DEVELOPMENT AND PERFORMANCE TEST OF MOTORIZED ROTARY WEEDER FOR ROW PLANTED CEREAL CROPS.

By

Beka Adugna Jima

DEPARTMENT OF MECHANICAL SYSTEMS AND VEHICLE ENGINEERING
SCHOOL OF MECHANICAL, CHEMICAL AND MATERIALS ENGINEERING

Thesis

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Agricultural Machinery Engineering

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

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Approval Sheet Paper of Board of Examiners

We, the undersigned, members of the Board of Examiners of the final open defense by Master of Science student Beka Adugna have read and evaluated his thesis entitle "Development and Performance Test of Motorized Rotary Weeder for Row Planted Cereal Crops" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of Master of Science in Agricultural Machinery Engineering.

APPROVAL BY BOARD OF EXAMINERS

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CANDIDATE'S DECLEARTION

This is to certify that the thesis entitled "Development and Performance Test of Motorized Rotary Weeder for Row Planted Cereal Crops" for the partial fulfillment of the requirements for the award of the degree of Master of Science in Agricultural Machinery Engineering is a true record of my own work carried out from March, to November, 2018 under the supervision of Dr. Amana Wako Department of Mechanical Systems and Vehicle Engineering Program, Adama Science and Technology University, Ethiopia.

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

By: Beka Adugna	____________________	____________________
Graduated Student	Signature	Date

ADVISORS DECLEARTION

This is to certify that the Thesis Title "Development and Performance Test of Motorized Rotary Weeder for Row Planted Cereal Crops" submitted in partial fulfillment of the requirements for the degree of Master of Science in Agricultural Machinery Engineering work carried out by Beka Adugna under my guidance and supervision. The candidate is correct to the best of my knowledge. This thesis has been submitted for examination with our approval.

Dr. Amana Wako	____________________	____________________
Major Advisor	Signature	Date

ACKNOWLEDGEMENTS

My foremost appreciation goes to Almighty Jesus Christ who made everything possible. I feel great pleasure to extend my sincere and deepest gratitude my advisor, Dr. Amana Wako, for his continuous support, guidance, creative ideas, thorough correction and suggestions greatly contributed in doing this thesis. In technical and during the preparation of the proposal; head of department of Mechanical Systems and Vehicle Engineering, Mrs. Indris at in SoMCME. Mr. Kamil Ahimed, head of Agricultural Engineering at Oromia Agricultural Research Institution for collaborative to the completion of the write-up of the thesis.

I would like to Acknowledge Asella Agricultural Engineering Research Center manager Mr. Ayelew Bekele and the co-ordinators Mr. Shamseden Abdallah, Mr. Gosa Bekele, Mr. Ashebir, Mr. Girma Lenco and all workers who assisted me in workshop and collect necessary data. Especial thanks to Mr Abdi Jambo for support technical in workshop of assemble the machine and Mr. Wabi and at AAERC and Mr. Shumi at ASTU soil lab (head of field equipment soil lab service department).

I will never forget, the Adama Science and Technology University for providing financial support in the form of scholarships for completing the work and for proving opportunity to carry out my Post Graduate. Also, with my heart full of joy, I also appreciate the support and help of my lovely mum, Birke Kelemu, an inestimable My brothers Takelign Lemma, Bacha Chala, Abebe Nuguise and outstanding who made me to know practically that with Jesus all are possible.

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ACRONYMS

AAERC	Asella Agricultural Engineering Research Center
AISI	American Iron and Steel Institution
ANISA	African Network of Information Society Actors
ANSI	American National Standard Institutions
ASABE	American Society Agricultural Biosystem Engineering
ASME	America Society of Mechanical Engineering
ASTM	American Society for Testing and Materials
ASTU	Adama Science and Technology University
BD	Bulk Density
BWC	Biological Weed Control
DAS	Day after sowing
CCW	Chemical Control Weed
FAE	Faculty of Agricultural Engineering
FAO	Food and Agriculture Organization
GTP	Growth and Transformation Plan
MC	Moisture Content
MRW	Motorized Rotary weeder
MWC	Mechanical Weed Control
MOA	Minister of Agriculture
MS	Microsoft
MSVE	Mechanical Systems and Vehicle Engineering
OARI	Oromia Agricultural Research Institution
RCBD	Randomize Complete Block Design
SR	Soil Resistance
SoMCME	School of Mechanical, Chemical and Material Engineering
WC	Weed Control
WCP	Weed Control Program

ABSTRACT

Weeds tend to reduced yields due to infestation, related to deterioration the quality of crops. Weeding with manual is labor intensive, time consumption and Chemical Control Weeding method also effect on environment pollution and kill specific species of weeds. The main objective of this study are to design, develop and test Motorized Rotary Weeder to remove weeds from row planted crops at desired depth and spacing. To attain predetermined design, the procedure started from gathering information about weed and continuous withstanding the properties of weeds of the crops, the weeder prototype would have been designed using AUTOCAD and (CATIA V5R20. The light weight three row Motorized Rotary Weeder has overall dimension 1230mm×560mm×900mm and the width of coverage of weeder is 60cm of the three rows in each 20cm spacing and depth of operation can be adjusted 2.5-3cm. After designed and constructed, the machine was tested for weed control in seedbed wheat crops at 20 DAS compared with traditional, CCW and in different travel speed with three different treatments for check the performance at AAERC field. The data recorded from the experimented would have been subjected the analysis of using MS. Excel, statistics R-software determined the profitability results of field performance. The results of field performance evaluation observed 0.224 ha/hr field capacity, 0.086 ha/hr effective field capacity, 94.7% weeding efficiency, 86% field efficiency and 10% decreasing crops damages of the motorized rotary weeder were respectively at soil moisture content 28% Wb. and 1390 kg/m^3 bulk density. The cost of operation 254 Birr per hectare and energy consumption 262.94 MJ/hr with MR weeder during 2.3 km/h operating travel speed. The power required to operating the weeding in the field found 2.63hp. the wheel slip was 6.84% occurred. Also, when it compared with manual weeding and CCW the theoretical field capacity 0.046ha/hr, 2.85ha/h, 0.086 ha/hr, effective field capacity 0.035 ha/hr, 2.56 ha/hr, 0.074 ha/hr and field efficiency 76%, 90%, 86% manual weeding, CCW and MRW respectively was observed. From the above observation that the machine works satisfactorily for weeding at 20 DAS.

CHAPTER ONE

1. INTRODUCTION

Weed control is one of the most difficult tasks in agriculture that accounts for a considerable share of the cost involved in agriculture production. For land preparation, the limit is due primarily to the intensity of the energy demand, whereas for weed control; the duration of demand is likely to be more restricted. Weeds were therefore one of the most important crop production constraints in field crops during growth. It's is unwanted plants growing in crops and competing with them for nutrients, water, space, light and etc. parish (1990). Farmers generally expressed their concern for the effective weed control measures to arrest the growth and propagation of weeds.

According to Lavabre (1991) Some weeds have beneficial uses but not usually when they are growing among crops. Factors weeds influencing crop production can be divided into three groups. Firstly, yield-defining factors such as radiation; secondly, yield-limiting factors which include soil moisture, nutrient availability and length of growing season; and thirdly, yield-reducing factors which encompass disease and insects.

Other side losses may be incurred through increased harvest cost. The presence of immature weeds (green materials) at harvest will result in the crop having to be swathing rather than straight-combined and potentially the rate of swathing could be reduced. Increased dockage, storage and transportation costs results from weed seeds in the grain, and weed seeds in the soil can result in increased future tillage and weed control costs. The greatest single cause economic loss.

The next GTP, for the years of 2015-2020 GC, will emphasize improved practices, including mechanization, to bring about value addition to agricultural output. The Government will also work further to ensure that farmers are given sufficient access and support to utilize these practices, an effective enabling environment to support their operation and ability to develop and supply such mechanized technologies for farmers. Through the technical development of mechanisms for physical weed control, it might be possible to control weeds in a way that meets consumer and environmental demands (Aditya *et al*., 2016).

1.1. Background and Justification

Weeds have major pests in crops based on cropping systems. Weeding is the removal of unwanted plants in the field crops. So, it done either manually or using simple hand hoe. Timelines operation is one of the most important factors which can only be achieved if appropriate uses of agricultural machines are made.

From whatever beginning, or significance weeds may have had for the primitive farmer, they have become one of the serious economic losses which confront the farmers of Ethiopian nation, and other nations. In storage of wheat, barley and other cereal crops the observable many problems and farmers in Ethiopia commonly lose up to 40% of their crops because of weed infestations. Because crops are not normally planted in rows, weeding is time consuming task, taking up to 140 h/ha (Starkey,2000).

Among the most difficult to manage grass weeds in cereals crops and root vegetable crops-based cropping systems are downy brome (Bromus tectorum), jointed goatgrass (Aegilops cylindrical), feral rye (secale cereal), ryegrass species (lolium spp), cheat (Bromus secalinus), Cyperus rotundus, Snowdenia polystachya (muja), Agremona mexicanu, wild oat (Avena fatua), rattail fescue (vulpia myuros) and ripgut brome (Bromus diandrus). These weeds thrive due to their biological similarities to the crops and existence, for several species, of herbicide-resistant biotype. (Yenish, 2004).

The selection and spread of herbicide-resistant weed biotypes, including several species exhibiting multiple-herbicide resistance. Those are predominant broadleaf weed species in wheat, barley and oat include: Russian thistle (salsola tragus) Canada thistle (cirsium arvensis) kochia (Thlaspi arvense), prickly lettuce (lactuca serriola), Bromus pectinatus gench mavilo, and wild mustard (brassica kaber), among others. With available herbicides, producers have been able to control these broadleaf weeds and avoid extensive yield loss. But Weeds were in what ever it the most important crop production constraints in field crops during growth. It’s is unwanted plants growing in crops and competing with them for nutrients, water, space, light and etc. parish (1990).

There are several methods that can be used for weed control. Manual weed control is a method using bare hands or handheld tools to uproot weeds, while MWC involves the use of machines to perform weed control. Chemical weeding uses herbicides to control weeds, and Bological Weed Control applies other organisms for weed control. In Ethiopia still, weeding with simple toolssuch as sickle, hand hoes, cutlass and etc. is labor intensive and time consuming; and using chemical which effect on environment (Helweg, 2003).

Mechanical Weed Control is very effective as it helps to reduce drudgery involved in manual weeding. It kills the weeds and also keeps the soil surface loose ensuring soil aeration and water intake capacity. For these reasons, it should be necessary the developing convenient and practical motorized rotary weeder machine using simple implements and tools for the farmers are turning to Mechanical Weed Control is favorable. A compressive understanding of environmental and management factors conditioning structure among scientists to ensure that cereals crops (wheat, barley) and per preparation for vegetables crops seedbeds.The dense weed infestation still results in significant losses in crop yield, crop quality and harvesting efficiency.

The maximum rate of working expected from the farmers would be applied rather inefficiently through the use of a simple hand tools, typically hoes of various designs; although cultivating had been associated with a lower power demand than land preparation, the time available may be inadequate to complete the task. This contributes to the drudgery of long hours of cultivating, a burden borne mainly by women who must accommodate cultivating within their schedule of domestic tasks (Ahmed, 2014).

1.2. Statement of the Problem

In general, weed management methods in crops have been done by manual weeding using by hand tools and chemical control using herbicides in overall crops weeding area of Ethiopia.

This resulted to: -

- Low yield of crops per hectare and high cost and time consuming for labor in case of manual weeding also during pre-emergence seedbed preparation.
- kill specific species of weed such as broadleaf weeds and it not use for the weed that have same species with grass in case of chemical control.
- CCW has an effect on animal and human being. It has consequence like cancer disease, environmental air pollution or global warming, soil erosion and increase soil acidity and salinity of soil.
- Weeding with the use of tools like sickle and hoe requires high labor force and injure quite a lot of money hence mechanical operated weeder is necessary to reduce the labor force.

Environmental degradation and pollution caused by chemical is reduced and low effective operation, low work effort and high time requirement for different types of hoe or sickle, can be overcome with the use of motorized rotary weeder machines.

1.3. Objective

1.3.1. General Objective

The main objectives of this study are to design, develop and evaluated a motorized rotary weeder machine.

1.3.2. Specific Objectives

- To design and develop a motorized rotary blade weeder for specific cereals crops.
- To evaluate the performance of the machines.
- Economic analysis of developed weeder and test in the field.

1.4. Significant of Study

To play a significant role in seed quality production, safe labor power and cost for agronomic and fee flow for herbicides using mechanical control method MR weeder is more prefer. The end goal of this initiative is to ensure seed utilization and change in productivity of farm land of smaller holders in the region. Weed Control Program is best viewed as part of an overall restoration program, so focus on what you want in place of the weed, the time when it going on, how to perform rather than simply eliminating the weed.

1.5. Scope of the Study

The farmers have start using mechanical techniques to control weed. The only difference is that instead of using conventional methods i.e. manual operation of the system farmers have to be started using motorized rotary weeder machines to achieve the goal.

CHAPTER-TWO

2. REVIEW OF LITERATURE

In this chapter, the comprehensive review of the research work done by various research workers relevant to the present study is presented and summarized under the following subheadings.

2.1. Weeds

Weeds are nothing but those unnecessary plants which are grow with the crop and they compete with the main crop growth for utilization of land, light, nutrients and water. The weed competition in direct seeded cereals crops were maximum during the first three weeks' period. The weed growth is generally vigorous and cause loss of yields. For the controlling of weed it is essential to know about the weeds for the experimental study to Agrawal and (Singh, 1968) listed the common weeds of agricultural land with their scientific and common names**.** Biswas (1984) reviewed and reported about weeds in Bhopal region. Weeds classified in different ways as per their place of occurrence or habitat, duration of life cycle, plant family etc. As per the occurrence weeds may be classified in two broad group 6**:**Upland weeds may further be classified as: Weeds of Agricultural land, Weeds of Pasteur land, Forests weeds and Weeds of wasteland. The Aquatic weeds may be Classified as: Fresh water weeds and Marine water weeds. As per the life cycle, weeds may be classified as**:** Annual weeds, Biennial weeds and Perennial weeds.

