Uri, 1988);

$W_{FO} = M_{FO} \times g$ ……………………………………………………………………(3.25)

$= 2.0017 \text{ kg} \times 9.81 \,{}^{\text{m}}/_{\text{s}^2} = 19.6366 \text{ N}$

The total Weight of three bottoms of Furrow opener $= 19.6366 \text{ N} \times 3 = 58.9098 \text{ N}$

Where:

A_{FO}= Area of furrow opener

V_{FO} = Volume of furrow opener

M_{FO} = Mass of furrow opener

ρ_{FO} = Density of furrow opener

W_{FO} = Weight of furrow opener

3.4.4.4. Weight of Three Point Linkage

The volume of the three-point linkage device used was estimated using the following equations (ITSI-SU, 2011);

$A_{TPL} = \text{total length} \times \text{width} = 730\ \text{mm} \times 70\ \text{mm} = 511\ \ \text{cm}^2$

$V_{TPL} = A_{TPL} \times \text{thickness three point linkage}$..(3.26)

$= 511\ \text{cm}^2 \times 1.2\ \text{cm} = 613.2\ \text{cm}^3$

The Mass of the three point linkage was determined by the equation (ITSI-SU, 2011);

$M_{FO} = V_{FO} \times \rho_{FO}$ ....(3.27)

$M_{FO} = 613.2\ \text{cm}^3 \times 7850\ {}^{\text{kg}}/_{\text{m}^3} = 0.0006132\ \text{m}^3 \times 7850\ {}^{\text{kg}}/_{\text{m}^3} = 4.8136\ \text{kg}$

The weight of the three point linkage was calculated by using the following equation (Gat and Uri, 1988);

$W_{FO} = M_{FO} \times g$ ……………………………………………………………………(3.28)

$= 4.8136\ \text{kg} \times 9.81\ {}^{\text{m}}/_{\text{s}^2} = 47.2214\ \text{N}$

Where:

A_{TPL}= Area of three point linkage

V_{TPL} = Volume of three point linkage

M_{TPL} = Mass of three point linkage

ρ_{TPL} = Density of three point linkage

W_{TPL} = Weight of three point linkage

3.4.4.5. Weight of Tine / Shank of Tie Ridging

The cross-sectional area of the shank device with rectangular shape material can be calculated from the following equations (Math, 2012);

$A_{cross-sectional} = L_{STR} \times W_{STR}$ ……………………………………………………….. (3.29)

$= 33\ \text{cm} \times 4\text{cm} = 132\ \text{cm}^2$

The volume of the shank of tie ridging material can be computed using the following equations (ITSI-SU, 2011);

$V_{STR} = A_{cross-section} \times \text{thickness}$ …………………………………………………(3.30)

$= 13{,}200\ \text{mm}^2 \times 10\ \ \text{mm} = 132{,}000\ \text{mm}^3 = 0.000132\ \text{m}^3$

Mass of shank material is can be computed using the following equations (ITSI-SU, 2011);

$M_{STR} = V_{STR} \times \rho_{STR}$ .... (3.31)

$$= 0.000132\ m^3 \times 7850\ {}^{kg}/_{m^3} = 1.0362\ kg$$

The weight of Shank material can be computed using the following equations (Gat and Uri, 1988);

$W_{STR} = M_{STR} \times g$ .... (3.32)

$W_{STR} = 1.0362\ kg\ \times 9.81\ {}^{m}/_{s^2} = 10.1651\ N$

$\text{Total weight of shank of tie ridging } = 10.1651 \times 3 = 30.4953\ N$

Where:

W_{STR} =Width of the shank of tie ridging

L_{STR} = Length of the shank of tie ridging

A_{STR}= Area of the shank of tie ridging

V_{STR} = Volume of the shank of tie ridging

M_{STR} = Mass of the shank of tie ridging

ρ_{STR} = Density of shank of tie ridging

W_{STR} = Weight of shank of tie ridging

3.4.4.6. Weight of Tine / Shank of Furrow Opener

The cross-sectional area of the shank of furrow opener device with rectangular shape material can be calculated from the following equations (Math, 2012);

$A_{cross-sectional} = L_{SFO} \times W_{SFO}$ .... (3.33)

$$= 50\ cm \times 4cm = 200\ cm^2$$

The volume of the shank of furrow opener material can be computed using the following equations (ITSI-SU, 2011);

$V_{SFO}\ =\ A_{cross-section}\ \times\ \text{thickness}$ ....(3.34)

$$= 20000\ mm^2 \times 10\ \ mm = 200000\ mm^3\ = 0.0002\ m^3$$

Mass of shank of furrow opener material is can be computed using the following equations (ITSI-SU, 2011);

$M_{SFO} = V_{SFO} \times \rho_{SFO}$ .... (3.35)

$$= 0.0002\ m^3 \times 7850\ {}^{kg}/_{m^3} = 1.57\ kg$$

The weight of the shank of furrow opener material can be computed using the following equations (Gat and Uri, 1988);

$W_{SFO} = M_{SFO} \times g$ ………………………………………………………………… (3.36)

$W_{SFO} = 1.57\ \text{kg} \times 9.81\ {}^{m}/_{s^2} = 15.4017\ \text{N}$

Total weight of shank of furrow opener $= 15.4017\ \text{N} \times 3 = 46.2051\ \text{N}$

Where:

W_{SFO} =Width of the shank of furrow opener

L_{SFO} = Length of the shank of furrow opener

A_{SFO}= Area of the shank of furrow opener

V_{SFO} = Volume of the shank of furrow opener

M_{SFO} = Mass of the shank of furrow opener

ρ_{SFO} = Density of shank of furrow opener

W_{SFO} = Weight of shank of furrow opener

3.4.4.7. Weight of the Central Driving Shaft

The area of the central driving shaft was estimated as follows (Math, 2012);

$A_{SH} = \frac{\pi(D^2)}{4}$ …………………………………………………………………………(3.37)

$= \frac{\pi(30^2)}{4} = 706.5\ \text{mm}^2 = 0.0007065\ \text{m}^2$

The volume of the central driving shaft was estimated using the following equations (ITSI-SU, 2011);

$V_{SH} = A_{SH} \times L_{SH}$ ……………………………………………………………………(3.38)

$= 0.0007065\ \text{m}^2 \times 1\ \text{m} = 0.0007065\ \text{m}^3$

The mass of the central driving shaft was estimated using the following equations (ITSI-SU, 2011);

$M_{SH} = V_{SH} \times \rho_{SH}$ ………………………………………………………………………(3.39)

$= 0.0007065\ \text{m}^3 \times 7850\ {}^{kg}/_{m^3} = 5.5460\ \text{kg}$

The weight of the metering shaft was estimated using the following equations (Gat and Uri, 1988);

$W_{SH} = M_{SH} \times g$ ………………………………………………………………… (3.40)

$= 5.5460 \text{ kg} \times 9.81 \, {}^{\text{m}}/_{s^2} = 54.4062 \text{ N}$

Where:

A_{SH}= Area of the central driving shaft

V_{SH} = Volume of the central driving shaft

M_{SH} = Mass of the central driving shaft

ρ_{SH} = Density of central driving shaft

W_{SH} = Weight of central driving shaft

3.4.4.8. Total Weight of the Prototype Tie Ridger

To estimate the loads on every part of the prototype tie ridger, it was necessary to estimate the weight of all parts. The total weight of the prototype tie ridger including frame, central driving shaft, the shank of furrow opener, shank of tie ridging, furrow opener, tie ridging was estimated to be 694.7923 N. Allowing 2% margins for the weights of welding bolts, nuts, etc. the total weight was found to be 708.688 N ≈ 709 N.

3.4.5. Estimation of Force, Torque and Power Required to Drive the Tie Ridger

3.4.5.1. Estimation of Force Required to Drive the Tie Ridger

A rolling resistance force (F), which was assumed to act horizontally at the wheel and ground interface or ground and wheel contact patch was estimated using the Eq. (41 and 42) (Reece,2002)

$$F = (C_R + i) \times N \qquad (3.41)$$

$$F = \left[\sqrt{\frac{z}{d}} + i\right] \times N \qquad (3.42)$$

Where:

CR = Coefficient of rolling resistance

d = Wheel diameter, (68 cm)

z = Maximum wheel sinkage depth, (on a soft surface z ≈ 0.05d = 3.4 cm)

N = Weight of the tie ridger on the wheel, (709 N)

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

$$F = \left[\sqrt{\frac{3.4\ cm}{68\ cm}} + 0.05\right] \times 709\ \mathrm{N} = 193.9872\ \mathrm{N}$$

3.4.5.2. Torque on the Ground Wheel

Torque on the ground wheel estimated by using equation (3.43) (Sharma and Mukesh, 2010)

$T = F\left(\frac{d}{2}\right)$ ………………………………………….……………………………….(3.43)

$= 193.9872\ \mathrm{N}\left(\frac{0.68\ \mathrm{m}}{2}\right) = 65.9556\ \mathrm{Nm}$

Where:

T = Torque, (Nm)

F = Rolling resistance force, (N)

d = Diameter of the ground wheel, (m)

3.4.5.3. Power Requirement of the Tie Ridger

The wheel covers 2.135 m in one revolution and taking a 1.111 $^{m}/_{s}$ (21 rpm) forward speed of tractor-drawn tie ridger.

The power requirement of the tie ridger is given by using equation (3.44) (Sharma and Mukesh, 2010).

$P = T \times N_W$…………………………………………………………………………..(3.44)

Where: Nw= wheel revolution, (21 rpm)

$P = (65.9556\ \mathrm{Nm}) \times \left(21 \times \frac{2\pi}{60}\right)$

$P = 144.97\ \mathrm{w} = 0.14497\ \mathrm{kw}$

3.4.6. Determination of Shaft Diameter

The design of the wheel shaft was based on ductile material (mild steel) whose strength is controlled by maximum shear stress. The wheel shaft diameter was needed to determine the load-carrying capacity of the shaft. The shaft is expected to be subjected to both torsion and bending moments. This may be due to the rotational effect of the shaft during the forward motion of the machine.

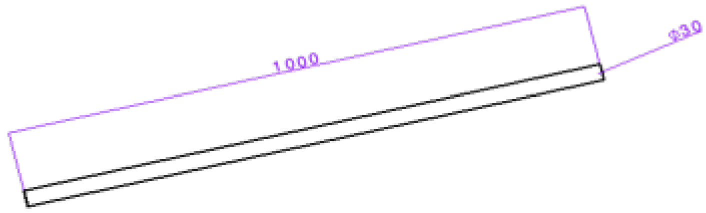


Figure 3. 7. Shaft isometric view

For a solid shaft with little or no axial load, the diameter of the shaft is determined as reported by Khurmi and Gupta (2005).

$$d^3 = \frac{16}{\pi s_s} \times \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad \text{.........(3.45)}$$

Where:

d = Diameter of the shaft

Ss = Allowable stress

Kb = Combined shock and fatigue factor applied to bending moment

Mb = Bending moment

Kt = Combined shock and fatigue factors applied to torsional moments.