2.2. Losses Due to Weeds

It is observed that due to weeds there is a reduction in green production resulting heavy economic losses. There are many studies have been carried out to access the losses. It differs region to region and also depends on several other factors including cultivation practices adopted. Smith (1961) reported that the weed competition is a serious problem in almost all rainy seasons' crops causing the losses in yield ranging from 9 to 60 per cent or more. Weeds decrease crop yields from 15 to 50% depending on species, density and weeding time through competition with main crop for light, water and nutrition (Hasanuzzaman, 2009). It was accounted that losses due to weeds in main crops are more than 40 million tons per year (Singh and Sahay,2001).

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2.3. Methods of Weed Control

Weed management is a multi-dimensional regime and cannot be achieved by focusing on a single approach (Bajwa, 2014). It is a strategy that makes a desired plant population successful in a particular agro ecosystem using knowledge of the ecology of the undesired plants that is the weeds Håkansson, (2003). The most effective method of weed management is by making physical contact with the weeds themselves, which is weed control. Currently, there are several ways of controlling weeds, either by using manual, chemical, mechanical or biological means.

2.3.1 Hand Weeding Control Method

Hand weeding is very popular in cereals crops. In this method the weeds are uprooted by the hands. It requires extra labor force for a farmer, consumes more time and leads to high weeding cost; this resulted a low field capacity to these traditional implements. The complicated operation of weeding is usually performed manually with the use of traditional hand tools in upright bending posture, inducing back pain for majority of laborers. An estimate of 400-600-man hours per hectare is the normal man-hour required for hand weeding which amounts to 2200 per hectare, which also depends upon weed infestation. Availability of labor is also a main challenge in weeding operation (Raut et al., 2013).

Datta et al. (1974) reported that the weeding is traditionally carried out with indigenous hand tools. These involve considerable time and labors. In single hand weeding the labor requirement is as high as 300 - 1200 man- h/ha. Availability of labors required during peak seasons of the year is a problem. Patel and Pandey (1983) reported that the hand weeding treatment was superior to chemical method of weed control in direct seeded upland paddy.

2.3.2. Chemical Weed Control Method

Chemical weed control is a weed control using chemical (herbicides). It is now extensively and intensively used. Some advantages of chemical weed control are the low labor requirement, easy to apply, can be applied on broadcasted crop, and highly effectiveness in killing weed. Fagade (1980) reported that the cost of herbicide application for weed control was half than that of hand weeding.

2.3.3. Mechanical Weed Control Method

A mechanical device to remove the weeds from an agricultural land is known as weeder. There are various types of weeders which can be used for mechanical weeding in row sown cereals crops. They are effective in controlling weeds as well as they benefit the crop by breaking up the surface crust, aeration of soil, stimulating the activity of soil micro flora, reducing the evaporation of soil moisture and facilitating the infiltration of rainwater, manipulate the crop root zone reducing plant mortality, enhance root and shoot growth, reduces time requirements and human effort.

This method of weed control is simple, easily operas able and mostly done by human labours, animal drawn or tractor drawn weeders and self-propelled weeders or power weeders. Manual and bullock drawn mechanical weeder are friendly to environment. It is not only the most important method used in controlling weeds but also the most economic and recommended method on pollution point of view of the environment. The mechanical weeders are also reported to be economical than chemical and other methods (Singh *et al*., 2001 and Bhardwaj, 2004).

Biswas (1999) reported that, the animal drawn weeder works between crop row spacing, the weeds left over a long row may be removed manually. The straight blades in traditional hoes tend to remove weeds up to the working width of the blades. However, due to clogging of the straight edges, the output is adversely affected.

Balachand (2006) designed and developed an animal drawn weeder considering the functional requirements and its required strength to bear soil forces acting on it. Manual weeder: small tools or aids, chopping hoes, pull type hoes, Push type weeder and Push pull weeder. The serrated blade of different sizes may be fitted in to the traditional blade hoe or blade harrow (cheki). The serrated blades easily penetrate into the soil and help in moisture conservation. Power operated weeder (A Motorized rotary weeder).

2.4. Timelines in Weeding

According to (Nabibagh *et al.*,2009) the wheel hoes are operated between the crop rows by push action. Rotate the handle of clamp adjustment assembly anticlockwise and free the shank of the rotary hoes in the clamp.

The tip of the blade should be about 20-25mm below wheel line thus the blade will cut or uproot the weed at a depth of 25mm. The depth of rotary hoes may be adjusted according to soil conditions and weed infestations. Force required to push the wheel hoe depends on depth of operation. But it required labor intensive.

2.5. Power Requirement

Aditya *et al*., (2016) studied soil resistance has a considerable effect upon the power requirement of weeder. Also, width of cut and speed of operation influences power requirement of weeder. For calculating power requirement of the weeder, maximum soil resistance was taken as 0.5 kgf/cm2. The speed of operation of the weeder was considered as 0.7 $\frac{m}{s}$ to 1.0 $\frac{m}{s}$. Total width of coverage of cutting blades was in the range of 12 to 30 cm. The depth of operation was considered as 5 to 8 cm; transmission efficiency is 82%.

Tajuddin (2006) developed engine operated blade harrow for weeding. They observed weeding efficiency of the equipment at 15 degrees, 25 degrees and 35-degree blade angles, 200,300, 350- and 450-mm blade widths and 30, 40 and 50mm depth of operation. It was noticed that as the blade angle increased weeding efficiency is also increased. Draught of the blade harrow increased with increase in depth of operation. However, the rate of the increase of the unit draught watt found to be decrease with increasing depth of operation.

Nkakini *et al*. (2010) designed and fabricated a rotor-weeder powered with 1.4 hp petrol engine and compared the field performance with the traditional manual hand hoe. The weeder consists of main frame, handle, rotary blades, shaft, sprocket and chain, chassis, cutting depth hint rear cutting depth adjuster, wooden engine seating, engine and ground wheel. Theoretical field capacity of the rotor weeder was 0.47 ha/h with an effective field capacity 0.34 ha/h which was approximately twenty times that of manual weeding. The performance index was 1,700 and fuel consumption was 3.2 l/day. Weeding efficiency of rotor weeder was 71% for removing shallow-rooted weeds.

Ojomo *et al*., (2012) conducted a study on machine performance parameters by developing and evaluating a motorized weeding machine for the effect of moisture content (10%, 13% and 16%) and the type of cutting blades (Flat blade, spike tooth blade and curved blade) on the machine efficiency, quality performance efficiency, per centage of uprooted weeds and percentage of partially uprooted weeds. At 16% soil MC, the spike tooth blades gave the best machine efficiency by 94%, quality performance efficiency by 84%, percentage of uprooted weeds by 2.8% and least percentage of partially uprooted weeds by 1.8%.

A cultivator is a machine used for MW control that is dragged behind a tractor and dislodges weeds by breaking up the surface of the soil with hoes. For centuries, farmers have pulled weeds by long wheeled handle or used hoes to cut them from the ground (Silas,2015). The twin wheel hoe is useful for cutting and uprooting of weeds, breaking soil crust and creating soil mulch. For getting optimum results, the soil MC may be around 22-25% or soil is in friable condition so that soil does not stick to the rotary hoes. The weeds may not be more than 30 days old in the field and should be in tender stage. The wheel hoes are operated between the crop rows by push and pull action.

Rotate the handle of clamp adjustment assembly anticlockwise and free the shank of the rotary hoes in the clamp. The tip of the blade should be about 20-25mm below wheel line thus the blade will cut or uproot the weed at a depth of 25mm. The depth of rotary hoes may be adjusted according to soil conditions and weed infestations. Force required to push the wheel hoe depends on depth of operation. But it required labor intensive (Nabibagh *et al*.,2009).

CHAPTER THREE

3. MATERIALS AND METHODS

Development and Performance Test of a Motorized Rotary Weeder for Row Planted Cereal Crops at the Department of MSVE in the program of Agricultural Machinery Engineering, SoMCME, Adama Science and Technology University. Fabrication and testing of the prototype was carried out at AAERC in agricultural machinery research process workshop. Testing of the weeder was carried out at Asella research trial field. The site has a suitable land and summary rain system. It has also the availability of well-organized technician and labor access for the fabrication and testing of the prototype.

3.1. Study Area Description

Construction and performance evaluation of the prototype weeder should be conducted at AAERI which is geographically located in Ethiopia, Oromia Region around 76-km south of Adama. It is found at an altitude of 2,430 m above sea level and lies on the geographical coordinates of 7° 57' 0'' N Latitude and 39° 7' 0'' E Longitude showed in (Figure 3.1)

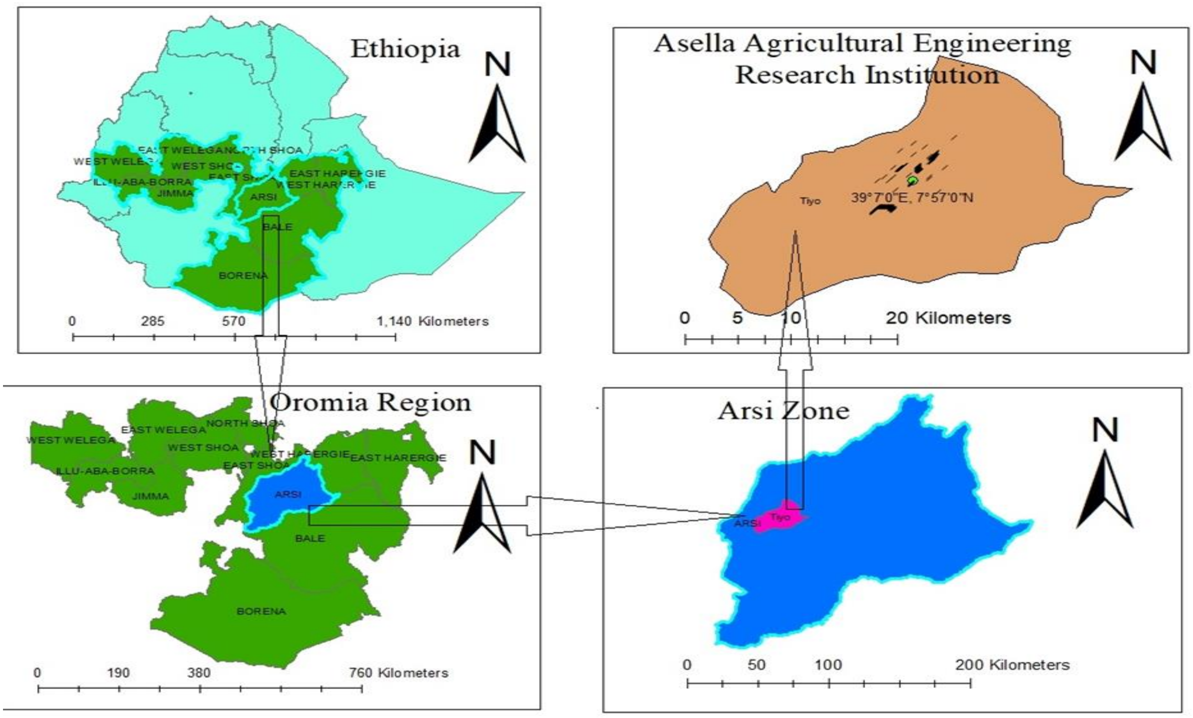


Figure 3.1. Location of the Site of Study Area with Reference Oromia AAERC.

3.1.1. Climatic Conditions

The general climate of this region is dry moist, sub humid and it has a highly variable rainfall that ranges between 1300 and 1350 mm annually. The dominant soil type in the area is sandy clay loam. Because of its agro-climatic condition, most varieties of cereals (wheat, barley, oat) crop and root, bulb (garlic, onion) vegetables grow well in the area. The performance of the develop weeder is to evaluate in the AAERC farm where the soils of the site belong to the sandy clay loam with good moisture retention and infiltration rate.

3.2. Design Consideration

3.2. 1. Design Concept

Several concepts were considered for the mechanism to perform weed control. The designed requirements for choosing the weeding mechanism were:

a) An effective weeding mechanism was able to uproot, bury, cut weeds and mulch weeds with soil at the same time.

b) The working diameter of the weeding mechanism should be as small as possible to operate within the crop row.

c) The weeding mechanism should not be required to work at a depth more than 3cm because early growth stage weeds have not penetrated deeply into the soil in cereals crops.

3.2.2. Existed Materials Before Design Consideration

3.2.2.1. Power Unit

The assumptions made in the design of the motorized rotary weeder are presented in terms of fieldconditions, machine capacity and energy requirement required to power it (Victor *et al*., 2003). The machine was powered by a 5hp internal combustion engine. The technical specifications of the engine are shown in Table 3.1

Table 3.1: Technical Specifications of the Engine Model Gx-140

S.N.	Particular	Specification
1	Dimension	315 mm× 355 mm × 335 mm
2	Bore	64 mm
3	Displacement	144 cc
4	Compression ratio	7.8:1
5	Fuel	Unleaded gasoline (octane No. 86)
6	Fuel tank capacity	3.6 litre or 0.7 gal.
7	Ignition system	Transistorized magneto ignition
8	Starter	Recoil starter
9	Net power	5 hp (3.6 kw) at 4000 rpm
10	Rated power	4.7 hp
11	Max. torques	$1.04\frac{kg}{m}$ / 2800 rpm (9.8 N.m)
12	PTO shaft rotation	Counter clock wise
13	PTO shaft	Key way or internal
14	Air cleaner	Sem dry
15	Lubrication oil capacity	0.5 litre
16	Stroke	45 mm
17	Dry weight	14 kg (30.9 lb)

3.2.2.2. Chain and Sprocket

Chain and sprocket were purchased from local market considered their matching pitch point and power transmit capacity with each other. Appendix C1 and C2

3.2.2.3. Gear Box

The bevel Gear box is used to change the direction of motion by 90˚ and reduced the speed. It was purchased from local market. No designing was performed for gear box. Gear box encompassed transmission units. shaft on the one end and it has a reduction of 4:1. Suitable nuts and bolts are used for fastening the gear box to main frame which can be removed when repair and maintenance is required. The figure shown in appendix

3.2.2.4. Engaging and Disengaging Unit

Clutches was purchased from local market by Asella Agricultural Engineering Research Institution. The aim of clutches in (Fig.3.3) to engage and disengage the rotary power drive by engine commanded by the controller. In this machine member used to connect the driving shaft which transmit power from engine to a driven rotary blade shaft provide by middle shaft, so that the driven shaft may be started or stopped at will, without stopping the engine power. A clutch thus provides an interruptible connection between two rotating shafts Clutches allow a high inertia load to be stated with a small power.

A popularly known application of clutch is in motorized rotary weeder where it is used to connect the engine and the wheel shaft and rotary blade shaft within sprocket and chain system. Here the clutch enables to crank and start the engine engaging the transmission and Disengage the transmission by change the mash direction in to lock direction to alter the torque on the wheels and rotary blade shaft.

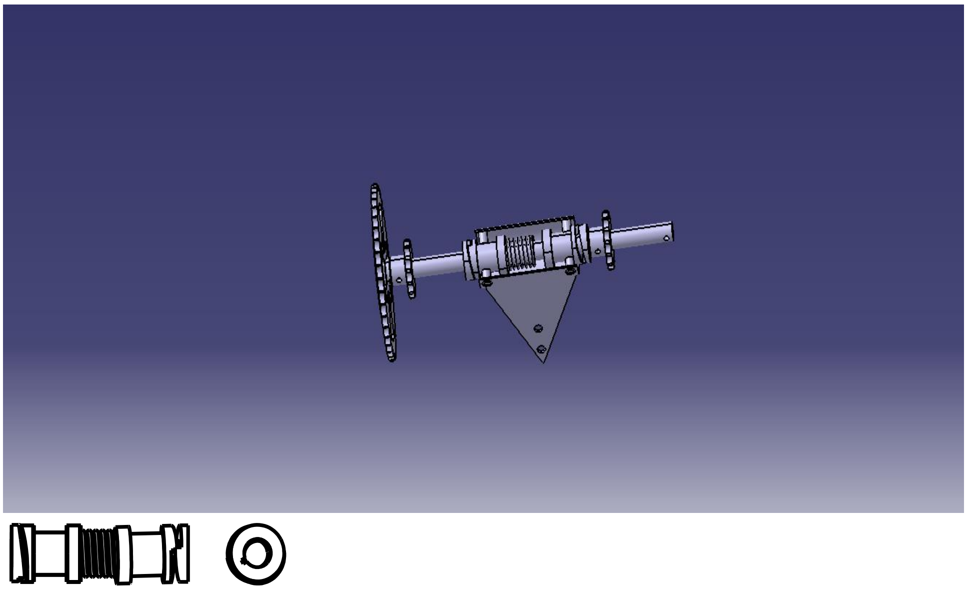


Fig. 3.2. Clutches

3.3. Materials Needed

The motorized rotary weeder designed and constructed the raw material which simple available in market and in our environment, which were considered the social economic balanced.

Table 3.2. Materials what need with specific dimension

S. N	Particular	Materials	Size	No. unit	Length	Width	Thickness
1	Sprocket	Cast Iron	Ø 180 mm	1			7mm
2	Sprocket		Ø 65 mm	4			7mm
3	Sprocket		Ø 200 mm	2			7mm
4	Chain	Standard	13mm, pitch	1	standard	standard	
5	Bearing	Chrome alloy steel	62.02 and 64.05	9			15cm
6	Bush	M.S	25 mm		10cm		2.5mm
7	Nut, bolt& washer	M.S	Kg	75g	standard		
8	Extension bolt	M.S	Ø 18 mm	1	355 mm		
9	Axle shaft	M.S rod	Ø 20 mm	1	560mm		
10	Rotary shaft	M.S	Ø 18 mm	1	500 mm		
11	Handle	M.S pipe	25 mm	2 kg			2mm
12	Chain	Standard	19 mm pitch	3			
13	Clutches	M.S	Standard	1			
14	Middle shaft	M.S rod	Ø 20 mm	1	400 mm		
.15	Sank	M.S flat	5 mm×50 mm	2		50 mm	5 mm
16	Blade	M.S flat	5 mm×30 mm	12		25 mm	5 mm
17	Engine	5 hp	14 kg	1	38 mm	30 mm	34 mm
18	Frame	Angle iron metal	6 m×30mm×50 mm	1			
19	Gear box		Reduction 4:1	1			

3.3.1. A CATIA Software Weight Determination Output of each Components

Table 3.3. A CATIA Software Weight Determination Output Analysis for each Component of Motorized Rotary Weeder

S. No.	Component	Quantity	Area(m^2)	Volume (m^3)	Unit off mass (Kg)	Total mass (kg)	Density (kg/m^3)
1	Frame	1	.1592	.000477	2.36	2.36	4947.58
2	Wheel	2	.271	.000814	0.6	1.2	1474.2
3	Engine	1	.1023	.035	14	14	400
4	Gear box	1	.88	.00352	1.02	1.02	289.77
5	Shaft	3	.0964	.000964	0.5	1.4	1452.28
6	Blade	12	.054	.00027	0.102	1.224	4533.33
7	Sank	2	.043	.000301	0.36	0.72	2392.02
8	Handle	2	.0048	.00000048	0.12	0.24	510638.3
9	Chain	3	.02333	.0001633	0.68	1.94	11879.97
10	Sprocket	6	1.95	.01363	0.42	1.244	91.269
11	Safe guard	2	.224	.000456	0.103	0.206	451.75
12	Adjuster	1	.06	.00006	0.12	0.12	2000
13	Wheel of adjuster	1	.12	.00045	1.2	1.2	2666.667
14	Clutches	1	.35	.00345	1.78	1.78	515.94
15	Clutches handle	1	.038	.00067	.37	0.37	552.238
16	Engine set	1	.034	.000102	0.21	0.21	2058.82
17	Bolts and nuts	46	.57	.00228	0.0508	2.34	1026.32
18	Spokes	20	.78	.0045	0.029	0.58	128.88
	Bearing	9	.23	.0065	0.1167	1.05	161.54
20	Hub	3	.089	.00071	0.25	0.25	352.113
The total weight						33.454	548012.987

The weight of machine without including wheel ground, shaft of wheel ground and wheel of adjuster = 30.554 kg. The total weight Taking 2% margins for the weights of welding bolts, nuts, chains, etc. the total weight was found to be 334.48 N.

3.4. Methods

3.4. 1. General Design Consideration

The development of weeder was initiated with considering the condition of field & soil, weed and crop by keeping in mind the various agronomical requirement of crop like spacing of crop and height of the crop from the ground level.

The soil parameters like soil type, moisture, bulk density and cone index influencing mechanical weeding of different crops were identified and measured.

3.4.1.1. Power Requirement

Soil resistance, width of cut and speed of operation has a considerable effect on the power requirement of weeder. For calculating power requirement of the weeder, maximum soil resistance was taken as 0.75 $^{\mathbf{kgf}}/_{\mathbf{cm^2}}$ The speed of operation of the weeder was considered as 0.65 m/s to 1.0 m/s. Total width of coverage of cutting blades was 60 cm. The depth of operation was considered as 2 to 3 cm; transmission efficiency is 82%. The power required is calculated by following formula.

$$p = \frac{SR \times d \times w \times v}{75} \times \eta \quad \text{.......} \quad (3.1)$$

Where: P = is power requirement in HP,

SR = is soil resistance (0.75 kgf/cm^2),

d = depth of cut (2.5 cm),

w = is effective width of cut (37.5 cm),

v = is speed of operation (2.3 km/hr) and

η = is transmission efficiency (82%).

Hence, power requirement is estimated as

$$p = \frac{0.75 \times 2.5 \times 37.5 \times 2.3}{75} \times \frac{1}{0.82} = 2.63\text{hp} = (2\text{kw})$$

Hence, A petrol engine (Honda Gx 140) of 144 cc (5 hp), 4-stroke, Air Cooled, Single Cylinder was used in the Asella Agricultural Engineering Research Center.

3.4.1.2. Functional Requirements

The weeder developed should fulfil the following functional requirements:

1. To meter the weeder properly such that weeding speed.
2. To know the soil to a specified position and the spacing of weeding weed and depth.
3. To cover the weeding space between row planted.

3.4.1.3. Weeding Blade Width Determination

A machine was designed by keeping in mind the various agronomical requirement of crop like spacing of crop (20 cm) and height of the crop (12 cm) from the ground level. It would have simple in designed and it easy to operated. Cost of the machine should be low so that it can be easily repairable by village artisan. Crop variety is an important parameter which influences the mechanical weeding operation since the growth factor and foliage varies for each variety. The weeding width of the blade was determined in equation (3.2) by using formula (Sharma and Mukesh *et al*., 2008). The spacing is recommended by spacing of wheat (dimensions in 20 cm) (FAO, 2004).

$$\mathrm{Sc} = \mathrm{Zf} + \mathrm{Zp} \quad (3.2)$$

Where: Sc = Crop spacing between row to row, cm

Zf = Effective soil failure zone, cm

Zp = Protective zone, cm

Let put the known value into equation the protection zone (Zp) is 3.5 cm for wheat and barley (FAO, 1983). and the protection zone was provided on both side of crops.

$$\mathrm{Sc} = \mathrm{Zf} + \mathrm{Zp}$$

$$20 \text{ cm} = \mathrm{Zf} + 2\ X 3.25 \text{ cm}$$

$$\mathrm{Zf} = 12.5 \text{ cm}$$

But, the total working width of implement 60cm Therefore number of blade Effective working soil failure zone needed that can provide 12.5 cm in each row.

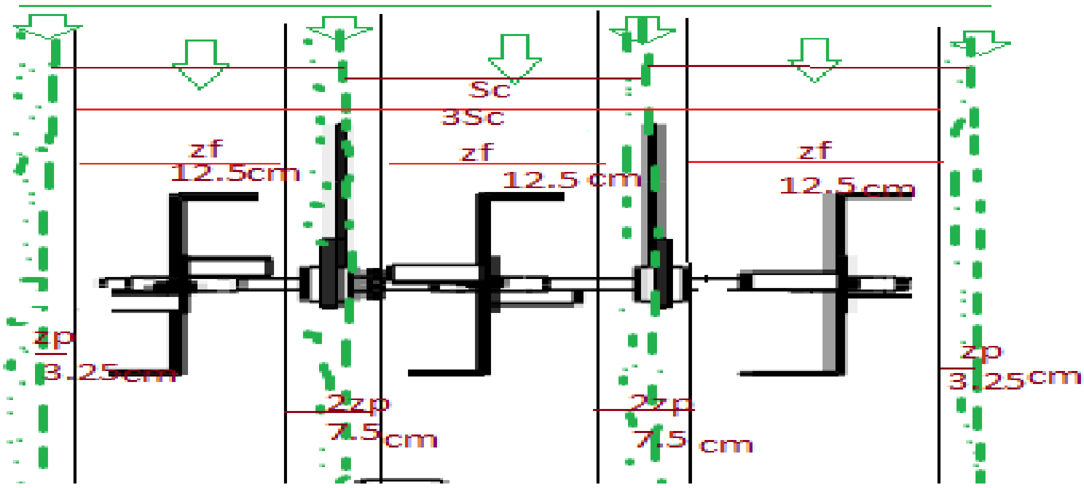


Fig.3.3. The space of crops row to row with its zone of crops protection

3.4.2. The mechanical Functional Requirements of Different Individual units of Machines

The mechanical functional requirements of different individual units of machines are given below

3.4.2.1. Frame

The frame (Fig.3.5.) is made of 50×30×2 mm thickness MS square hole iron section of 620 mm length and 200 mm width to accommodate the power unit, transmission system and cutting unit and also strips of MS plates of size 280×104 mm and 3mm thickness were welded in between the square hole iron as braces and supports. The two square hole irons of size 50×30 mm of length 250 mm was welded between the main frame and supported the engine unit, gear box, transmission system and cutting unit, the strips of MS plates of size 115× 32 mm were welded in between the angle iron as braces and supports. Two angle irons of size 35×5 mm of length 150 mm was welded on rear ends of the main frame as a support to handle braces.

A. The Force Analysis on Main Frame Using by CATIA Software Analyzed

Force Analysis on the main frame Using CATIA software analyzed. The force analysis on the frame is done. A uniformly distributed load of 20000 N is applied on the frame. This force generated a Von Misses stress of 12.7x10^{11} N/m^2. The yield strength of the frames 386 MPa. This rendered the deformed safe from the loading forces.