For rotating shafts, when the load is suddenly applied with minor shock, Khurmi and Gupta (2005) recommended that values of Kb = 1.2 to 2.0 and Kt= 1.0 to 1.50 be used. Furthermore, it was noted that for shaft without key way, the allowable stress (Ss) must be 55 MN/m^2, and for the shaft, with the key way, the allowable stress (Ss) should not exceed $40 MN/m^2$.

Torsional moment (Mt) on the shaft was calculated using Eq. (3.46 and 3.47) (Ryder, 1989).

$$M_t = \frac{P \times 60}{2\pi N} \quad \text{.........(3.46)}$$

$$M_t = \frac{144.97 \times 60}{2\pi \times 21} = 65.95 \text{ Nm}$$

Where:

P = Power required to drive the machine (144.97 w)

N = Speed of the shaft (21 rpm)

V = Forward speed (1.1111 $^{m}/_{s}$)

F = Force required to drive the machine (193.9872 N)

The figure below shows the load distribution on the shaft. The maximum bending moment on the shaft was determined from the following expressions (Richard *et al.*, 2011);

$$M_b = \sqrt{{M_v}^2 + {M_h}^2} \quad \text{.........(3.47)}$$

Where:

Mb = Maximum bending moment, (Nm)

Mv = Vertical bending momentum= 177.25 Nm from bending moment diagram

Mh = Horizontal bending momentum = 48.49 Nm from bending moment diagram

$M_b = \sqrt{177.25^2 + 48.49^2}$

$= 183.76 \text{ Nm}$

Using equation (3.38)

$d^3 = \frac{16}{\pi \times 55 \times 10^6} \times \sqrt{(2 \times 183.76)^2 + (1.5 \times 65.95)^2}$

$= 32.79 \text{ mm}$

By considering the availability of material and standard size.

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

a) Vertical Forces Distribution on the Shaft

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

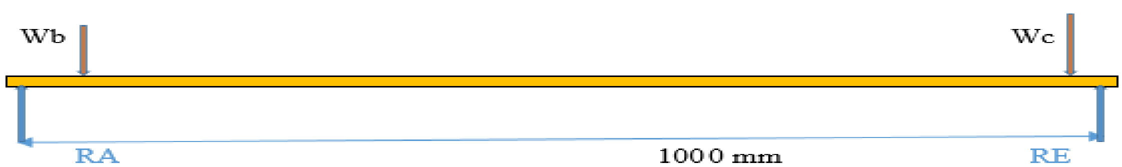


Figure 3. 8. Vertical forces distribution on the shaft

Where:

RA=Vertical reaction at A

RE= Vertical reactions at E

W = The total weight acting on the shaft

The total weight of the tie ridger which lay on the shaft was 709 N.

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

$\sum MA = 0$

$-1\, R_E + 709 \text{ N} \times 0.5 \text{ m} = 0$

$1\, R_E = 354.5$

$R_E = 354.5 \text{ N}$

$R_E = R_A = 354.5 \text{ N}$

b) Vertical Shear Force and Bending Moment Distribution

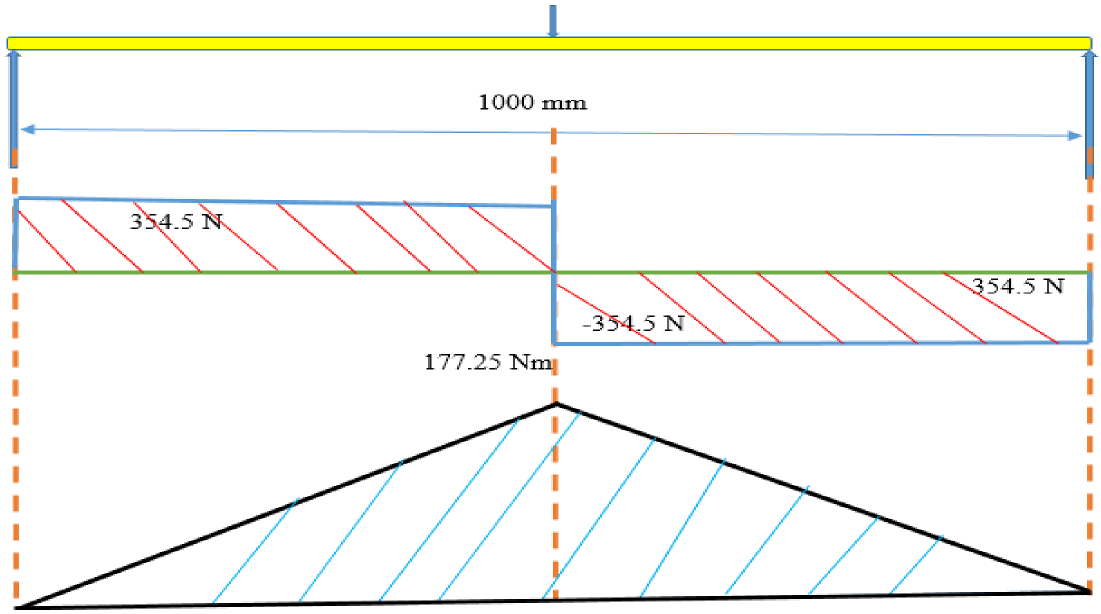


Figure 3. 9. Shear force and bending moment diagram representation

The maximum moment was 177.25 Nm.

c) **Horizontal Force Distribution On the Shaft**

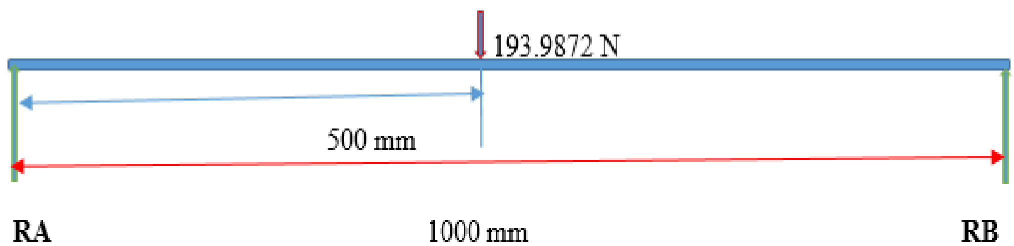


Figure 3. 10. horizontal force distributions

$\sum MA = 0$

193.9872 N × 0.5 -RB × 1 = 0

96.99 = 1 RB

RB = 96.99 N = RA

D. **Horizontal Shear Force and Bending Moment Distribution**

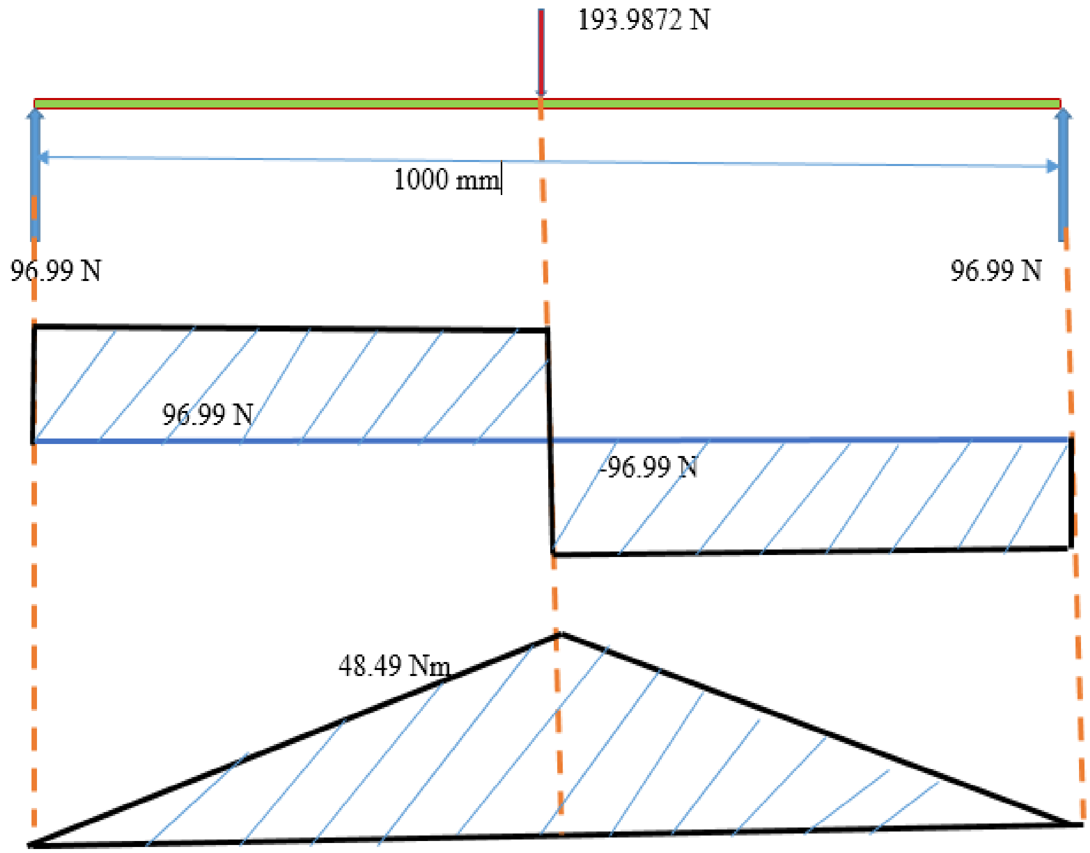


Figure 3. 11. Horizontal shear force and bending moment diagram

3.4.7. Selection of Bearing

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

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

3.4.8. Three Point Linkage

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

Table 3. 4. Three-point hitch specifications

Category	Hitch pin size		Lower hitch spacing	Tractor drawn power
	Upper link	Lower link		
0	17 mm	17 mm	500 mm	<20 hp
1	19 mm	22.4 mm	718 mm	20-45 hp
2	22.5 mm	28.7 mm	870 mm	40-100 hp
3	31.75 mm	37.4 mm	1010 mm	80-225 hp
4	45 mm	51 mm	1220 mm	180 – 400 hp

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

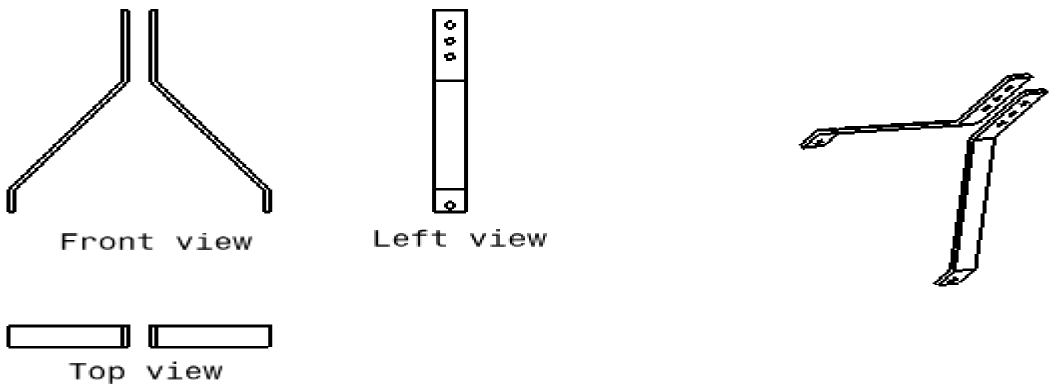


Figure 3. 12. Three-point hitch isometric and 3D views

3.4.9. Wheel Design

The dimensions of the rigid welded wheel having a thin wall where thickness (t) is very much less wheel diameter (d) computed using Eqns. (3.50) and (3.51). The width of the wheel was calculated using Eqn. (3.53).

The ground wheel diameter was selected based on the trial and error method depending on the height of the machine above the ground surface (Sharma, 2010). Therefore, the diameter of the ground wheel was selected to be 68 cm. The young's modulus of the mild Steel plate and Poisson ratio were 205GPa and 0.30, respectively.

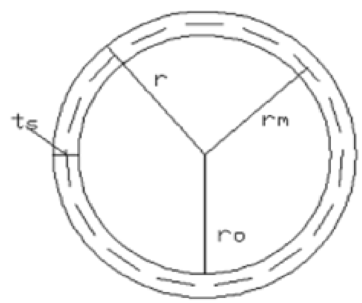
Poisson's ratios of the soils are suggested to be between 0.30 and 0.45 (Raper and Erbach, 1990).

Young's modulus of elasticity of sandy soil, 10-50MPa (loose to compact).

The weight of the machine is 709 N; hence, it exerts 709 N loads on these wheels. Thus, using Eqn. (3.46) the width (b) of the wheel was determined to be 80.00 mm. Assuming the maximum shear strength of the wheel material to 80.00MPa and the thickness of the wheel to be 6.00 mm, the shear stress developed in the wheel was determined 15.41278 Kpa.

3.4.9.1. Wheel Strength

The wheel of the tie ridger was made from mild steel sheet metal whose maximum shear strength, **τ**max, is 80 MPa. Reinforcing bars were used to strengthen the wheels. For the simplicity of the analysis, it was assumed that the stress occurs on the wheel was pure torsion. Therefore, the formula used in the analysis was the one that estimates the sheer amount in "welded closed thin wall, t<<<d", as dictated by (Richard and Nisbett, 2011).



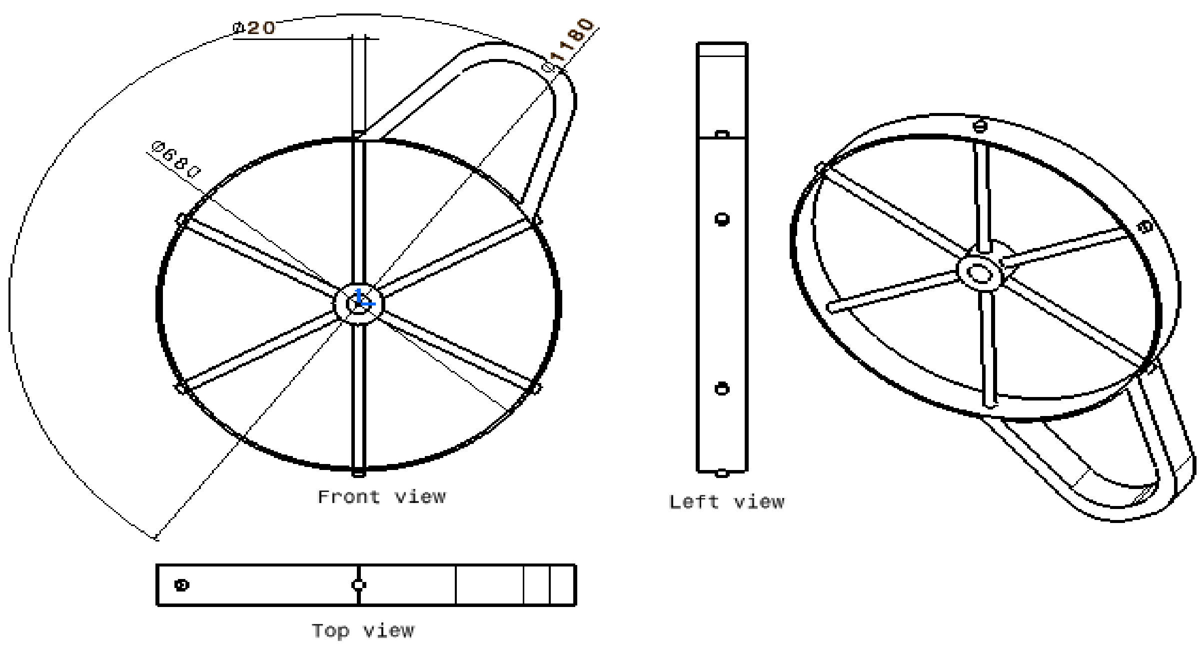


Figure 3. 13. Three dimensional and cross-section view of the wheel

$$\tau = \frac{T}{2A_m \times t_s} \quad (3.49)$$

But $A_m = 2\pi r_m{}^2$

$$r_m = r - 0.5t_s \quad (3.50)$$

Hence, $\tau = \frac{T}{2\pi(r-0.5t_s)^2 \times t_s}$

where:

T = The torque produced by the wheel (Nm), 65.9556 Nm

A_m = The area of the wheel calculated based on the mean diameter of the wheel (m^2)

r = The outer radius of the wheel (m), 0.34 m

ro= The inner radius of the wheel (m), 0.334 m

rm= The mean radius of the wheel (m), 0.337 m

ts= The thickness of the wall/wheel (m), 0.006 m

Therefore, the shear stress on the wheel is,

$$\tau = \frac{T}{2\pi(r-0.5t_s)^2 \times t_s}$$

$$\tau = \frac{65.9556}{2\pi(0.34-0.5\times 0.006)^2 \times 0.006}$$

$$\tau = 15{,}412.78 \text{ pa}$$

τ = 15.41278 Kpa $<<<$ τmax

Comparing this shear stress with the maximum allowable shear stress of the metal, τ (15.41278 KPa)<<<τmax,80 MPa, which tells us the wheel is safe for operation.

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

$$\theta = \left(\frac{TL_m}{4GA_m{}^2 t}\right) L \quad (3.51)$$

$$\theta = \left(\frac{65.9556 \times (0.34-0.003)}{4\times 80\times \pi \times 0.337^2 \times 0.006 \times 10^9}\right) \times 0.08 = 3\times 10^{-8} \text{ rad } (\textit{negligible})$$

where:

L = Length or width of the wheel (m)

T = Torque produced by the wheel (Nm)

Lm = The length of the median line of the wheel (m)

θ = The angle of twist (radian) and

G = Modulus of rigidity (N/m^2)

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

3.4.9.2. Estimation of Wheel Width

The required width of the wheel can be calculated using Eqn. (3.52), (Richard and Nisbett, 2011).

The stress created has an elliptical distribution across the contact zone (Hertz, 1881). The following equations are used to calculate the width and pressure:

$$b = \sqrt{\frac{\frac{2F}{\pi l}\left[\frac{(1-v_1{}^2)}{E_1}+\left(\frac{1-v_2{}^2}{E_2}\right)\right]}{\frac{1}{d_1}+\frac{1}{d_2}}} \ldots\ldots (3.52)$$

$$P_{max} = \frac{2F}{\pi bL} \ldots\ldots (3.53)$$

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

where:

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

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

E_1 = Young‟s modulus of elasticity of mild steel sheet metal, 200GPa (Norton, 2005).

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

d1 = Diameter of the wheel , 0.68 m

d2 = Diameter of the contacting surface ∞

F = The force exerted by the wheel, 193.9872 N

b= Widths of contact of the wheel with ground

l = Contact length/width of the wheel with the ground (m), 0.08 m

Pmax= The maximum pressure on the soil (N/m^2)

The width of the wheel specified in the design was 8 cm and this had to be checked whether the width selected would allow the wheels to rotate on the surface of the ground without sinkage or not. The pressure (Pmax) developed on the contact patch (wheel and ground) was compared with the minimum con-index (Pmin) measured at 20-30 cm depth using a cone-penetrometer. If Pmax<Pmin, it is assumed that the width of the wheel is safe. However, if Pmax>Pmin, the width of the wheel has to be increased to some level to avoid wheel sinkage in operation.

$$b = \sqrt{\frac{\frac{2\times193.9872}{\pi\times0.08}\left[\frac{(1-0.3^2)}{200\times10^9}+\left(\frac{1-0.4^2}{50\times10^6}\right)\right]}{\frac{1}{0.68}+\frac{1}{\infty}}}$$

$$= 0.004010 \text{ m}$$

Solving for Pmax,

$$P_{max} = \frac{2F}{\pi bL}$$

$$= \frac{2\times193.9872}{\pi\times0.004010\times0.08} = 385.158 \text{ Kpa}$$

$385.158 \text{ Kpa} \lll 500\text{Kpa}$ (safe).

The selected width of the wheels is sufficient and the wheels will rotate on the surface of the ground without sinking into the soil.

The wheel numeric for cohesive soil may be determined using Eqn. (3.54) (Wismer and Luth, 1973).

$$N_{CS} = \frac{CIbd}{W} \quad (3.54)$$

$$= \frac{5\times10^5\times8\times10^{-2}\times6.8\times10^{-1}}{709} = 38.36$$

Maclaurin (1990) has developed the following models for rolling resistance coefficient and for sinkage.

The traction coefficient of the wheel can be determined using Eqn. (3.55) below,

$$\mu_R = \frac{T_w}{r_r\times W} \quad (3.55)$$

$$= \frac{65.9556 \text{ Nm}}{0.34 \text{ m}\times709 \text{ N}} = 0.2736$$

$$z = \frac{0.224d}{{N_{CS}}^{1.25}} \quad (3.56)$$

$$= \frac{0.224\times0.68}{38.36^{1.25}} = 0.001595$$

The diameter of the spokes can be calculated using Eqns. (3.57 and 3.58) considering maximum principal shear stress theory (Richard and Nisbett, 2008).