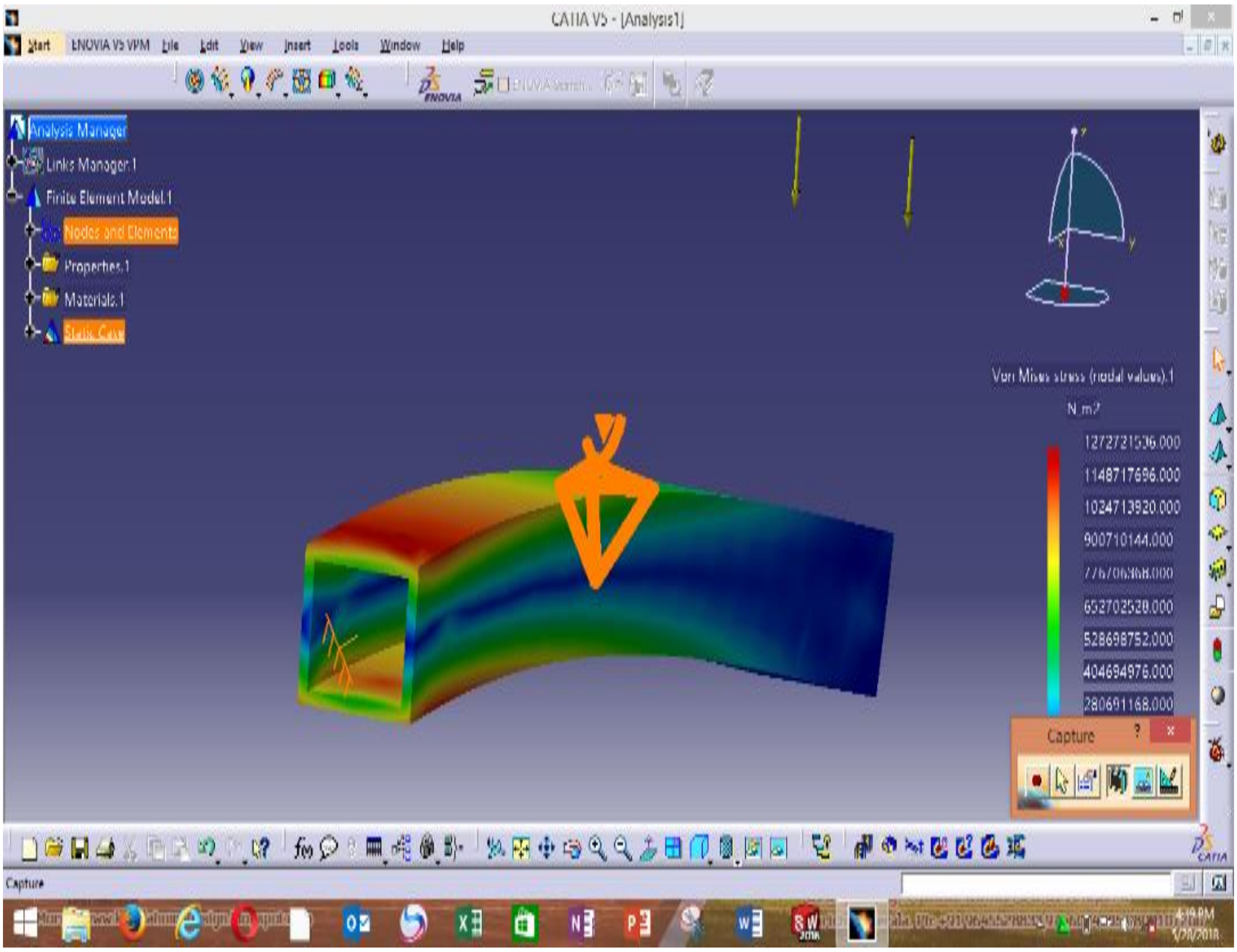
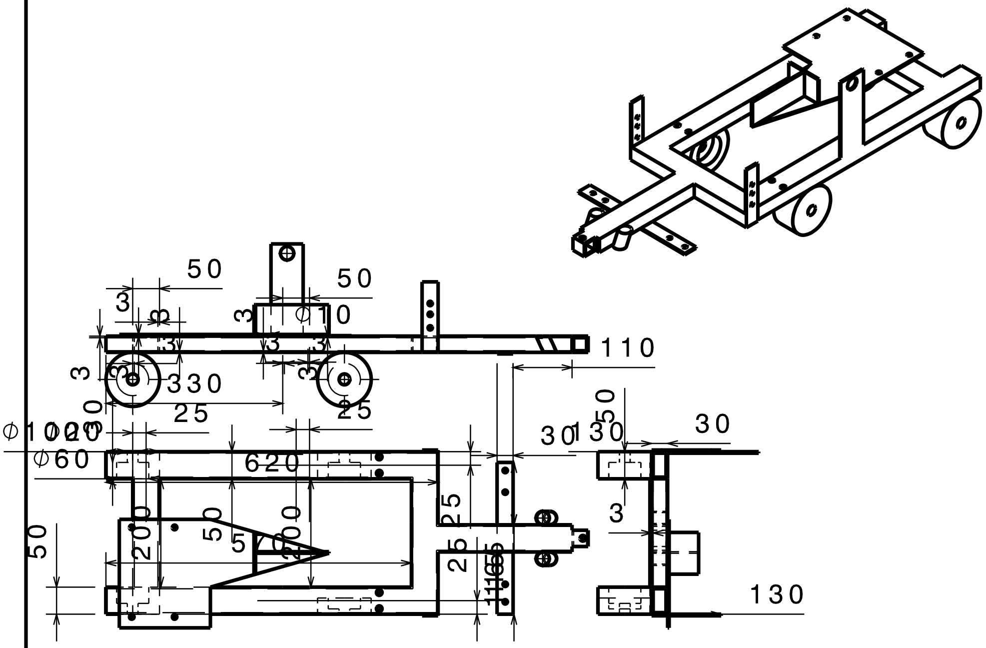


Fig.3.4. Force Analysis on the Frame



DESIGNED BY: Beka Adugna DATE: 4/5/2018		
CHECKED BY: Dr. Amana Wako DATE: XXX		
SIZE A4		motorized rotary weeder
SCALE 1:10	WEIGHT (kg) 2.36	DRAWING PART frame — SHEET 1/1

This drawing is our property; it can't be reproduced or communicated without our written agreement.

Fig.3.5. Frame

B. Weight of the Main Frame

The weight of each part designs was calculated using CATIA software. The input of the software was part design equipped with dimensions and material type selection. The software has its own material types with their densities. Once the part design was feed with dimensions and its material type, the CATIA gave the output of the selected component area, volume and mass in (Table: 3.3) Rectangular hollow pipe was used in the construction of the rotary weeder frame (Fig. 3.5). The weight of frame was calculated in equation (3.3), (3.4), (3.5), (3.6) as follows.

The cross-sectional area of the frame material can be calculated as:

$$A_{cross\,section} = A_{outer} - A_{inner} \quad (3.3)$$

$$= (50 \times 30) - (47 \times 27) = 231mm^2$$

The length of frame material is:

$$L_{FM} = (2 \times 620) + (3 \times 200) + 250 = 2{,}090\ mm$$

The volume of frame material is:

$$V_{FM} = A_{cross\,section} \times L \quad (3.4)$$

$$= 231mm^2 \times 2090\ mm = 482790\ mm^3 = 0.00048\ m^3$$

Mass of frame material is:

$$M_{FM} = V_{FM} \times \rho_{FM} = 0.00048\ m^3 \times 4947.58\ {}^{Kg}/_{m^3} = 2.36\ kg \quad (3.5)$$

Weight of frame material is:

$$W_{FM} = M_{FM} \times g = 2.36\ kg \times 9.81\ {}^{m}/_{s^2} = 23.152N \quad (3.6)$$

Where: A_{crs} = 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

3.4.2.2. Ground Wheel

The ground wheel (Fig.3.6.) was made up of 90x3 mm MS flat having length 1696.46 mm by bending in circular shape the ring of 540 mm diameter. The rim of wheel was made from hole bar metal iron 5 mm thick and 90 mm length the inner bush hole drilled by 20.5Ø. and the outer 30 Ø. Each wheel had 8 spokes made from MS rods with diameter of 10 mm and length of 252 mm, and were welded to the rim and hub at the center of the wheel that served as bushing or shaft bearing, at equal interval (Fig. 3.6). Design of the ground wheel at the outer which contact with soil discussed in section ere welded griper metal at the periphery of the wheel for better griping with soil for better traction in the field during operation. It was fitted on the both side of the frame with the help of supports. They are connected to the middle shaft which trans mitted the power from engine produces the necessary force through chain-sprocket drive on the ground.

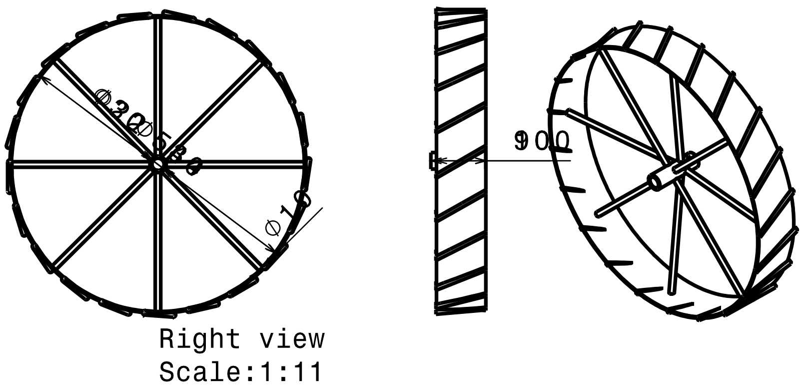


Fig. 3.6. ground wheel

A. Wheel Strength

The wheel of the motorized rotary weeder was made from mild steel sheet metal whose maximum shear strength, $\boldsymbol{\tau}_{max}$, is 80 MPa. Reinforcing bars were used to strengthen the wheels. For the simplicity of the analysis, it was assumed that the stress occur on the wheel was pure torsion.

Therefore, the formula used in the analysis was the one that estimates the shear amount in "welded closed thin wall, t<d", from (Fig. 3.7.) as dictated in equation (3.7) Richard et.al, (2011).

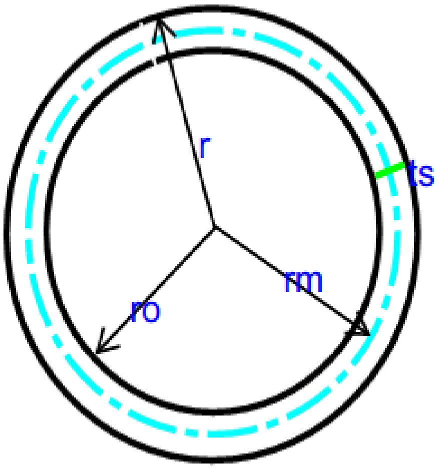


Fig. 3.7. Cross sectional view of the wheel

$$\tau = \frac{T}{2A_m t_s} \dots\dots (3.7)$$

$$= \frac{T}{2(\pi {r_m}^2)t_s}$$

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

Torque on the ground wheel using in equation (3.8) (Sharma and Mukesh.*et al*, 2010

$$\mathrm{T} = \mathrm{F}(\frac{\mathrm{d}}{2}) \dots\dots (3.8)$$

A rolling resistance force (F), which is assumed to act horizontal at the wheel and ground interface or ground and wheel contact patch, was estimated using the Eq. (3.9) (Reece,2002).

$$\mathrm{F} = (C_R + \mathrm{I})\mathrm{xN} \quad \dots\dots (3.9)$$

$$= \left(\left(\frac{\mathrm{z}}{\mathrm{d}}\right)^{0.5} + \mathrm{I}\right) \mathrm{x\ N})$$

$$= \left(\left(\frac{2.5}{54}\right)^{0.5} + 0.05\right) \times 149.87) = 39.74\mathrm{N}$$

Where: C_R = coefficient of rolling resistance

d = wheel diameter, 54. mm

z = maximum wheel sinkage depth (on a soft surface z = 0.05d, let z ≈ 2.5cm)

N = weight of the rotary weeder on each wheel, (299.73/2) =149.87N from appendix

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

$T = (39.74) \times (\frac{0.54}{2}) = 10.73$ Nm

Where: T= the torque produced by the wheel, 10.73 Nm

A_m=the area of the wheel calculated based on the median Ø of the wheel (Fig.3.7)

r= the outer radius of the wheel, 0.27m

r_o= the inner radius of the wheel, 0.24m

r_m= the median radius of the wheel

t_s= the thickness of the wall/wheel=0.003m

Therefore, the shear stress on the wheel is,

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

$$= \frac{10.73}{2(\pi[0.27-0.0015]^2)\times 0.003} = 7896\ Pa\ = 7.896\ KPa\ <\ \tau max$$

Comparing the result, $\tau_{ac} < \tau_{max\ (80\ mpa)}$, indicated the wheel was safe.

The angle of twist can be estimated using the equation (3.10) (Richard et.al, (2011)

$$\theta = \theta_1 L \quad \text{...} \quad (3.10)$$

$$= \left(\frac{TL_m}{4GA_m{}^2 t_s}\right) \times L\ = \left(\frac{10.73\times 2\pi\ (0.27-0.0015)}{4\times 80\times 0.4530^2\times 0.003\times 10^9}\right) x0.09 \quad = 8.3\times\ 10^{-9} rad$$

$$= 475.59x10^{-5} degree\ (negligible)$$

Where: L= length or width of the wheel, 0.09m

T= torque produced by the wheel, 10.73Nm

L_m= the length of the median line of the wheel

θ_1= the angle of twist

G= modulus of rigidity, 80GPa for stainless steel

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

B. Design of Hub

The hub of a wheel is one of the most important components of rigid wheel. It gives support to the spokes and the shaft. The diameter of the hub was calculated using the equation (3.11) the outside of the hub Richard and J. Nisbett *et al. (*2011).

D =1.50d + 25.00 mm…………………………………………………… (3.11)

= 1.50 x 20mm +25mm = 55 mm

Where: D = outside diameter of hub, mm

d = diameter of shaft, mm

The length, L, of hub was determined in equation (3.12) by Richard and J. Nisbett.*et al.* (2011).

$L=\pi\times\frac{d}{2}$………………………………………………………………(3.12)

=31.42 mm

The inner diameter of hub was taken equal to the diameter of the shaft i.e. 20mm.

C. Estimation of Wheel Width

When two cylindrical objects of length L and diameters d_1 and d_2 contact, a narrow rectangle of width 2b and length L is created. The stress created has an elliptical distribution across the contact zone the following equations (3.13) (Hertz 1881) are used to calculate the half width and pressure:

$$b = \sqrt{\frac{\frac{2F}{\pi L}[\frac{1-{V_1}^2}{E_1}+\frac{1-{V_2}^2}{E_2}]}{d1^{-1}+d2^{-1}}} \quad \text{…………………………………………………… (3.13)}$$

$$P_{max} = 2F\pi bL \quad \text{…………………………………………………………(3.14)}$$

Where: v_1= Poisson ratio of steel, 0.3

V_2= Poisson ratio of sand clay loam soil, 0.3 - 0.35

E_1 = Young's modulus of elasticity of steel, 200GPa

E_2=Young's modulus of elasticity of sand clay loam soil, 5- 20MPa

d_1= diameter of the wheel, 0.54m

d_2= diameter of the contacting surface, ∞

F= the force exerted by the wheel, 39.74N

L= contact length/width of the wheel with the ground, 0.09m

P_{min}= the minimum penetration resistance pressure of the ground (0-10 cm) at optimum MC, 500 KPa

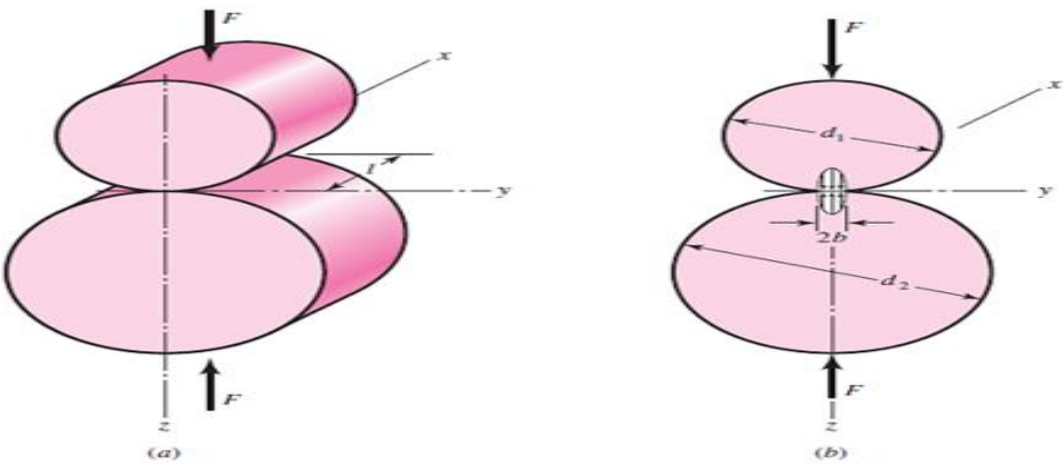


Fig. 3.8. Contact stress between two cylinders

According to Richard et.al. (2011), the above equations apply to a cylinder and a plane surface (d= ∞) contact. When the equations are used to estimate the half width contact length and the pressure produced for cylindrical object and a plane surface contact, some of the parameters will have different values. The width of wheel specified in the design was 9 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 (P_{max}) developed on the contact patch (wheel and ground) was compared with the minimum con-index (P_{min}) measured at 0-10cm depth using cone-penetrometer. If $P_{max}<P_{min}$, it is assumed that the width of the wheel is safe. However, if $P_{max} > P_{min}$, the width of the wheel has to be increased to some level to avoid wheel sinkage in operation.