Bending moment,

$$M_b = W\mu_R\left(\frac{D-d}{2}\right) \qquad (3.57)$$

$$= 709\text{ N} \times 0.2736\left(\frac{0.668-0.055}{2}\right) = 59.455\text{ Nm}$$

Bending stress,

$$\frac{\sigma_1}{f_s} = \frac{1}{2}\left(\sigma_b + \sqrt{\sigma_b{}^2 + 4\tau_{xy}{}^2}\right) \qquad (3.58)$$

The bending moment of the spoke shall have occurred at the hub and there was no torsional moment. Therefore the equation (3.59) can be simplified in to,

$$\frac{\sigma_1}{f_s} = \frac{1}{2}(\sigma_b + \sigma_b) = \sigma_b = \frac{32M_b}{\pi d^3}$$

Rearranging the above equation, the diameter of the spokes shall be calculated as follow,

$$d^3 = \frac{32f_sM_b}{\pi\sigma_1} \qquad (3.59)$$

$$= \sqrt[3]{\frac{32\times 59.455}{3.14\times 80\ MPa}} = 19.638\text{ mm}$$

The diameter of the spokes was calculated found to be 19.638, hence a round bar of Ø 20 mm was used.

$$n = 2.16\sqrt{\frac{D_w}{100}} \qquad (3.60)$$

$$n = 2.16\sqrt{\frac{680}{100}} = 5.6 \approx 6$$

The number of spokes, n, was calculated found to be 5.6; hence, six spokes were used.

where:

M_b = Bending moment (Nm)

σ_b= Bending stress (N/m^2)

W = Total load (N)

μ_R= Coefficient of rolling resistance

D = Diameter of the wheel rim (m)

D_w = Diameter of the wheel (mm)

d = Outer diameter of the hub (m)

τ_{xy}= Torsional shear stress (N/m^2)

σ_1 = Stress at proportional limit (N/m^2)

f_s= Factor of safety

The hub of a wheel is one of the most important components of a rigid wheel. The hub of a the wheel gives support to the spokes and the axle. The diameter and length of the hub being calculated using Eqns. (3.61 and 3.62).

$D_h = 1.5d_s + 25mm$…………………..……………………………………………(3.61)

$= 1.5 \times 0.03 + 0.025 = 0.07$ m

Length of the hub,

$L = \frac{\pi d_s}{2}$……………………………..………………………..………………………(3.62)

$= \frac{\pi \times 0.03}{2} = 0.0471$ m

where:

D_h= Outside diameter of the hub (mm)

d_s = Diameter of shaft (mm)

L = Length of hub (mm)

3.5. Working Principle of Tie Ridger

Before using the tie-ridger in a field, land should be plowed and harrowed. There should not be any clods in the field. The tie-ridger has attached to the tractor through the three-point linkage provided to the implement. As the weight of the implement has 709 N. The tractor required to trail it should be 40 hp. As the tie ridger moves forward, the ground wheel had rotated and the depth controller on the ground wheel controls the depth and length of the tie ridged.

3.6. Performance Test and Evaluation of the Tie Ridger

A day before starting the performance test, a preliminary test run was undertaken to see whether the machine was functionally acceptable or not and to check the existence of any malfunctioning parts and defects. Fortunately, the tie ridger had good stability in terms of operation and performed the intended job acceptably.

The developed tractor-drawn tie-ridger was tested and evaluated at the laboratory and actual field conditions. The trials were conducted at Melkassa agricultural research center.

Figure 3.14. Fabricated tractor drawn tie ridger

3.6.1. Laboratory Test

The following parameters were used for evaluating the tie ridger.

3.6.1.1. Checking of Specification and Material

After the development of the tie-ridger, all specifications have checked for their accuracy. The material of each component of the implement has been checked for conformity with the specifications.

3.6.1.2. Visual Observation and Provision for Adjustment

The tie-ridger has been kept on a firm, leveled, and horizontal surface. The working depth of the tie-ridger had been checked and adjusted to penetrate the soil and collect sufficient soil for forming the basin. The tightness of nut and bolts have been checked.

3.6.2. Field Test

A field test of the tie-ridger has been conducted at MARC. Rectangular plots were prepared. Before operating the tie-ridger in the selected plots, care was taken that the soil was in a loose condition. Various parameters related to soil and implement were recorded during the test.

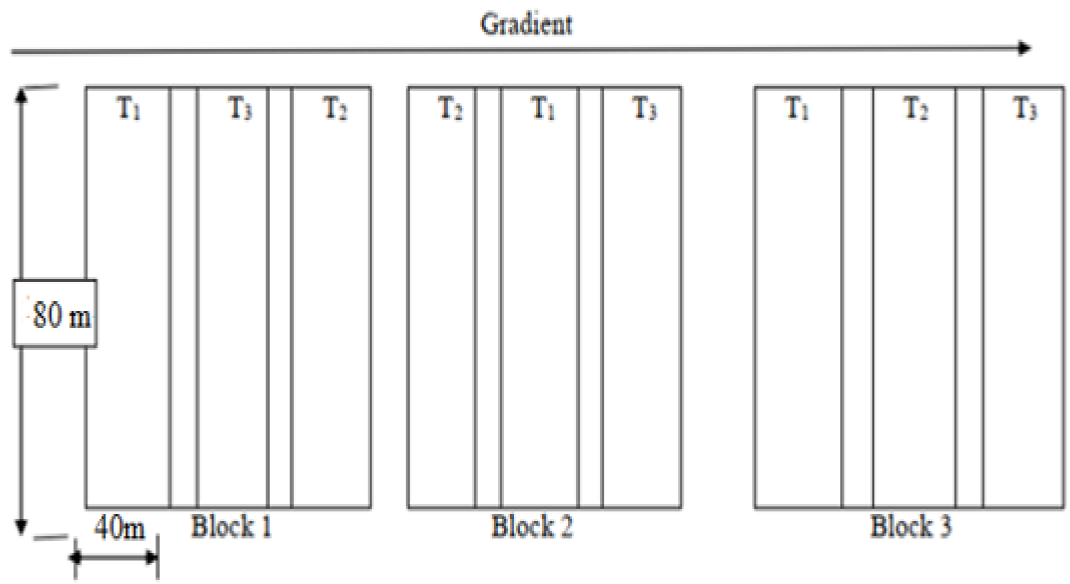
3.6.2.1. Field Description

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

i. Type of soil
ii. Soil moisture content in percent
iii. Bulk density
iv. Size of plot
v. Depth of ridging

3.6.2.2. Experimental Design

The experiments were conducted in the field and three forward speeds of the tractor of 3.6 $\mathrm{km.h^{-1}}$,4.3 $\mathrm{km.h^{-1}}$,and 5.0 $\mathrm{km.h^{-1}}$, with forming three treatments. Each treatment was replicated three times with Randomized Complete Block Design (RCBD). RCBD is one of the most widely used experimental designs in agricultural research. The design is especially suited for field experiments where the number of treatments is not large and the area of the experiment has a predictable productivity gradient. The primary distinguishing feature of the RCBD is the presence of blocks of equal size, each of which contains all the treatments. Therefore, the design has three treatments that are not large and the experimental area has a predictable productivity gradient.



Where: T-Treatment with index numbers 1, 2, 3

Figure 3. 15. RCBD plot size sample representation

The well-prepared experimental field was divided into 9 plots each having an area of 3200 m^2 (i.e.40 m x 80 m plot size). Various adjustments in the machine were done to get the required tie ridging depth and length of tie ridge before testing. The tie ridger was prepared and adjusted for ridging operation. The tractor-drawn tie ridger was adjusted at throttle position and tie ridging operation was carried out for each randomly selected plot sample by taking performance evaluation data. The data was analyzed in the result and discussion section.

3.6.2.3. Soil Parameters

3.6.2.3.1. Moisture Content

The samples were collected from 0 to 25 cm depth of soil surface before operations for determination of moisture content and bulk density. The soil moisture was determined by the oven dry method. Five samples were collected randomly from the test plots. The samples were kept in an oven for 24 hours at a temperature of 105°C. The samples were weighed before and after drying. The moisture content (dry basis) was determined by the following formula (Rangapara, 2014).

Moistureя content (%) = $\frac{Ww-Wd}{\text{Wd}} \times 100$ …………………………………………………(3.63)

Where:

Ww= Weight of the wet soil sample, and

Wd= Weight of the dry soil sample

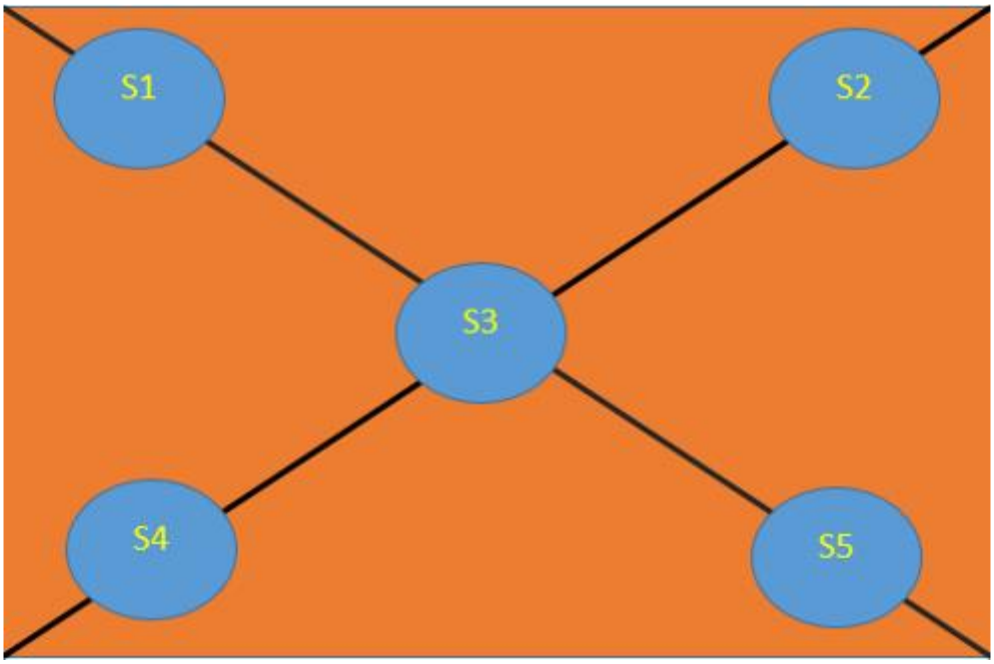


Figure 3.16. Soil sample taking method on the field.

3.6.2.3.2. Bulk Density of Soil

To determine the bulk density of soil, a metallic core sampler was used to take the sample from the field having 5 cm diameter and 5 cm length. The samples were weighed and dry weights of the samples were calculated with the help of moisture content (d.b). The ratio of the dry weight of soil to the volume gave the bulk density. The bulk density of soil was calculated by using the following formula (Rangapara, 2014).