Solving for b,

$$b = \sqrt{\frac{\frac{2\times39.74}{0.09\pi}[\frac{1-0.3^2}{200\times10^9}+\frac{1-0.4^2}{50\times10^6}]}{1/0.54+1/\infty)}}$$

$$= 0.0034m$$

Solving for P_{max},

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

$$= 2 \times 39.74/\pi(0.09 \times 0.0034) = 81.102\ KPa \ < 500\ KPa\ (safe)$$

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

D. Uplift Pressure on the Ground Wheel

When a wheel operates on flooded soil, it sinks, and displaces a certain volume of the soil. The displaced volume of the flooded soil develops an upward thrust on the wheel. This upward thrust reduces the pressure at the soil wheel interface. This is one of the reasons for low tractive efficiencies obtained in flooded soil. When the upward thrust balances the normal load on the wheel, the wheel operates in the floating condition. Assuming the flooded soil to be a liquid with specific weight "γ" the upward thrust developed at the bottom of a wheel of radius "r" of 270 mm and width "w" of 90 mm sinks 18 mm in the soil, then upward thrust experienced equation (3.15) (Mahilang et al.,2013) given below.

Q = (specific weight) × (volume of soil) …………………………….…………… (3.15)

$$Q = w\gamma^2[r^2\ \cos^{-1}\left(\frac{r-h}{r}\right) - \mathrm{r} - \mathrm{h} \times \sqrt{2 \times r \times h}\ - h]$$

Where: h = sink age of the wheel, mm

Q = upward thrust, kg

r = radius of wheel, mm

γ = specific weight liquid

By substituting the values in equation;

$$Q = 9 \times .00001^{1}[270^{2}\ \cos^{-1}\left(\frac{270-9}{270}\right) - 270 - 9 \times \sqrt{2 \times 270 \times 9}\ - 9]\text{=1.93 kg}$$

The uplift pressure on the wheel was calculated to be 1.933 kg which is appropriate for design of cage wheel.

E. Optimum Lug Spacing

The ground wheel should be designed to run at a maximum slip of 30 per cent at which the lug spacing required for a wheel with radius 270. mm, lug sinkage 18 mm and minimum shear spacing 60 mm is given by equation (3.16) (Mahilang et al. 2013)

$$L = \frac{2}{(1-i)}[r \cos^{-1}(\frac{r-h}{r}) - r\ \sqrt{1-\left(\frac{r-h}{r}\right)}^{2}\ + \frac{S}{2}] \quad \text{………..…………………………. (3.16)}$$

Where: h = depth of lug linkage, mm

S = minimum shear spacing, mm

i = maximum slip,0.5 %

r = wheel radius, mm

By substituting the value in equation

$$L = \frac{2}{(1-i)}[270 \cos^{-1}(\frac{270-9}{270}) - 270\ \sqrt{1-\left(\frac{270-9}{270}\right)}^{2}\ + \frac{60}{2}]$$

The optimum lug spacing was 151 mm. Apart from this, the lug spacing does not clogged by the soil.

3.4.2.3. Ground Wheel Axle Shaft Dimension

The shaft subjects both bending moments as well as twisting moment, then the shaft must be designed by considering both moments simultaneously. This shaft is a rotating member, usually of circular cross-section for transmitting power. It is supported by bearings and supports two flywheels. It is subjected to torsion, and bending in combination. According to maximum shear stress theory or guest's theory the shaft is designed.

As the machine weighing W kg is supported on two-wheel hubs A and B, then it is apparent from the shear force diagram and bending moment diagram fig. below that is subjected to maximum

bending moment. Therefore, the value of this moment is given by equation (3.17) (Khurmi *et al*., 2010)

$$M = \frac{W \times L}{2} \qquad (3.17)$$

Where: M= maximum bending moment, kg - cm

W= weight of the machine, kg

L= distance between the two-wheel shaft, A and B, cm

The power weeder has to be operated by 5 hp (144 cc) S.I. engine. So, the torque developed is determined by the equation (3.18) given below:

$$B.H.P = \frac{2 \times \pi \times N \times T}{4500} \qquad (3.18)$$

Where, B. H. P = break horse power available, hp

N = rpm of the engine

T = torque developed, kg-m

The weight of the machine parts such as weight of engine, gear box and frame were supported on the ground wheel axle shaft and is calculated to be 33.454 kg and it is supported by two-wheel shaft at a distance of 68 cm. It reveals that, 35 percentage of machine weight (30.554kg) is supported by two ground wheels and the remaining weight is supported by gauge wheel substituting the value in equation (3.19).

$$\mathrm{M} = \frac{30.554\ kg \times 68\ cm}{2} = 1038.8 \text{ kg-cm} = 10388 \text{ kg-mm}$$

Substituting the values in equation (3.18) determined the torque as below equation (3.19)

$$T = \frac{5HP \times 4500}{2 \times \pi \times 2200} \quad (3.19)$$

=1.63kg-m

$$T = \frac{5HP \times 4500}{2 \times \pi \times 715} = 5.008\text{kg-m}$$

$$T = \frac{5HP \times 4500}{2 \times \pi \times 92} = 38.92 \text{ kg-m}$$

Again, when the ground wheel axle shaft rotates at 23 rpm the maximum torque developed on the wheel shaft is given by:

$$T = \frac{5HP \times 4500}{2 \times \pi \times 23} = 155.695 \text{ kg-m}$$

The twisting moment acting

on shaft can be written as equation (3.20) below:

$$T = \frac{\pi}{16} \times d^3 \times fs \quad (3.20)$$

Hence, equivalent twisting moment, Teq. is given by equation (3.21) (Ragesh *et al.*, 2015),

$$Teq = \sqrt{M^2 + T^2} \quad (3.21)$$

$$= \sqrt{10.388^2 + 155.6^2} = 155.94 \text{ kg.m} = 15594 \text{ kg. cm}$$

The equivalent twisting moment is that twisting moment, which when acting alone, produces same shear stress as actual twisting moment. Then the both equation (3.20), (3.21) (Khurmi.*et al*, 2010) can be written as equation (3.22).

$$Teq = \sqrt{M^2 + T^2} = \frac{\pi}{16} \times d^3 \times fs \quad (3.22)$$

Assuming permissible shear stress as 760 kg/ cm^2 for axle shaft steel, diameter of shaft can be calculated as follows equation (3.23) (Victor *et al.* 2003).

$$d = \sqrt[3]{\frac{16(M^2+T^2)}{\pi \times fs}}^{0.5} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.23)}$$

$$= \sqrt[3]{\frac{16(10.388^2+155.6^2)}{3.14 \times 760kg}}^{0.5} \quad = 2\text{cm}$$

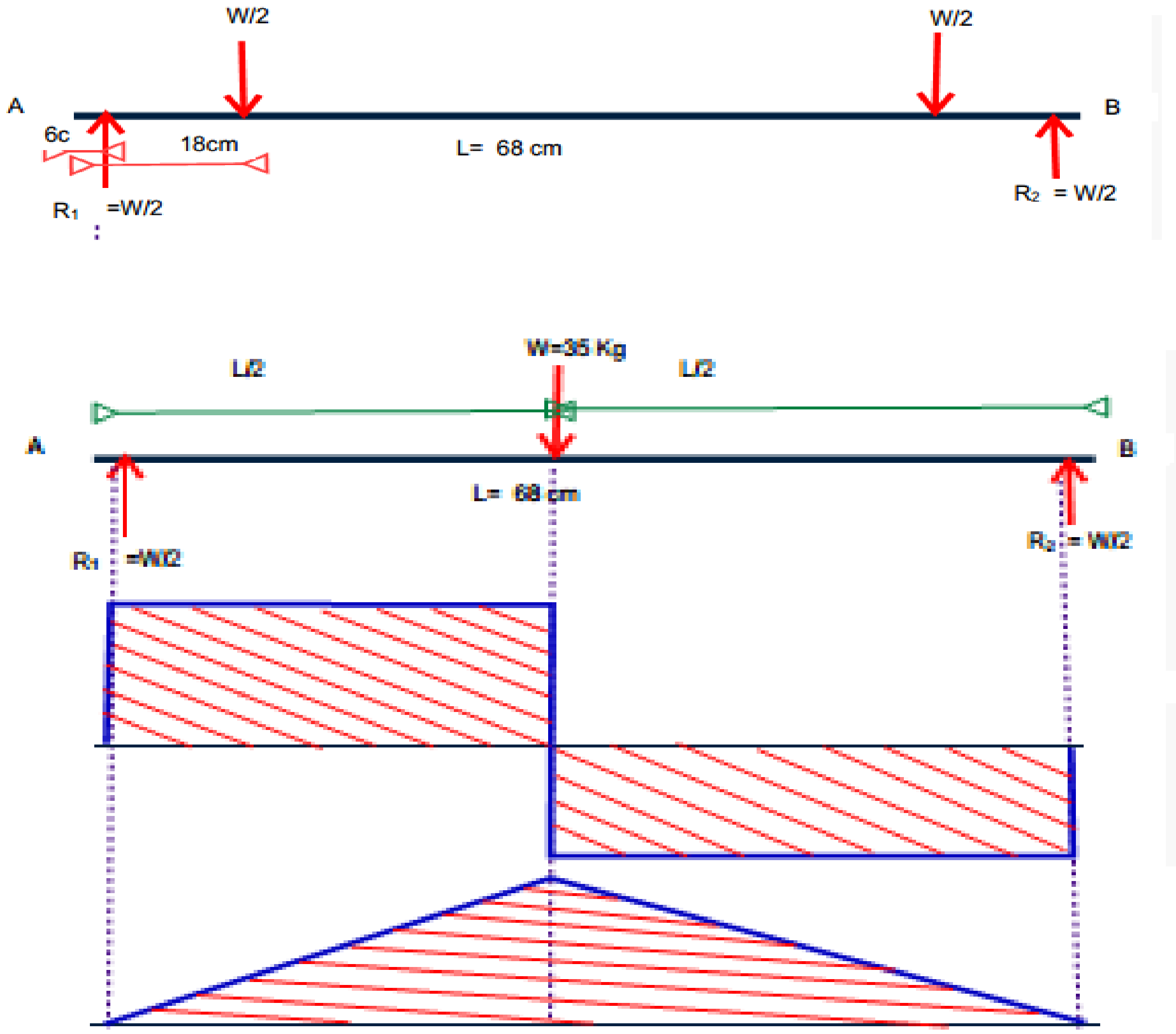


Fig.3.9. Bending moment and shear force diagram for axle shaft

Hence, 20mm diameter MS rod of 600 mm length is selected as ground wheel axle shaft so that it can accommodate wheel on either side and the distance between wheel hubs is 560 mm.

3.4.2.4. Sank

To support the rotary blades shaft assembly two shanks are welded below the frame of the weeder. The shank has a 50mm width × 5mm thickness and 400 mm length, curvature was made with the radius of 100mm and its width was increased to 60mm to the end of the shank. Another curved MS flat of 150 mm length is fixed to the main frame. The two curved supports are made adjustable by means of nut and bolt for setting of the complete cutting unit and are fixed to the rotary shaft. The rotor shaft assembly was fitted on to these shanks such a way that the bearings No. 62.02 rests on the shanks lower portion.

Considering the available draft of 586.95 kgf and the weight shaft and blade exerted on the tip of the sank of 340 mm length was determined in equation (3.24) (Bosai, et al., 1987 and Singh, 1989). (Fig.3.9)

$$\text{Draft availablefor MR weeder(D)} = \frac{2.63\ \text{hp} \times 270}{(\text{v})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (3.24)$$

Where: 270= factors calculated as, 1km/1hr

V= speed of travel and weeding speed in. km/hr

D =Draft of MR weeder in, kgf

The four blades were arranged in one each of the three rotary blade bars. The design was based on the total stress produced on assembled blade bar the power required for weeding was 2.6 hp from eq. (3.1) and the weeding speed was 17.9 km/hr from appendix then, substituted in equation (3.24). To estimate total draft of rotary blade was given by equation (3.25) (Bosai, *et al.*,1987)

Bending moment = draft x length of shank = 39.7(kgf) x 34 cm = 1348.7 kg-cm

$$\text{f} = \frac{\text{M}\times\text{c}}{\text{I}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.25)$$

Where: f = Bending stress, kg/cm^2

I = Moment of inertia, cm^4

M = Bending moment, kg-cm

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

The section modulus axis is computed by using formula.

$$Z = \frac{M}{c} \qquad (3.26)$$

From (3.25) and (3.26), Assuming the bending stress in vibration is equal to 6088 kg/cm^2

$$Z = \frac{1348.7}{6088} = 0.2215\ cm^3$$

Section modulus of the sank

$$Z = \frac{bh^2}{6} \qquad (3.27)$$

Width of shank was considered as 1:4 i.e. (h: 4b)

$$Z = \frac{b \times 4b^2}{6} \qquad (3.28)$$

$$0.2215 = \frac{16b^3}{6}$$

$$b^3 = 0.333$$

$$b = 0.693 \text{ cm} = 6.93 \text{ mm}$$

Considering the factor of safety and availability of material is standard size. The thickness of shank was selected =7 mm. Therefore, the width of the shank = 2 x 7 = 14 mm.

3.4.2.5. Rotary Weeder Blades

The design of rotary weeder in (Fig 3.10.) and intercultural machine blades depends on the type and number of blades and also on the working condition. In this project as discussed in literature review the L- type blades were considered for the machine design according to the working conditions enumerated. The machine rotor shaft assembly of the blades action will be jointly on the soil condition by (Khodabakhshi, 2013). The total power of the machine is distributed between the blades. The number of rotor blades can be calculated in equation (3.29).

$$\text{Nb} = \frac{\text{b}}{\text{bi}} \qquad (3.29)$$

Where: Nb= is the number of rotor blades

b = is the working width of rotor assembly

bi = is the distance between the two adjacent blades of the rotor.

In the present case the working width of rotor assembly was 600mm and spacing between three adjacent blades 50mm.Therefore, the total number of blades is obtained:

Nb = 600 / 50 = 12

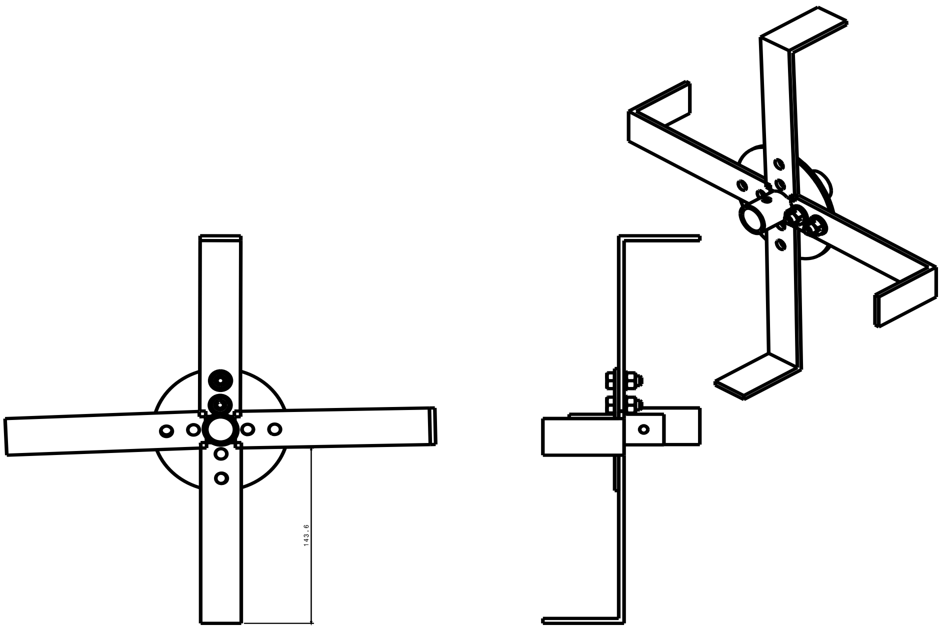


Fig. 3.10. Rotary blade assembled

3.4.2.6. Middle Shaft:

For commercial steel shaft, Actual shear stress, **τact** = **55 N/mm**. The stress on the shaft at a particular point varies with rotation of shaft there by introducing fatigue. Even a perfect component when repeatedly subjected to loads of sufficient magnitude, will eventually propagate a fatigue crack in some highly stressed region, normally at the surface, until final fracture occurs. Extensive work has been carried out by failure analysis research community investigating the nature of fatigue failures using analytical (FEA) and experimental methods determined in equation (2.30) (D. Ferreno,2008)

$$T = \frac{\pi}{16} \times \tau act \times d^3 \quad \text{..........} (3.30)$$

Where: T= torque

τact = shear stress

d = diameter of shaft

$= 38.92 \times 10^3 = \frac{3.14}{16} \times 55$ N/mm $\times d^3$ =198.22 mm

d =5.8mm select d=20mm because avalable in market

3.4.2.7. Safe Guard

To avoid throwing of mud and stones towards operator and as a safety, a safe guard is provided covering the upper and rear side of the blades of the rotary cutting units. Upper side is made up of plastic sheet and the rear side is covered by rubber sheet. Both is connected and supported to the inner end of the handle by means of nut and bolt with the help of MS flat.

3.4.2.8. Handle

Handles (Fig.3.11) are made of 20 mm MS conduit pipe with plastic grip fitted at the ends. The overall length of handle 1100 mm with two bends from point of attachment by bolt and nut and have a height of 900 mm from ground level also Convenience for the operators. The length of handle cross bar is 400 mm and diameter of handle grip is 25 mm with a length of 180mm. The handle is attached to the angle iron on main frame at the rear of the machine with help of M S flat of size 32×5 mm of length 150 mm as braces. With help of handles machine can be steered.

A throttle lever is provided on right side of the handle to control the engine speed and engage and disengage controller setting at the middle of the two handles (Varshney, 2004).

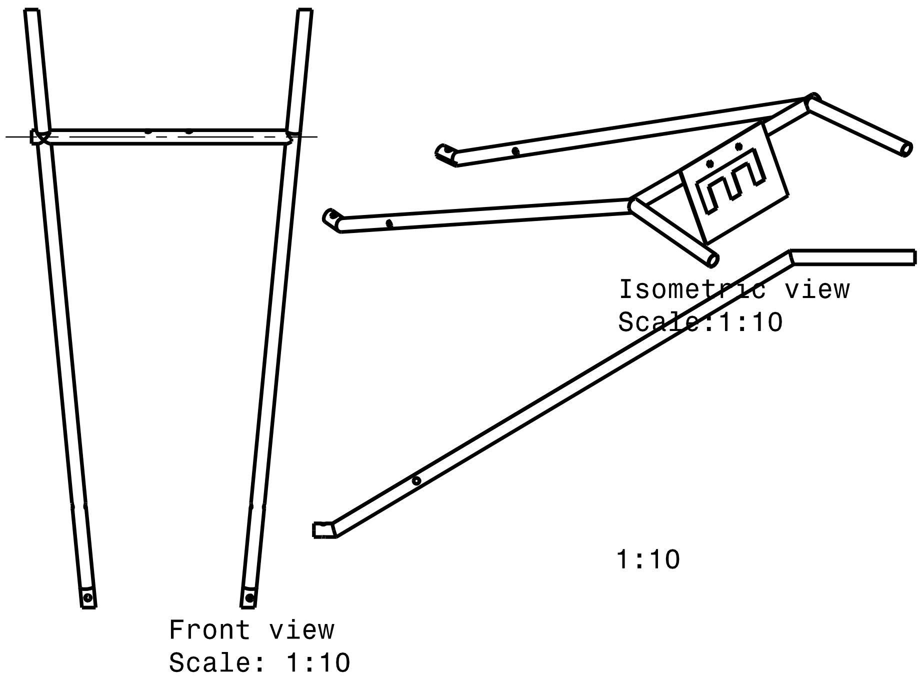


Fig. 3.11. Handle

Weight of Handle was determined in the equation (3.31), (3.32), (3.33), (3.34) as follow:

$$A_H = \left(\frac{\pi(D^2 - d^2)}{4}\right) \quad \text{.......... (3.31)}$$

$$= \frac{\pi(20^2 - 16^2)}{4} = 12.56mm^2 = 1.256 \times 10^{-4}m^2$$

$$L_H = 2 \times (790 + 60) + 2 \times (180) + 400 = 2{,}460mm = 2.46m$$

$$V_H = (A_H \text{ x } L_H) \quad \text{.......... (3.32)}$$

$$= 2.460m \times 1.256 \times 10^{-4}m^2 = 3.089 \times 10^{-4}m^3$$

$$M_H = V_H \text{x} \rho \quad \text{.......... (3.33)}$$

$$= 3.089 \times 10^{-4}m^3 \times 7850 \, {}^{Kg}/_{m^3} = 2.425kg$$

$$W_H = M_H \times g \quad \text{.......... (3.34)}$$

$$= 2.425kg \times 9.81 \, {}^{m}/_{s^2} = 23.8 \, N$$

Where: A_H = Area of handle

$L_{H =}$ Length of handle

V_H =Volume of handle

ρ_H = Density of handle

M_H = Mass of handle

W_H= weight of handle

3.4.2.9. Gauge Wheel

A gauge wheel is attached to the front of the frame for depth adjustments of the rotary blades. An iron wheel of diameter 153 mm was utilized for the purpose. The 10.5 mm diameter bush is provided on which 4 numbers of spokes of 60 mm each are fixed for better strength of wheel. The gauge wheel is attached to the frame with the help of two standards of 16 mm diameter of length 360 mm. For adjustments such as raising and lowering the gauge wheel, a threaded bolt of 18 mm diameter and 355 mm length was provided so as to alter the depth of cutting and weeding by the rotary blades.

3.4.2.10. Coupling

A coupling is a device used to connect two shafts together at their ends between engine and gear box keyway system for the purpose of transmitting power.

3.4.3. Design Parameters in Motorized Rotary Weeder Development

The rotor shaft assembly (Fig.3.12) basically conceptualized to have the basic components as solid shaft, soil working blades, sprockets for power transmission and end bearing blocks fitted over the mounting end support brackets. The design and fabrication details of rotary shaft assembly were detailed below.The dimensions of the rotor blades and shafts were determined on the basis of speed of operation, width, depth of cut during operation and soil conditions.

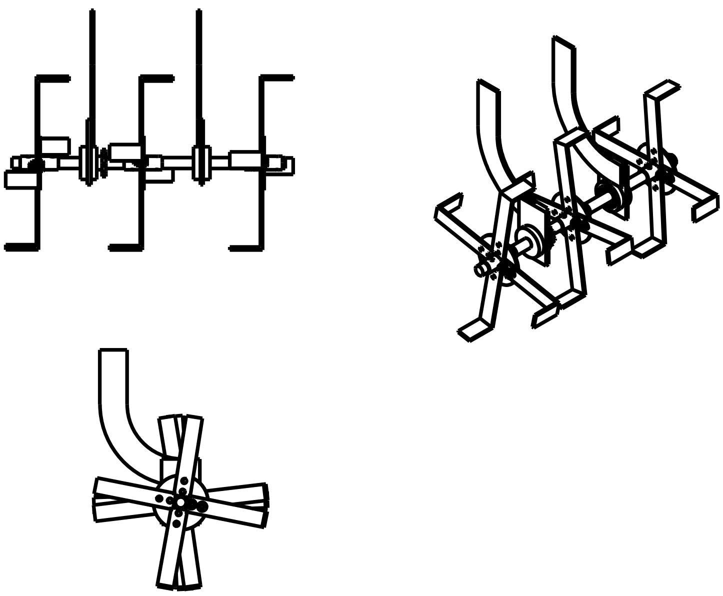


Fig.3.12. Rotary Weeder Blade Assembled

3.4.3.1. Cutting Blade Shape

The performance of any weeding machine depends on the design of the cutting element (blade shape) in this case soil working blade fitted on the rotary shaft. In this study types of blades “L” was used as weeds cutting elements as shown in (Fig. 3.13). However, the width of blades was kept similar as much as possible in effective cutting zone for these blades the rotor shaft assembly was optimized.

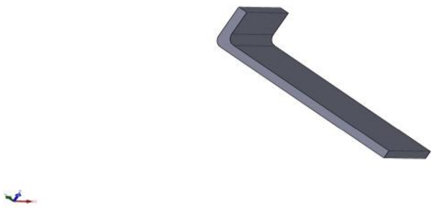


Fig.3.13. Blade shape

3.4.3.2. Tangential Force Acting on the Blade

The maximum tangential force which can be endured by the rotor was considered. The maximum tangential force occurs at the minimum of blades tangential speed was calculated in equation (3.35) (Bernacki, 1972).

$$\mathrm{Ks} = \frac{\mathrm{Cs} \times 75 \times \mathrm{Nc} \times \eta\mathrm{c} \times €\mathrm{z}}{\mu} \quad \text{...} \quad (3.35)$$

Where: Ks = Maximum tangential force, kgf

Cs = Reliability factor (1.5 for non-rocky soils and 2 for rocky soils)

Nc = Power of engine, hp

η_c = Traction efficiency for the forward rotation of rotor shaft as 0.9

$€_z$ = Coefficient of reservation of engine power (0.7 - 0.8)

μ = Minimum tangential speed of blades.

Tangential peripheral speed μ was calculated using equation (3.36)

$$\mu = \frac{2 \times \pi \times \mathrm{N} \times \mathrm{R}}{6000} \quad \text{...} \quad (3.36)$$

Where: N = Revolution of rotor, rpm

R = Radius of rotor, mm

Different parameters used in the study and have been in consideration to give safe strength and bending values for manufactured blades during weeding operation. The calculation and assumptions are based on standard handbook of machine design were followed (Aditya *et al*., 2016). Assumption was made as follows; Number of blades in one working set = 4; Length of blade = 12.3 cm; Width of blade = 4 cm. To calculate the design strength of blade; revolution per minute of rotor shaft (N) = 715 rpm; radius of rotor (R) = 13.3cm. Therefore, speed of engine output (μ) will be determined above as 9.95 m/s.The soil force acting on each of the blade (Ke) was calculated in equation (3.37) (Ragesh *et al*., 2015).

$$\text{Ke} = \frac{(Ks\times Cp)}{(Nb\times Ne)\times i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.37)}$$

Where: Ks = maximum tangential force, kgf

Cp = coefficient of tangential force

Nb = total number of blades on rotor assembly

i = Number of flanges is 2,

Ne = number of blades which action jointly on the soil to the total number of blades. Considering these definitions, Ke can be calculated:

Ke = (37X 2)/ (2×4×1/4) = 37kgf

substituting values for revolution of rotor shaft (715rpm) and its radius as 133mm in equation (μ), tangential peripheral speed was obtained as 9.95 m/s Using the tangential peripheral speed and other parameters in equation (3.37), the maximum tangential force was determined as 35.62 kgf.