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

3.6.2.4. Tie Ridger Performance Parameters

3.6.2.4.1. Operating Speed

The operating speed of the tie ridger was carried out by observing the time required for traveling 80 m distance with the help of a stop watch along the longest direction.

3.6.2.4.2. Total Operating Time

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

3.6.2.4.3. Fuel Consumption

The fuel consumption was measured as per the standard method by observing the fuel required for traveling 80 m long distances. A known volume cylinder was directly attached to the fuel tank and was filled up to some level by keeping the tractor on level land and after completing the operation, the final measurement of the cylinder was noted down. The volume of fuel used was taken into account as fuel consumed for a particular period.

$$\text{Fuel consumption (lit.h}^{-1}\text{)} = \frac{\text{Fuel consumed during operation,lit}}{\text{Time required for operation,h}} \qquad (3.65)$$

3.6.2.4.4. Effective Field Capacity

It is the actual area covered by the implement, based on its total time consumed and its width. The machine was operated for continuous fieldwork with a fixed time and the area covered during the period was measured to determine the average output per hour. Rangapara (2014) expressed the relation of effective field capacity as:

$$\text{Effective field capacity(ha.h}^{-1}\text{)} = \frac{\text{Actual area,ha}}{\text{Time taken to cover the test area,h}} \qquad (3.66)$$

3.6.2.4.5. Theoretical Field Capacity

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

$$\text{Theoretical field capacity (ha.h}^{-1}\text{)} = \frac{\text{width,m} \times \text{speed,km.h}^{-1}}{10} \qquad (3.67)$$

3.6.2.4.6. Field Efficiency

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

$$\text{Field efficiency, \%} = \frac{\text{Effective field capacity,ha.h}^{-1}}{\text{Theoretical capacity,ha.h}^{-1}} \times 100 \qquad (3.68)$$

3.6.2.4.7. Draft Requirement Test

The draft was measured using a digital drawbar dynamometer attached to the front of the tractor on which the implement was mounted. Another auxiliary tractor was used to pull the implement
mounted tractor through the drawbar dynamometer. The auxiliary tractor pulls the implement mounted tractor which was in neutral gear but with the implement in the operating position. The draft was recorded in the measured distance of 80 m. On the same field, the implement was
lifted off the ground and the draft recorded. The difference between the two readings gave the draft of the implement. This procedure was repeated for all the speeds considered in the study.

3.6.2.4.8. Wheel Slippage

A mark was made on the tractor drive wheel with colored tapes and the distance the tractor moves forward at every 10 revolutions under no-load condition and the same revolution with load on the same surface was measured. Wheel slip for any given load was determined by equation (3.70) (Rangapara, 2014). The observations are tabulated in Appendix-D.2.

$$\text{Wheel slip}, \% = \frac{\text{Revolution without load} - \text{Revolution with load}}{\text{Revolution without load}} \times 100 \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (3.70)$$

3.7. Operation Cost of Machine

The cost of operation for the machine was worked out by calculating the fabrication, fixed and variable costs as presented in Appendix C. Estimation of hourly operational costs of the tie ridger were based on the capital cost of the tie ridger, interest on capital, cost of repairs and spare parts, labor cost, and depreciation. The operational cost components of the prototype tie ridger were estimated in Birr (ETB) by using equation (3.71) (Geonse & Blaauw, 1995).

Estimation of annual and hourly operational costs of the tie ridger have based on the capital cost of the implementation, interest on capital, cost of repairs and spare parts, labor cost, and depreciation.

The operational cost components of the tie ridge have been estimated in Birr (ETB) as follows:

I. $D_p = \frac{C_c - S_{vc}}{E_l}$, $\frac{ETB}{hr}$ .... (71)

II. $I_c = \left(\frac{C_c + S_{vc}}{E_l}\right) x \left(\frac{I\%}{N_{AOHT}}\right), \frac{ETB}{hr}$ .... (72)

III. $L_W = \frac{D_{LW}}{D_{WH}}, \frac{ETB}{hr}$ .... (73)

IV. $C_{RS} = \frac{C_c x 6\%}{A_{WHT}}$, $\frac{ETB}{hr}$ .... (74)

V. $W_T = \frac{D_{TW}}{D_{WH}}, \frac{ETB}{hr}$ .... (75)

VI. Hourly operational costs $= I + II + III + IV + V$ .... (76)

Where:

A_{WHT} = Annual working hours of the tie ridger

Dp = Depreciation

C_C = Capital cost

S_{VC} = Salvage Cost

C_{RS} = Cost of repairs and spares

E_l= Estimate life (h)

I = Interest %

N_{AOHT} = Number of the annual operating hours of the tie ridger (EB/h)

D_{LW} = Daily labor wage

D_{WH} = Daily working hours (EB/h)

I_C = Interest on capital (EB/h)

W_T = Wage of tractor

D_{TW} = Daily tractor wage (EB/h)

L_W = Labor wages

3.8. Data Analysis

All the data collected during the laboratory and field performance evaluations were analyzed using Microsoft Excel (2016) and Statistix 8.0 software, a commercial software package developed by the United States Department of Agriculture (USDA). It was chosen by a team of Plant Materials scientists based upon several factors. Ease of use and ability to import data from spreadsheets are two of the factors that weighed in heavily during the selection process. It provides almost all of the statistical analysis techniques that the Plant Materials Program will use.

The data were subjected to analysis of variances following a procedure appropriate for the design of the experiment (Gomez and Gomez, 1984).

CHAPTER FOUR

4. RESULTS AND DISCUSSION

The newly developed tractor-drawn tie-ridger was tested in the field to evaluate its performance. Field tests were conducted after the general test. The data collected was analyzed and presented in tables.

4.1. General Test

1) The implement was trailed to the tractor of 40 hp through a three-point linkage.
2) Tightness of nut and bolt was checked and greasing and oiling of moving part was done.
3) The visibility from the operator's position was found good.

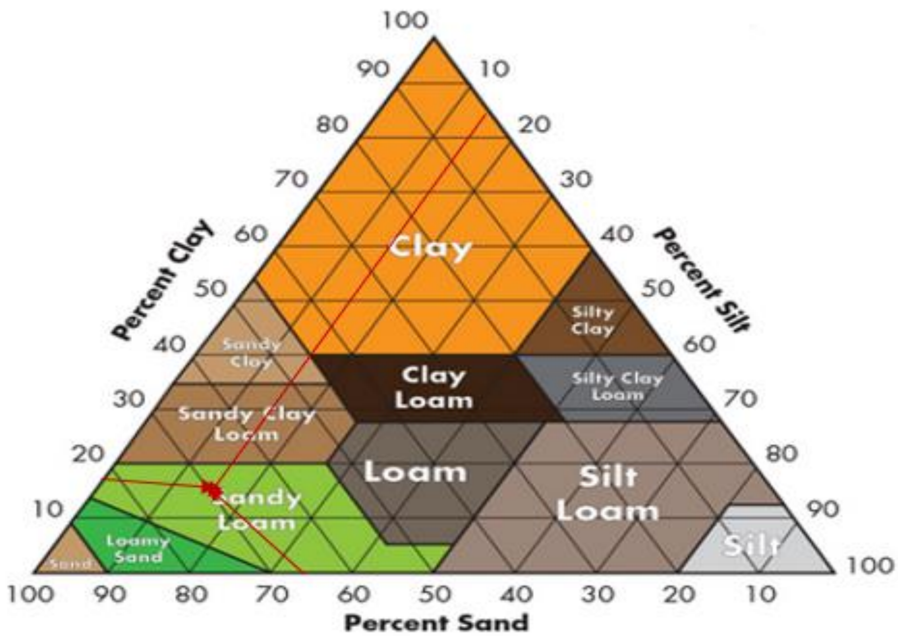
4.2. Physical Properties of Soil from the Experimental Site

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

4.2.1. Type of Soil

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

Figure 4.1. Identify the soil texture of the soil sample



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

Figure 4. 2. Soil classifications

The soil texture of the field was determined by using the hydrometer analysis and results obtained for soil texture was shown in Appendix E. The results are an average of several soil samples taken from the test area. With the different of the site no. each site was considered a test for tie ridger. Site no. which was a sandy-loam soil, all soils fell into the sandy-loam soil category.

4.2.2. Moisture Content and Bulk Density of Soil

The average value of moisture content (dry basis) and bulk density of experimented plot was found 10.23 % (d.b) and 1.134 g/cm^3 respectively. The volume of the core sampler (v) is calculated by using equation (4.2) (Rangapara, 2014).

Figure 4. 3. Measurement of soil bulk density by core sampler

Table 4. 1. Moisture content and bulk density of soil

Observation	Weight of soil sample (gm)	Weight of soil after oven-dried (gm)	Soil moisture content (d.b) %	Volume of core sampler (cm^3)	Bulk density (g/cm^3)
1	613	561.6	9.15	491	1.143
2	596.3	544.5	9.51	491	1.108
3	632.7	572.6	10.49	491	1.166
4	612.1	554.8	10.32	491	1.129
5	615.7	551.3	11.68	491	1.122
Average	613.96	556.96	10.23	491	1.134
S.D	5.1786	4.2806	0.3930		0.00883

The moisture content at 5 different places was found to be 9.15%, 9.51%, 10.49%, 10.32% and

11.68% respectively. The average moisture content of the experimental field was 10.23%. The bulk density of soil was measured by a core sampler. Bulk density of soil was found to be

1.143 g/cm^3, 1.108 g/cm^3, 1.166 g/cm^3, 1.129 g/cm^3 and 1.122 g/cm^3, respectively (Table:4.1). The average bulk density of experimented plot was found 1.134 g/cm^3.

4.3. Field Tests

4.3.1. Description of Field Evaluation

The field was well prepared by performing operations like plowing, harrowing and rotavating. The data of field tests were analyzed to determine the field capacity, field efficiency, fuel consumption and cost of operation, etc. The field performance observation is presented in Table 4.2. The details of the field used for the field test are as follows.

- Type of soil - sandy loam
- Soil moisture content – 10.23 %
- Bulk density - 1.134 g/cm^3
- Depth of tie ridging – 20-25 cm
- Size of each plot – (40 x 80) m^2

4.3.2. Performance Evaluation of Tie Ridger

Field performance evaluations were carried out to obtain actual data on the overall performance of the tie ridge. The field test was done in the experimental farm of Melkassa Agricultural Research Center (MARC). The performance of the tractor-drawn tie ridger in terms of tie ridging, agricultural machine parameters were assessed at different forward speeds of 3.6, 4.3 and 5.0 km/h. During the field performance test, the parameters determined were theoretical field capacity, effective field capacity, field efficiency, wheel slippage and power requirement of tractor operated tie ridger with three replications of each. The detailed data of these tie ridger parameters are given in Appendix D.