3.4.3.3. The Maximum Momentum of the Rotary Shaft

The maximum momentum of the rotary shaft (Ms)was determined in equation (3.38).

$$\text{Ms} = \text{ks} \times \text{R} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.38)}$$

Where: Ks=Maximum tangential force, kgf

R = Radius of rotor, cm

With rotor shaft radius of 13.3 cm, moment acting on it was 473.74 kg-cm.

The yield stress of rotor made from rolled steel (AISI 304) was 763 MPa. The allowable stress on the rotary was determined in equation (3.39) (Mott, 1985).

$$\tau_{all} = \frac{0.577 \times K \times \sigma_y}{f} \qquad (3.39)$$

Where: τ_{all} = Allowable stress on rotor shaft, $\frac{Kg}{cm^2}$

K= Coefficient of stress concentration (0.75),

f = Coefficient of safety (1.5), and

σ_y =Yield stress, 763 MPa

By substituting above equation, the values were τ_{all} = 220.38 $\frac{Kg}{cm^2}$ in then determined the rotor shaft diameter (ø) in equation (3.40)

$$D = \sqrt[3]{\frac{16 \times Ms2}{\tau_{all} \times \pi}} \qquad (3.40)$$

D= 17.75 mm

3.4.3.4. Determining the Blade Width

Each blade must be capable to carry and throw the soil mass along the strip and it is possible only when the blade has enough width. It was assumed that most of the tilled soil mass is in the first half of the blade is working depth and maximum working depth was assumed 6cm for power weeder so that the minimum blade width (W) would be determined using Equation (3.41), (3.42) (3.43) (Aditya *et al.*, 2016). The cutting angle (Ʈ) was defined as angle between the blade plane and tangent to circumference.

$$W = \frac{Hh}{\sin \beta} \qquad (3.41)$$

and

$$\beta = 90° + Ʈ - \alpha \qquad (3.42)$$

Where: Hh=half of maximum working depth, m

α= angle of blade rotation from the horizontal, degree (º)

β= angle of inclination of the blade from horizontal, degree

τ= cutting angle, 23.8°

Inclination angle (β) was calculated from Eq. (3.42). To solve Eq. (3.43), angle α was determined as

$$\alpha = \sin^{-1}\frac{\mathrm{H-Hh+R}}{\mathrm{R}} \qquad (3.43)$$

$$= \sin^{-1}\frac{3-6+13.3}{13.3} = 50.33°$$

Where: Hh= maximum working depth

H= working depth

R= radius of rotor

The cutting angle τ was determined as 23.8°. By substituting above calculated values of angles τ and α in Eq. (3.42), inclination angle β was calculated as:

$$\beta = 90° + \tau - \alpha = \beta = 90° + 23.8° - 50.33° = 63.47°$$

According to Eq. (3.41), the calculated minimum blade width W was 3.48cm.

3.4.3.5. Maximum Expected Length of Soil Slice

Maximum expected Length of soil slice determined in equation (3.44) as follow;

$$\mathrm{Ls} = \frac{v_f \times 2\pi \times R}{\mu \times Z} \qquad (3.44)$$

$$= \frac{65 \times 2\pi \times 13.3}{9.95 \times 4} = 1.8\text{cm} \qquad \mathrm{Ls} = 1.8\text{cm}$$

Where: Ls= Length of soil slice

v_f = forward speed, cm/sec

μ = peripheral speed of rotor with radius R.

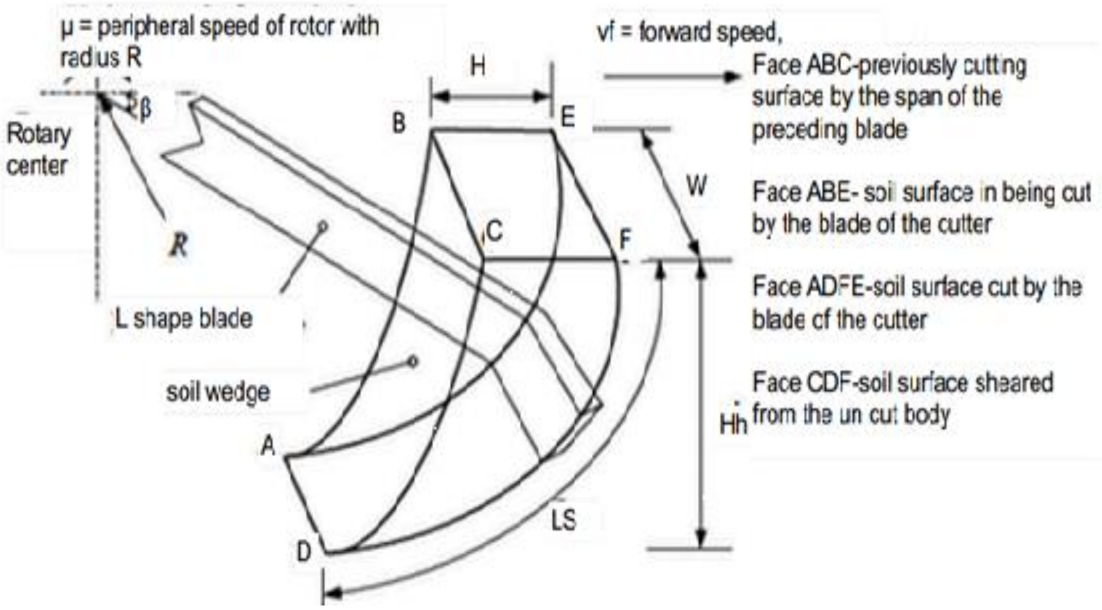


Fig.3.14. Soil- tool interaction of L shaped blade.

3.4.3.6. Maximum Force Required to Cut the Soil for each Blade (F)

$F = pA = 0.58 \times 3 \times 5.9 = \frac{8.85 \quad kgcm^2}{each\ blade}$………………………….…………………… (3.45)

Where: p = Maximum specific resistance of soil = 0.75 kg/cm^2

A = Area to be disturbed,

A= a × length of soil slice; and

a = edge length of the blade, 3 cm.

l = length of blade, 13.3 cm

If we have maximum four blades but only one can cut and disturb the soil, and 3 sets in the power rotor, so the maximum force required to cut the soil by the weeder.

$Pmax = 8.85 \times 3 = 26.55kg$……………………………..…………..……… (3.46)

Cutting force per unit length of blade

$Pa = \frac{Pmax}{l} = \frac{26.55}{13.3} kg/cm$ = 1.996kg/cm =2kg/cm…………….…………… .. (3.47)

Taking this as beam (cantilever) with uniformly distributed load, both maximum bending load and moment of inertia can be calculating as below

$$\text{Bending load} = \frac{\text{Pa}\times \text{I}^2}{2} = \frac{2\times 13.3^2}{2} = 176.89 \text{ kg cm} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.48)$$

$$\text{Moment of inertia(I)} = \frac{1}{12}\text{be} \times \text{Ss}^3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.49)$$

$$= \frac{1}{12} 0.4 \times 4^3 = 2.1 cm^4$$

Where: Ss =is width of blade edge, 4 cm; and

be =is maximum thickness of blade edge, 0.4 cm.

To check for bending;

$$\text{Deflection for cantilever beam} = \frac{\text{Pmax}\times \text{I}^3}{3\text{EI}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.50)$$

Where: E = 2.1 × 106 kg /$cm^2$for mild steel.

The value would be $= \frac{26.55\times 13.3^3}{3\times 2.1\times 10^6\times 2.1} = 3.7 \times 10^{-3}\ mm$

It is almost negligible and for safe design deflection should be $< \frac{a}{1200}$($3.7\times 10^{-3} < 5 \times 10^{-3}$), so, it is safe.

3.4.3.7. Kinematics of Rotary Blade

The working tools of rotary machines execute a complex motion consisting of relative-rotary motion around the axis of the rotor with a peripheral speed of (μ) and translator with a travel velocity of (**v**). The motorized rotary weeder designed on the principle of the rotary tiller. It is powered by engine. The theory of operation on which the design of the weeder is based is presented as follows. (Fig.3.15) is the sketch of a rotary blade with a number of shares denoted as, A0, A1, A2, ... An. The sketch shows the mechanism of operation and various parameters of the soil slice. The radius of the rotor is (**R**) and depth of cut is denoted by (**h**). Let $\mathbf{V_f}$ and **ω** be the forward speed of the implement and the angular velocity of the blade, respectively.

So, as the implement moves forward a distance of $\mathbf{V_{ft}}$, the blade rotates through an angle of ω_t and the shares assume the positions A1'…An'. The coordinates of say A1' referred to the **x** and **y** axes are given by

$$X = v_f + R\cos wt \quad \ldots (3.51)$$

$$y = R(1 - \sin wt) \quad \ldots (3.52)$$

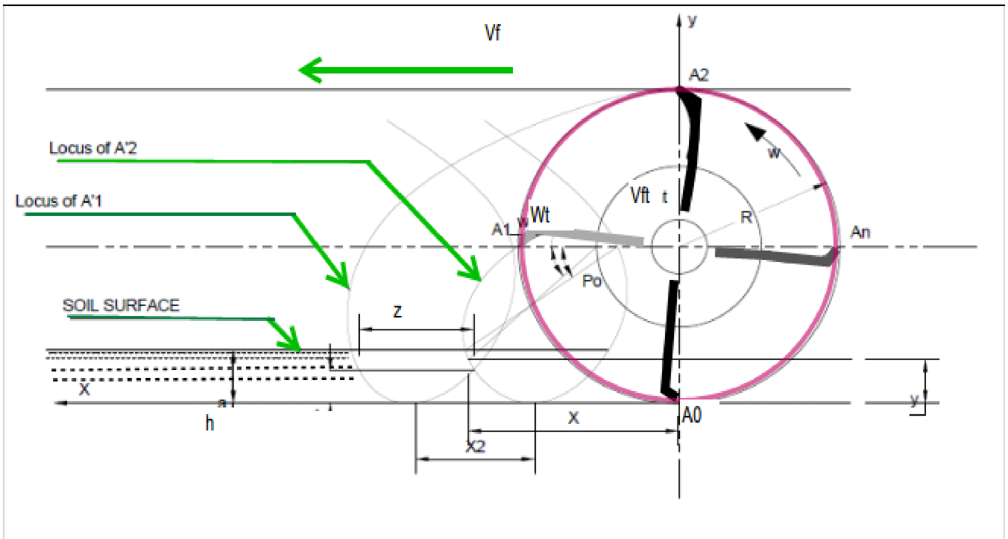


Fig. 3.15. Mechanism of operation of rotary weeder blade

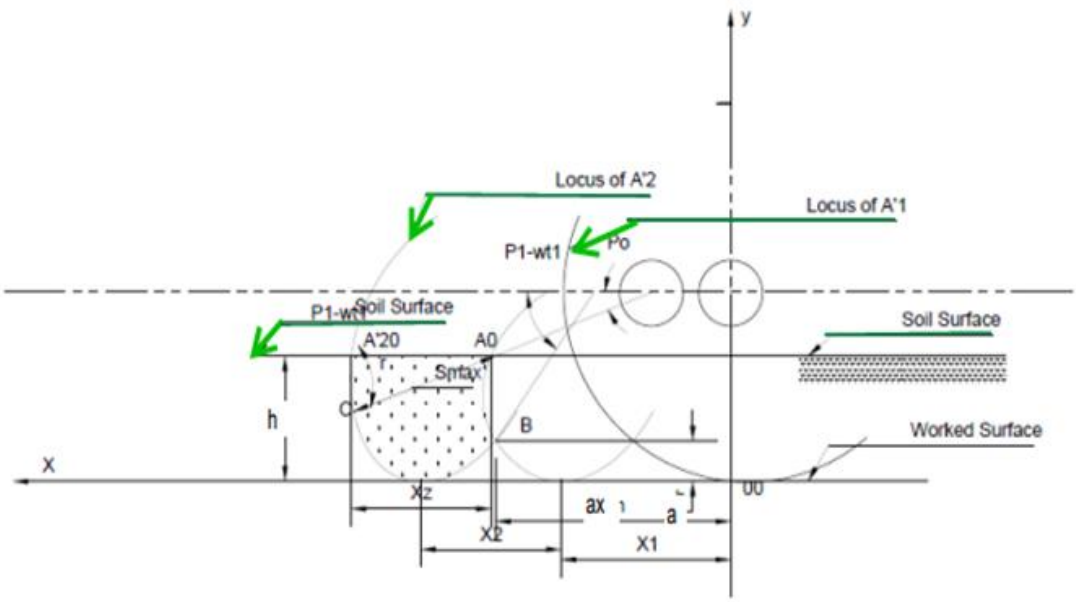


Fig. 3.16. parameters of soil slice

3.4.3.8. Estimation of Force Required to Drive the Weeder

The wheel covers 1.696m in one revolution and taking a 6.3m/s forward speed of motorized rotary weeder determined in equation (3.53) (Kefyalew, 2014), we have 23 RPM.

$$P = T * Nw \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.53)$$

$$= (10.7) * (23x2\pi/60) \quad = \ 26.59W \ = 0.02659 \text{ Kw}$$

where: N_w= wheel shaft revolution, 23 RPM

P = Power requirement (Kw)

3.4.3.9. Criteria for Ergonomic Design

1. Design within the capability to operate handle push by human power.

2. Use of proper posture of the operator for efficient performance of the machine/weeder at a lesser fatigue.

3. Suitability of the Machine/weeder for workers for varying age and body dimension.

4. The time when the crops for weeding was recommended.

5. Suitability of the row to row dimension for weeding.

Table: 3.4. Agronomical requirement of selected weeding

S. N	Types cereal crops	Dimension row to row during seeding/planted	Dimension row to row during weeding	Duration of weeding after seeding/ post emergence/
1	Wheat	18-20 cm	12 cm	20-30 days
2	Barley	18-20 cm	12 cm	20-30 days

3.4.3.10. Cutter Selection:

Assume maximum force to be required to cut the weed is 4 kg, (9.81 5)

Torque required to cut the weed by force given in eq. (3.54), (3.55), (3.56) and (3,57) as follow;

$F = mg$………………………………………………………….………………..………. (3.54)

Where: F= force require for cutting

m = mass cutting weeds

g = acceleration gravity

$F = 5 \times 9.81$ =49.05 N

$T = F \times R$ ………………………………………………..………………………… (3.55)

Where: T= torque required for rotary shaft

R=radius of cutter blade

$T = 49.05 \times 0.12$ = 5.88 N-m

Let we have the motor range specifications given below,

Assume speed of blade motor =715 rpm.