Table 4. 2. Mean of measured performance evaluation of tie ridger during field test

Sr. No	Parameters	Operating speed, km/hr		
		3.6	4.3	5.0
1	Fuel consumption, l/hr	5.93	4.68	3.75
2	Draft requirement, kg	101.57	108.20	115.84
3	Power requirement, hp	1.35	1.59	2.09
4	Wheel slip, %	4.17	4.93	5.99

5	Theoretical field capacity, ha/hr	0.79	0.93	1.1
6	Effective field capacity, ha/hr	0.58	0.66	0.77
7	Field efficiency, %	72.78	70.96	70.00

4.3.3. Width of Operation

The width measured center to center of the tie ridges was observed to be 35.88, 33.77 and 33.22 cm during the 1st, 2nd and 3rd trials, respectively. The average width of tie ridge was observed to be 34.29 cm. The length of the tie ridge was on an average of 2.78 m. The average depth of tie ridge was 22.92 cm.

Table 4. 3. Test results of performance evaluation of tractor-drawn tie ridger

Sr. no	Particulars	Values			
		Trial I	Trial II	Trial III	Average
1	Total area covered, m^2	3200	3200	3200	3200
2	Operation time, hr	0.388	0.35	0.33	0.36
3	Time lost, hr	0.16	0.15	0.15	0.15
4	Effective working width, m	1.73	1.70	1.68	1.70
5	Length of tie ridge, m	2.88	2.76	2.72	2.78
6	Width of tie ridge, cm	35.88	33.77	33.22	34.29
7	Depth of tie ridge, cm	21.22	23.55	24	22.92
8	Distance between successive tie ridge, cm	48.33	51.55	52.66	50.84

The distance between two successive tie-ridges was observed to be 48.33, 51.55 and 52.66 cm for the 1st, 2nd and 3rd trials, respectively. The average distance between two successive tie-ridges was 50.84 cm. Thus the basins of an average size of 2.78 m × 34.29 cm were constructed by this tie-ridger.

The analysis of variance (ANOVA) revealed that tie ridger forward speed had a significant effect ($p< 0.05$) on length of tie ridging whereas, it had no significant effect ($p > 0.05$) on depth, distance between successive and width of tie ridging (see Appendix F).

4.3.4. Fuel Consumption

The data stated the effect of the operating speed of tractor 3rd gear on the fuel consumption were determined for the area of 3200 m^2 and are presented in Table 4.4. From field data collected the average fuel consumption was 1.53 lit. for each plot.

Table 4. 4. Fuel consumption

Operating speed	Average fuel consumption to cover 3200 m^2 (lit.)	Average fuel consumption ($lit.hec^{-1}$)
3.6	1.9	5.93
4.3	1.5	4.68
5.0	1.2	3.75
Mean	1.53	4.78
SD	0.16	0.51
CV	10.45	10.66

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

4.3.5. Draft and Power Requirement of Tie Ridger

The data recorded the effect of different speeds on the draft (kg) and power (hp) are presented in Appendix D Table D.3. Draft increased with the increase in operating speed as shown in Table 4.5 and Fig 4.4. The net draft observed were 101.57, 108.20, 115.84 (kg) at forward speeds of 3.6, 4.3 and 5.0 ($km.hr^{-1}$), respectively. As speed increased volume of the soil mass per unit time through the tie ridger was increased and therefore soil resistance was also increased which resulted in draft value. The tractor requires more power at a higher speed to overcome more resistance developed at the tractor and working place.

The data presented in Table:- 4.5 indicates, the operating speed of the tractor significantly affected the draft requirement.

Table 4. 5. Draft and power measurement

Operation speed (km/hr)	Draft (kg)			Power (hp)		
	Load condition	Unload condition	Net draft	Load condition	Unload condition	Net power
3.6	339.68	238.11	101.57	4.52	3.17	1.35
4.3	358.12	249.92	108.20	5.70	3.98	1.72
5.0	369.42	253.58	115.84	6.84	4.69	2.15
Mean	355.74	247.20	108.53	5.68	3.94	1.74
SD	7.07	3.8	3.27	0.54	0.35	0.19
CV	1.98	1.53	3.0	9.50	8.88	10.91

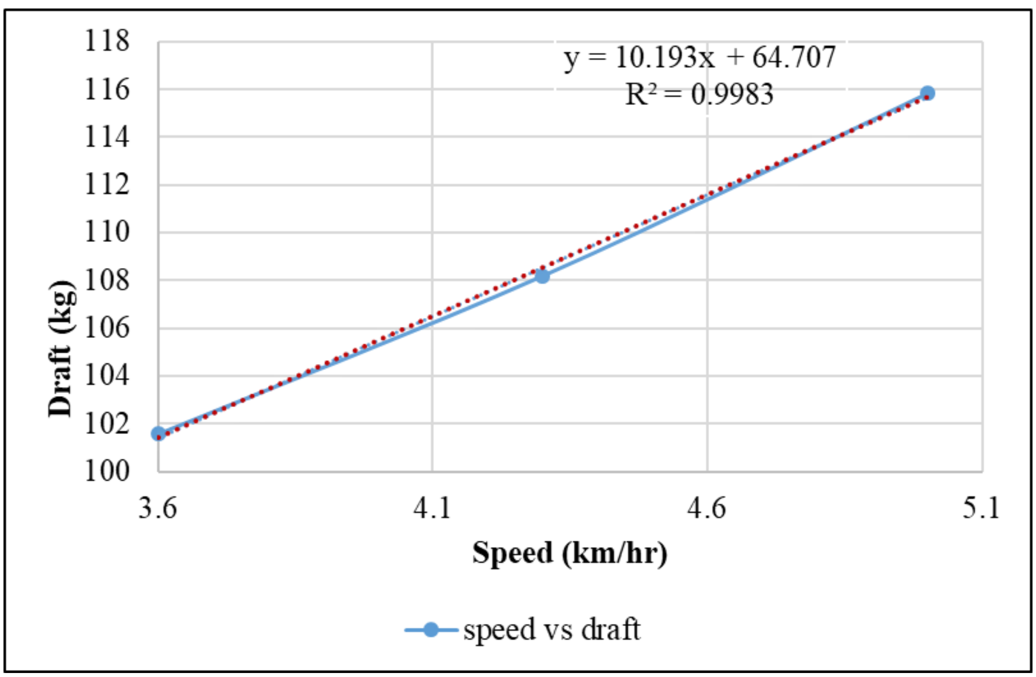


Figure 4. 4. Effect of operating speed on draft

The higher the CV, the less the precision of the experiment for a determined parameter. There was a good correlation between draft and operating speed in all trials, with a high coefficient of determination (R^2= 0.9983) (Fig.4.4).

4.3.6. Time and Labour Requirement

The data concerning the effect of different speeds on the time to cover 1 ha area are presented in Table 4.6. Time consumed by the tie ridger per unit area (ha) decreased as the speed of the operation increased. As speed increased the field capacity increased because at a higher speed more area per unit time was covered hence time per unit area decreased.

Table 4. 6. Time and labour requirement

Operating speed (km/hr)	Time to cover 3200 m^2(sec)	Time to cover 1 hac. (h)	No. of labour
3.6	1,986	1.723	1
4.3	1,745	1.514	1
5.0	1,496	1.298	1
Mean	1,742.33	1.511	1
SD	200.05	0.173	0
CV	11.4	11.4	0

The tie ridger was required one skilled labour for operating. The labour requirement for operation on hectare on the field with tie ridger showed the effect of different speeds on labour requirements. Based on turning time at the headlands, no significant variations among the means of the treatments were observed. It is clear that as speed increases time decreases to cover 1 ha area.

4.3.7. Wheel Slip

The wheel slip of the tractor-drawn tie ridger was determined by using the method mentioned earlier and the results obtained for wheel slip data obtained at different operating speeds was shown in Appendix D Table D.2. The wheel slip increased with an increase in speed. The minimum wheel slips i.e. 4.17 % and maximum wheel slip i.e. 5.99 % was observed at speed of 3.6 km/h and 5 km/h, respectively. Fig: 4.5 shows that the wheel slip increased with an increase in speed.

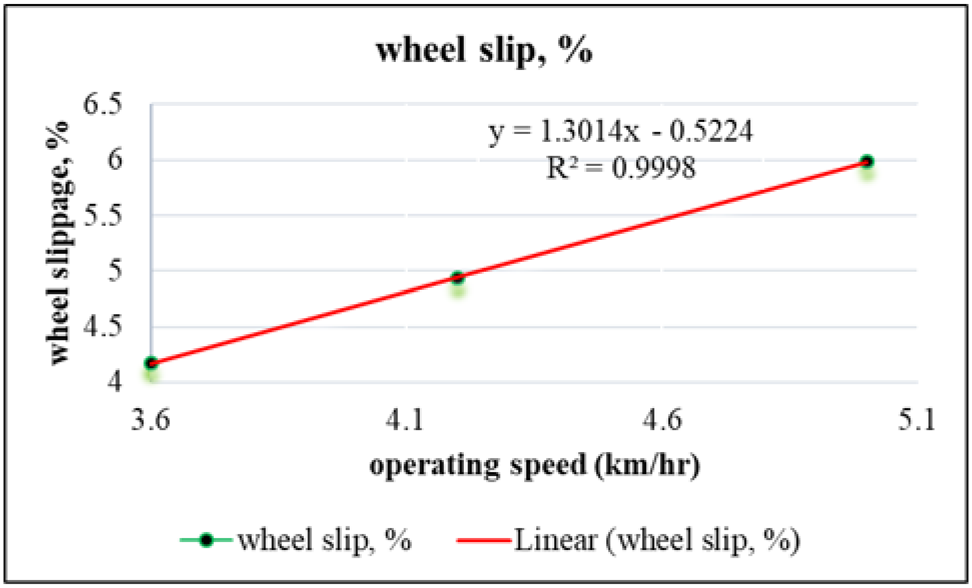


Figure 4. 5. Effect of operating speed on wheel slip

The data showed in Fig 4.5 good correlation between wheel slippage and operating speed in all
trials, with positive and high coefficient of determination (R^2= 0.9998).

4.3.8. Field Capacity and Field Efficiency

The data about the effect of different speeds on the theoretical field capacity, effective field capacity field efficiency to cover 1 ha area is presented in Table 4.7.

Table 4. 7. Theoretical field capacity, effective field capacity and field efficiency

Speed (km. hr^{-1})	Total time required (sec)	Theoretical field capacity (ha. h^{-1})	Effective field capacity (ha.h^{-1})	Field efficiency (%)
3.6	1,986	0.79	0.58	72.78
4.3	1,745	0.93	0.66	70.96
5.0	1,496	1.1	0.77	70.00
Mean	1,742.33	0.94	0.67	71.24
SD	200.05	0.073	0.044	0.66
CV	11.4	7.76	6.6	0.93

Both the theoretical field capacity and effective field capacity were increased as the speed increase.

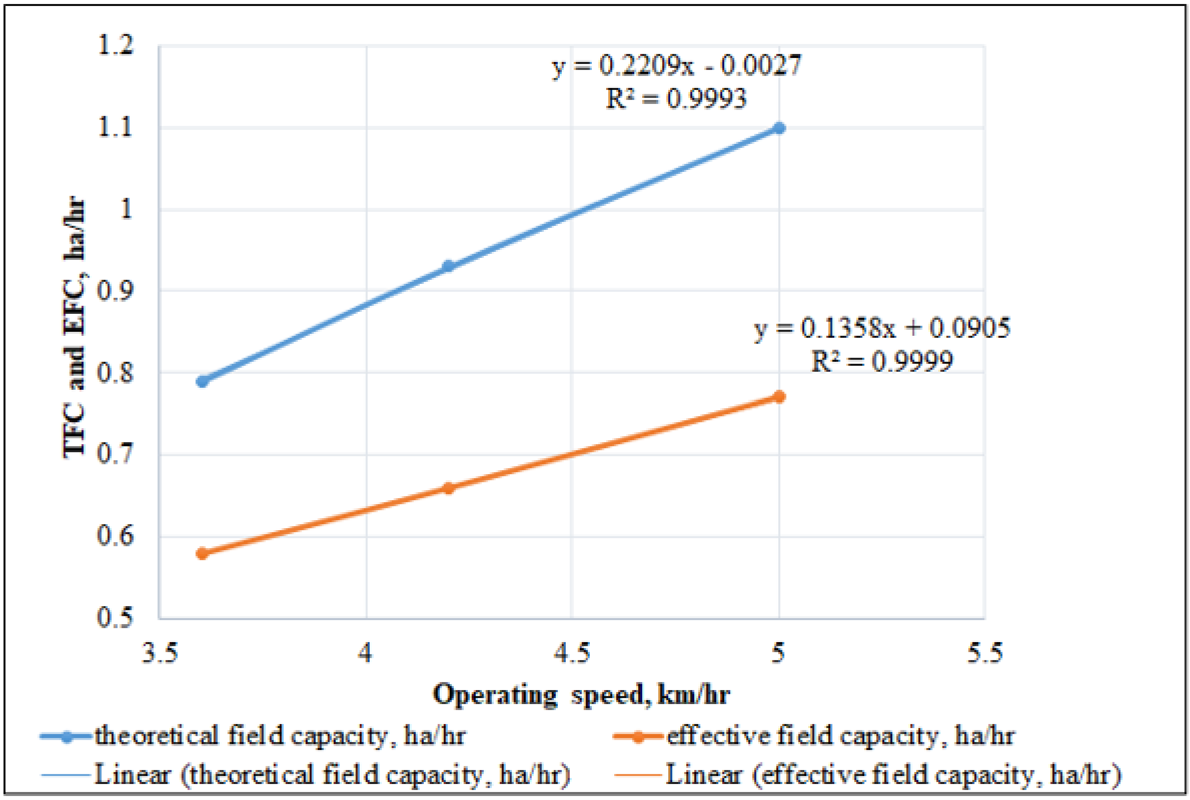


Figure 4. 6. Effect of forward speed on theoretical and effective field capacity

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

The field efficiency test is presented in Table 4.7. The field efficiency was varied from 70.00 to

72.78 (%) at the three speeds. It shows that the average field efficiency to cover 1 ha area was 71.24 % and average effective field capacity of tractor-drawn tie ridger was 0.67 ha.hr^{-1}.

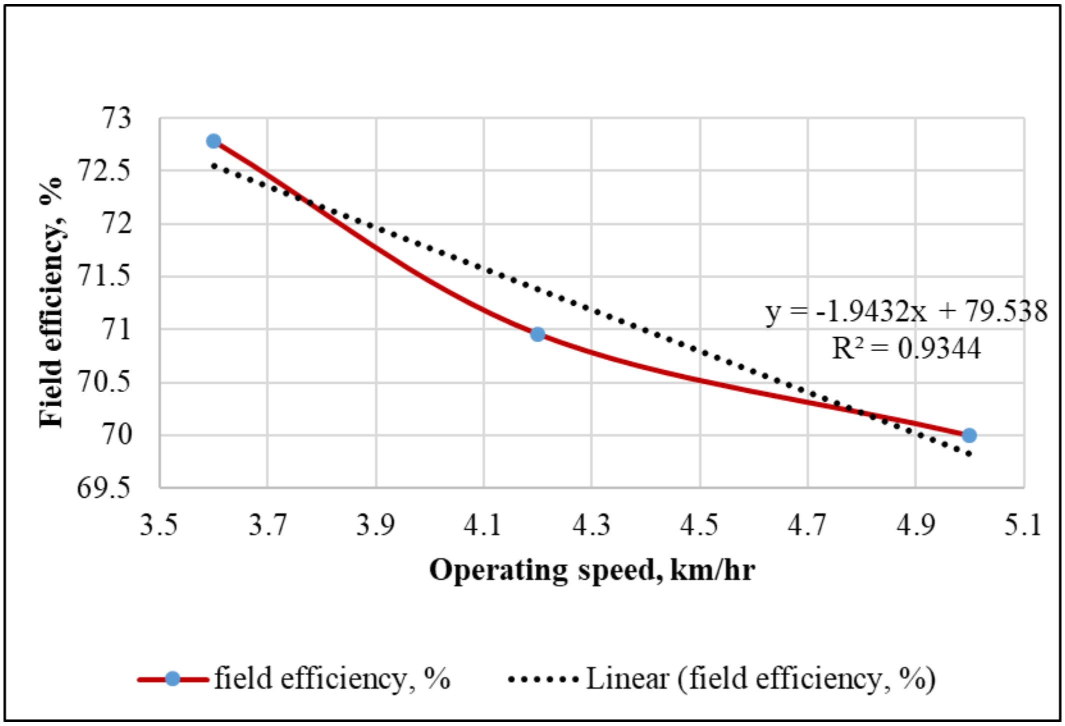


Figure 4. 7. Effect of forward speed on field efficiency

The data showed in Fig 4.7 good correlation between field efficiency and operating speed in all trials, with positive and high coefficient of determination (R^2= 0.9344).

4.3.9. Manual Method of Tie Ridging

An extension program has been launched to promote the use of tie ridging, including the use of a simple, oxen-drawn tie-ridging implement. Farmers are often discouraged from adoption when they see tie-ridging demonstrated in inappropriate situations.

Table 4. 8. The performance of the tie ridger as compared to conventional practice.

Sr. No	Parameters	Units	Tractor drawn tie ridger	Animal drawn tie ridger
1	Effective working width	mm	1,700	537
2	Row to row space	mm	720	Only one row
3	Field efficiency	%	71.24	-
4	Working depth	mm	229.2	162
5	Length of tie ridging	m	2.78	-
6	Effective working width	-	Three rows	One row

4.3.10. Cost Estimation and Cost of Operation

The unit cost of a tractor-drawn tie ridger was determined based on the cost of different components and their fabrication cost as given in Appendix C. The estimated cost of the one unit of tractor-drawn tie ridger was determined as 19,683.45 ETB.

Table 4. 9. Cost summary

No.	Cost variables	Summary
A	Raw materials cost	12,656.6 ETB
B	Machine wastages 2.5 %	316.41 ETB
C	Machine cost	1,964 ETB
D	Labor cost	500 ETB
E	Overhead cost 5% (C+D)	123.02 ETB
F	Profit 10% (A+B+C+D+E)	1,556.02 ETB
G	Sell tax 15%	2,567.40 ETB
	Selling price	19,683.45 ETB

The result showed that the developed tractor drawn tie ridger worked satisfactorily functionally and therefore proposed its use for the tie ridging using a 40 hp tractor.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The tractor-drawn tie ridger was developed for tie ridging operation suitable for medium (model) farmers and its performance was evaluated. The machine was powered by 40 hp YTO tractor. The tie ridger consists of the mainframe, shaft, shank, furrow wing, bearing, hub, spokes and central driving wheel. The field testing of tractor-drawn tie ridger was carried out at the field of MARC. The field was well prepared which was 25 cm depth, firm, fine structure, smooth and level, relatively free of surface trash. In the field test, a tractor-drawn tie ridger was operated at 3rd gear with speed of 3.6, 4.3 and 5.0 km. hr^{-1}.

The tie-ridger was developed and fabricated with care so; that the components were free from cracks and visual defects. The welded joint was not porous. The anti-corrosive and rust preventive paint was applied to each components. The mainframe was made strong enough to support all components fixed on it.

The following conclusions are made from the study.

1. Under normal moisture content (10.23 %) the average wheel slip was observed to be 5.03 % (tractor operated at 3rd gear).
2. The tie ridger can be used to form the tie-ridged basin of 2.78 m × 34.29 cm in size in the prepared field.
3. It formed an average of 34.29 cm width and 22.92 cm depth
4. The average distance between two successive tie-ridges was 50.84 cm.
5. The implement was attached easily to the tractor with the help of a three-point linkage.
6. The average field efficiency (%) and effective field capacity ($ha. hr^{-1}$) were 71.24 and 0.67, respectively.
7. The average draft of 1,063.59 N was required for operating the implement.
8. The average fuel consumption for the tie-ridger was about 4.78 lit.hac^{-1}
9. The average cost of operation was about 220.12 ETB/hr.
10. The cost of fabrication of the tie ridger was estimated at approximately 19,683.45 ETB.

The conclusions revealed that the tractor-drawn tie ridger works satisfactorily and saves time.

5.2. Recommendations

1. The tie ridger is needed to be tested and demonstrated in the farmer's field.
2. Popularization of the new tie ridger technology needs to be made.
3. Systematic, coordinated and relentless efforts are made to get the tie ridger adopted, effectively and efficiently used by the farmers.
4. Rapid adoption of tie-ridging by small-scale farmers requires targeting situations with high probability of beneficial effect.

5.3. Suggestions for Future Work

To make the present equipment 'tractor-drawn tie-ridger' more versatile and to suit it in all respect for its commercialization one should adopt the following suggestion for future work

1. To increase the length of tie ridging, it is a must to have different diameters of the central driving wheel.
2. The tie ridger may be tested for different soils and feedback received may be used for further design refinements, if any.

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APPENDICES

Appendix – A

Table A.1. Specification of tractor drawn tie ridger

Sr. No.	Parameter	Specification
1	Power source	40 hp
2	Overall dimensions	
A.	Length, mm	2160
B.	Width, mm	1550
C.	Height, mm	570
D.	Weight, N	709 N
3	Furrow openers	Shovel type
4	Tie ridge maker	Trapezoidal shape
5	Number of row	Three
6	Row to row space	Adjustable
7	Central driving wheel	Cage wheel type with low sinkage
8	Machine cost	12,656.6 ETB

Appendix B

Material Type and Specification

Table: B.1. Selected types of materials for construction of the prototype tie ridger

No.	Name of part	Materials
1	Frame and toolbar	Mild steel (MS)
2	Central driving wheel	MS
3	Furrow opener	MS
4	Shank	Flat iron
5	Three point linkage	Flat iron
6	Tie ridging part	MS
7	Central driving shaft	MS

Appendix C

Production and operational cost of tie ridger

Table: C1: Materials for constructions of the tie ridger and its cost

No.	Type of material	Standard size	Unit price	Used materials	Total cost (birr)
1	70x50x3mm square pipe hollow	70 x50 x 6000 mm	1500	13,620 mm	3,405
2	Mild steel 6 mm thick	6 x 60 x 6000 mm	2100	120,000 mm^2	700
	Mild steel 8 mm thick	8 x 40 x 6000 mm	2100	249,600 mm^2	2,184
	Mild steel 8 mm thick	8 x 70 x 6000 mm	2100	102,200 mm^2	511
3	Plate 5 mm thick	50 x 1000 x2000 mm	2550	49,500 mm^2	630
4	Angle iron	5 x 60 x 6000 mm	350	1200 mm	420
5	Metal bolt and nut	M- 16 x100	30	24 pcs	720
6	Metal bolt and nut	M-18 x120	30	16 pcs	480
7	Round bar	∅ 10 x 6000 mm	620	2000 mm	206.6
8	Bearing with housing	P 207	800	4	3200
9	Electrodes	∅ 2.5	150	1	150
10	Paint		350	1litre	350
11	Anti – rust		200	1gallon	200
	Subtotal				**12,656.6**

Table: C2. Machine and labor cost

Sr. No.	Type of machine	Machine cost			Labour cost		
		Machine cost/hr	Working hour	cost	Labour cost/hr	Working hour	cost
1	Universal cutting machine	20	12	240	6.25	12	75
2	Welding machine	18	48	864	6.25	48	300
3	Power hack saw	10	16	160	6.25	16	100
4	Lathe machine	25	20	500	6.25	20	125
5	Grinding machine	15	12	180	6.25	12	75
6	Bending machine	10	8	80	6.25	8	50
7	Radial drill machine	15	12	180	6.25	12	75
Subtotal				**1,964 EB**			**500 EB**

Table: C.3. Cost summary

No.	**Cost variables**	**Summary**
A	Raw materials cost	12,656.6 ETB
B	Machine wastages 2.5 %	316.41 ETB
C	Machine cost	1,964 ETB
D	Labor cost	500 ETB
E	Overhead cost 5% (C+D)	123.02 ETB
F	Profit 10% (A+B+C+D+E)	1,556.02 ETB
G	Sell tax 15%	2,567.40 ETB
	Selling price	19,683.45 ETB

C.4. Calculation of operational cost tractor drawn tie ridger machine

Assumptions: Yearly working hour (NAOHT) Number of the annual operational hours of the tie ridger (ETB/h) = 300

Rate of interest, I = 10%

C.4.1. Operational cost of the tie ridger

I. Fixed cost

<u>A) Depreciation (Dp), was calculated as follows:</u>

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

Capital cost, CC = 19,683.45 ETB

Salvage cost, SVC = 10 % x 19,683.45 (considering 10 % of Capital cost)

SVC = 1,968.34 ETB

Assume, Economic Life, EL = 10 years.

$$D_P = \frac{19{,}683.45\ ETB - 1{,}968.34\ ETB}{300X10}$$

$D_P =$ 5.09 ETB/hr

<u>B) Interest on capital (IC), was calculated as follows:</u>

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

$$IC = \left(\frac{19{,}683.45+1{,}968.34}{2}\right) \times \left(\frac{10\ \%}{300}\right)$$

IC = 3.60 ETB/hr

Total fixed cost = DP + IC

Total fixed cost = 5.09 ETB/hr + 3.60 ETB/hr

Total fixed cost = 8.69 ETB/hr

II) Variable cost

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

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

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

LW = 7.5 ETB/hr

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

$CSR = \frac{CC\times 6\%}{NAOHT}$

$CSR = \frac{19{,}683.45\ ETB\times 6\%}{300\ hr}$

$CSR =$ 3.93 ETB/hr

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

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

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

WT = 200 ETB/hr

DTW - Daily Tractor wage (ETB)

DWH - Daily working hours (hr)

Total Variable cost = LW + CRS +WT

Total Variable cost = 7.5 ETB/hr + 3.93 ETB/hr + 200 ETB/hr

Total Variable cost = 211.43 ETB/hr

Total operational cost = Fixed cost + Variable cost

Total operational cost = 8.69 ETB/hr + 211.43 ETB/hr

Total operational cost = 220.12 ETB/hr

Appendix D

Field test

Table: D.1.Tie ridger performance evaluation result on different speed operation

Trip	Speed, km/hr	depth of tie ridge, cm	length of tie ridge, cm	Width of tie ridge, cm	Distance between successive tie ridge, cm	Effective working width, m
		21	295	36	40	170
		22	298	37	41	175
		23	290	42	50	173
	3.6	20	286	34	51	170
		22	283	36	54	180
		22	279	33	51	178
		20	285	36	48	170
		19	294	37	52	168
		22	286	32	48	173
Mean		**21.22**	**288.44**	**35.88**	**48.33**	**173**
		24	273	40	59	182
		23	272	30	52	168
		22	274	37	48	166
		25	277	32	45	165
	4.3	24	272	34	54	176
		24	280	33	55	167
		22	279	32	52	169
		25	282	31	50	172
		23	280	35	49	170
Mean		**23.55**	**276.55**	**33.77**	**51.55**	**170.55**
		25	270	33	54	173
		25	267	37	52	171
		24	274	34	56	170

	22	277	31	53	168
5.0	25	276	30	55	164
	24	272	32	50	168
	22	270	36	49	166
	24	273	34	52	167
	25	269	32	53	170
Mean	**24**	**272**	**33.22**	**52.66**	**168.55**

Table: D.2.Wheel slips percentage determination

Speed, (km/hr).	Sr.No	Distance covered in 10 revolution		Wheel slip, %	Average slip (%)
		Under no load, m	Under load, m		
	1	36.36	34.78	4.34	
3.6	2	36.38	34.85	4.20	4.17
	3	36.24	34.80	3.97	
	1	36.14	34.45	4.67	
4.3	2	36.09	34.25	5.09	4.93
	3	36.17	34.35	5.03	
	1	35.98	33.85	5.93	
5.0	2	35.88	33.65	6.21	5.99
	3	35.80	33.71	5.83	

Determination of slippage of wheel

Wheel slippage (%) was computed by using the formula:

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

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

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

Table D.3. Draft and Power Measurement

Operation speed (km/hr)	Draft (kg)			Power (hp)		
	Load condition	Unload condition	Net draft	Load condition	Unload condition	Net power
	338.39	236.08	102.31	4.51	3.14	1.37
3.6	341.64	239.37	102.27	4.55	3.19	1.36
	339.02	238.88	100.14	4.52	3.18	1.34
Mean	**339.68**	**238.11**	**101.57**	**4.52**	**3.17**	**1.35**
	358.45	249.82	108.63	5.70	3.97	1.73
4.3	361.44	250.03	111.41	5.75	3.98	1.77
	354.49	249.92	104.57	5.64	3.98	1.66
Mean	**358.12**	**249.92**	**108.20**	**5.70**	**3.98**	**1.72**
	370.25	254.17	116.08	6.85	4.70	2.14
5.0	368.37	254.05	114.32	6.82	4.70	2.11
	369.64	252.52	117.12	6.84	4.67	2.16
Mean	**369.42**	**253.58**	**115.84**	**6.84**	**4.69**	**2.15**

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

Appendix E

Calculations of hydrometer soil analysis

Hydrometer correction

(T-20) x 0.36 + H = corrected hydrometer

Sand determination (%)

100 – ((corrected hydrometer at 40sec/ dry weight of soil sample) *100) = % sand in sample

Clay determination (%)

((corrected hydrometer at 6hr 40 sec / dry weight of soil sample)*100) = % clay in sample

Silt determination (%)

100 – (%sand + % silt +%clay) = % silt in sample

Texture

% sand +%silt +%clay = 100

Hydrometer calibration temperature = 20 ℃

Suspension temperature at 40 sec = 21℃

Suspension temperature at 6 hours = 23 ℃

Hydrometer reading at 40 sec = 16, Corrected hydrometer reading = 16 + (1*0.36) = 16.36

Hydrometer reading at 6 hours 40 sec = 8, Corrected hydrometer reading = 8 + (3*0.36) =9.08

% Sand = 100 – ((Corrected hydrometer at 40sec/ dry weight of soil sample) *100)

= 100 – ((16.36 / 50)*100)

= 67 %

% Clay = ((corrected hydrometer at 6hr 40 sec / dry weight of soil sample)*100)

= ((9.08/50)*100)

= 18%

% Silt = 100 – (% sand + +%clay)

= 100 – (67 + 18)

= 15 %

Where, T = temperature

H = hydrometer

Appendix F

Analysis of variance

Table F1. Analysis of variance (RCBD Design) on depth of tie ridging

Source	DF	SS	MS	F	P
Replication	2	13.3294	6.66471		
Treatment	2	0.3198	0.15988	0.24	0.8006
Error	4	2.7188	0.67969		
Total	8	16.3680			

Grand Mean 22.922 CV 3.60

Table F2. Analysis of variance (RCBD Design) on length of tie ridging

Source	DF	SS	MS	F	P
Replication	2	432.439	216.220		
Treatment	2	92.793	46.396	11.71	0.0213
Error	4	15.844	3.961		
Total	8	541.076			

Grand Mean 279.00 CV 0.71

Table F3. Analysis of variance (RCBD Design) on Distance between successive tie ridging

Source	DF	SS	MS	F	P
Replication	2	30.3998	15.1999		
Treatment	2	17.8502	8.9251	1.39	0.3475
Error	4	25.6314	6.4078		
Total	8	73.8813			

Grand Mean 50.849   CV 4.98

Table F4. Analysis of variance (RCBD Design) on Width of tie ridging

Source	DF	SS	MS	F	P
Replication	2	11.8835	5.94173		
Treatment	2	0.6909	0.34543	0.06	0.9387
Error	4	21.4959	5.37397		
Total	8	34.0702			

Grand Mean 34.293   CV 6.76

Appendix- G

Photo graphs of the tie ridger and during manufacturing activities

a) Under fabrication

b) Fully fabricated

c) Field test