We know that,

P= $\frac{2\times\pi\times N\times T}{60}$ …………………………..……………………………………………...(3.56)

Where: P= power required

N = Motor speed

P= $\frac{2\times3.14\times715\times5.88}{60}$=243.04 watt

We have standard motor available in market of power 2233.5-watt N =300 - 600 rpm

$2233.5 = \frac{2\times\pi\times N\times T}{60}$ ……………………………………..………..…………... (3.57)

$2233.5 = \frac{2\times3.14\times300\times T}{60}$= 71.13 N-m

Torque(T)= 71.13Nm

3.4.3.11. Operational Energy

The energy requirement for planting operation per hectare was calculated for developed machine. The energy was determined in equation (3.58) by Navneet (2016)

$$\text{Machine energy (MJ/ha)} = \frac{W}{L_f} \times Hr \times EE \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3.58)$$

Where: W = Total weight of implement, kg

L_f = Total useful working life of implement, h

Hr = Hours of useful life of implement h/ha

EE = Energy equivalent (MJ/ha)

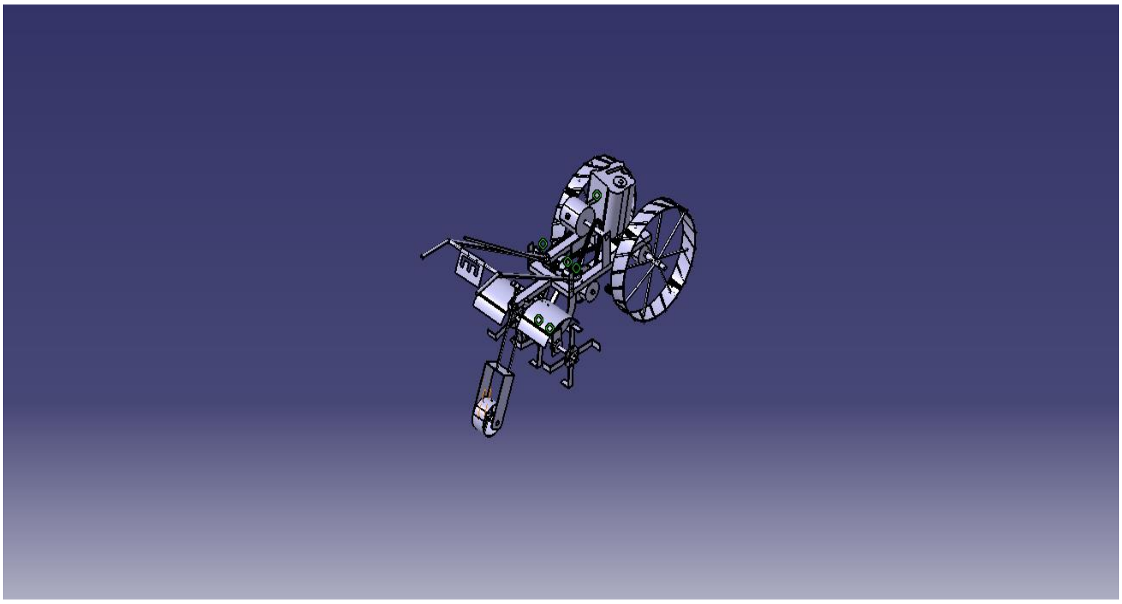


Fig .3.17. Development of motorized rotary weeder using CATIA V5R20.

3.4.3.12. Power Transmission System

The power transmission in the existing power weeder was done by chain and sprocket system. it was shown satisfactory result in transmitting the adequate power for weeding purpose. A coupling is used to transmit power from engine to gear box unit by joining both the ends of the shafts in coupler and is locked by one side.

The 65mm diameter sprockets (S_1) were attached on the sides of gear box shaft. Sprocket (S_2), power is transmitted by means of chain and a 180 mm diameter sprocket installed on the mid shaft and then diameter sprocket (S_3) on middle shaft the diameter is 65 mm transmit power to sprocket(S_4) 200mm diameter which is fixed on the ground wheel axle shaft for providing power to wheel. For power to the rotary cutting unit, used by chain is attached directly from middle shaft the left side sprocket (S_5) of 65 mm diameter sprocket (S_6) on the rotary blade shaft. The required rpm, diameter of sprocket, number of teeth on sprocket were determined in eq. (3.59), (3.60) obtained by using the following relationship (Khurmi, 2005).

$$N' = N'' \times \frac{D2}{D1} \quad \text{...} \quad (3.59$$

Where: N' = rpm of the driven sprocket

N''= rpm of the drive sprocket

D_1 = diameter of the driven sprocket

D_2 = diameter of the drive sprocket

For obtaining the number of teeth on the sprocket the following relation may be use.

$$N' = N'' \times \frac{T1}{T2} \quad \text{...} \quad (3.60)$$

Where: N'= rpm of the driven sprocket

N'' = rpm of the drive sprocket

T_1= number of teeth in drive sprocket

T_2= number of teeth in driven sprocket

Schematic diagram of the power transmission system is shown in (Fig. 3.18) The different diameters of sprocket used were given below:

Diameter of sprocket on gear box (left side), S_1 = 65 mm

Diameter of sprocket on mid shaft, and, S_2 = 390mm, S_3= 65 mm and S_5 = 65 mm

Diameter of sprocket on ground wheel shaft, S_4 = 250 mm

Diameter of sprocket on blade shaft, S_6 =50 mm.

By substituting, the above values in equation (3.61). The range of rpm for various shafts and number of teeth for different sprockets were obtained respectively as given below.

Rpm on engine shaft, A=	2200 (rated rpm)
Rpm on gear box shaft, B=	550
Rpm on mid shaft, C =	92

Rpm on rotary blade shaft, D = 715

Rpm on ground wheel, E = 23

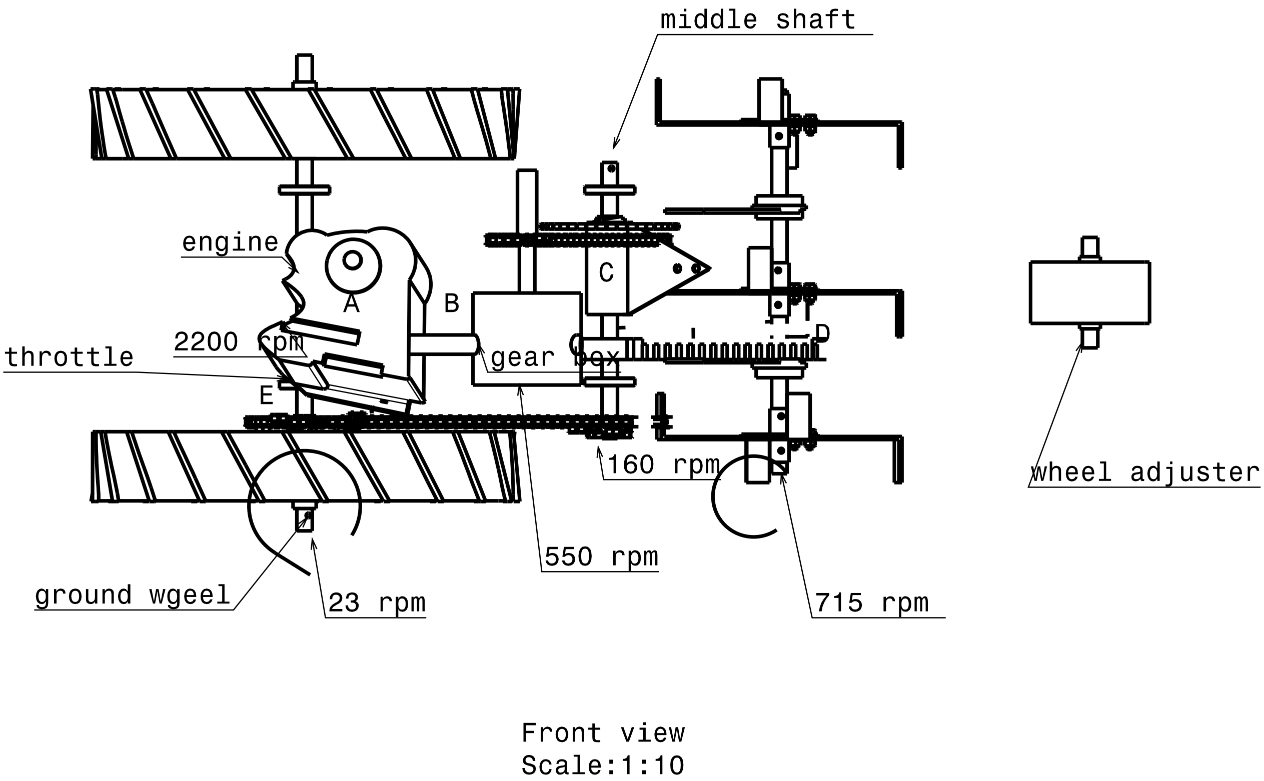


Fig.3.18. Transmission power system

Thus, the final reduction of rpm from engine (2200 rpm) reduced to 550 rpm at gear box, 23. rpm at ground wheel and 715 rpm at the rotary cutter shaft (rotary blades. By substituting, the above values in equation (3.61), (3.61). The numbers of teeth on sprockets were obtained as follows.

Number of teeth on sprocket of gear box, S_1=14

Number of teeth on sprocket of mid shaft S_2= 84

Number of teeth on sprocket of mid shaft, others S_3 = 14 and S_4= 65

Number of teeth on sprocket of ground wheel, S_5= 48

Number of teeth on sprocket of rotary shaft, S_6= 12

The power transmission by designed chain and sprocket system in rotary power weeder is shown in (Fig.3.18).

3.4.3.13. power Considered Selection of Chain Driven

A power equivalence of 5 hp (3.7 KW) for an engine was considered, at 23 rpm wheel shaft of driven by manual motorized weeder and blade shaft at 715rpm.

$$\text{Power rating of the chain } = \frac{KW\ to\ be\ transmit \times kt}{k1 \times k2} \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.61)$$

$$= \frac{3.7335 \times 1.0}{1.25 \times .85} = 3.514 \text{ kw}$$

Where: kt= Service factor = 1.0

$k1$= Multiple strand factor = 1.25

$k2$= Tooth correction factor = 0.85

The sprocket was selected as 12 teeth. It was further assumed that the chain is a transmitted power from engine to wheel shaft and blade shaft as the standard. The power rating of the chain 08B at 23 rpm and 2200 rpm are 3.5 kw. Therefore, the 08B simplex chain is manufactured in accordance with International Organization for Standardization (ISO) R606 so all 08B chains interchange with each other the chain number 08B was selected Appendix. C2. (Table 1). Dimension of this chain were given by

Pitch (P): 12.7mm

Roller Width (W): 7.75mm

Roller Diameter (D): 8.51mm

Pin Diameter (E): 4.45mm

Plate Height (H): 11.8mm

Roller diameter of sprockets: 65mm and 390mm

For 12 teeth

$$\text{Pitch circle diameter } = \frac{12.7}{sin\frac{180}{14}} \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.62)$$

$$=3.6 \text{ mm}$$

Chain Force

The chain force is calculated by using (Sharma and Mukesh *et al.*, 2010). The total load (force) on the driving side of the chain is given by:

$$F_T = F + F_C + F_f \text{……………………………………………………………………}(3.63)$$

where : F_T= the total force, N

F = the force due to power transmission, N

F_f= Frictional force, N

F_c=Centrifugal force on the chain, N

$$F = \frac{P}{v_{av}} \text{…………………………………………………………………………}(3.64)$$

$$= \frac{243.04 \text{ watt}}{1.87 \text{ m/s}} = 125.15 \text{ N}$$

$$F_C = \frac{W \times {v_{av}}^2}{g} \text{…………………………………………………………………………}(3.65)$$

$$= \frac{3.924 N/m \times (1.87 m/s)^2}{9.81 \frac{m}{s}} = 0.748 \text{ N}$$

$$F = W \times k_f \times C_c \text{…………………………………………………………………………}(3.66)$$

$$= 3.924 \text{N/m} \times 2 \times .2575 \text{ m} = 2.020 \text{ N}$$

Where: Cc = Nominal center to center distance between the sprockets, 0.257 m

P= Power at weeder wheel/ power to be transmitted, 343.04 w

kf= Friction factor= 4 for horizontal drive, 2 for inclined drive kf =2 (Norton, 2005).

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

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

Thus, F_T = 125.15 N+ 0.748 N + 2.020 N = 127.9 N

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

$$S_f = \frac{Tensile\ strength}{F_T} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.67)$$

$$= \frac{3470}{127.9} = 27$$, the value is greater than unity. It is safe.

3.4.4. Details of Fabrication Machine Components in Work Shop

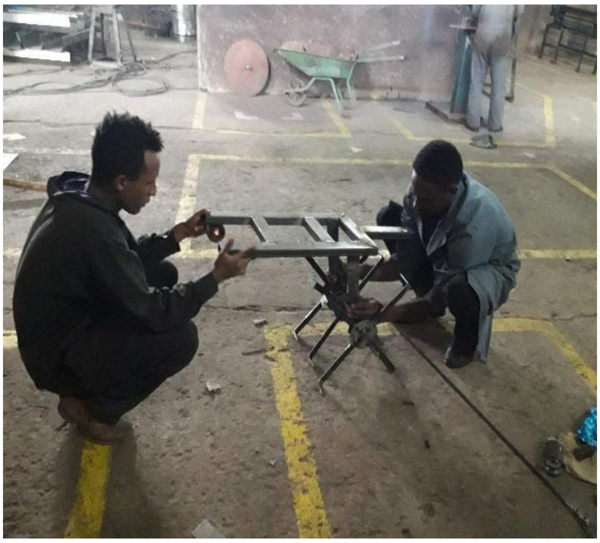


Fig. 3.19 Frame, sank and blade part manufacture

Fig.3.20. Fabrication of motorized rotary weeder component in AAERC workshop.

3.4.4.1. Construction CATIA and Assembled of the Developed Components

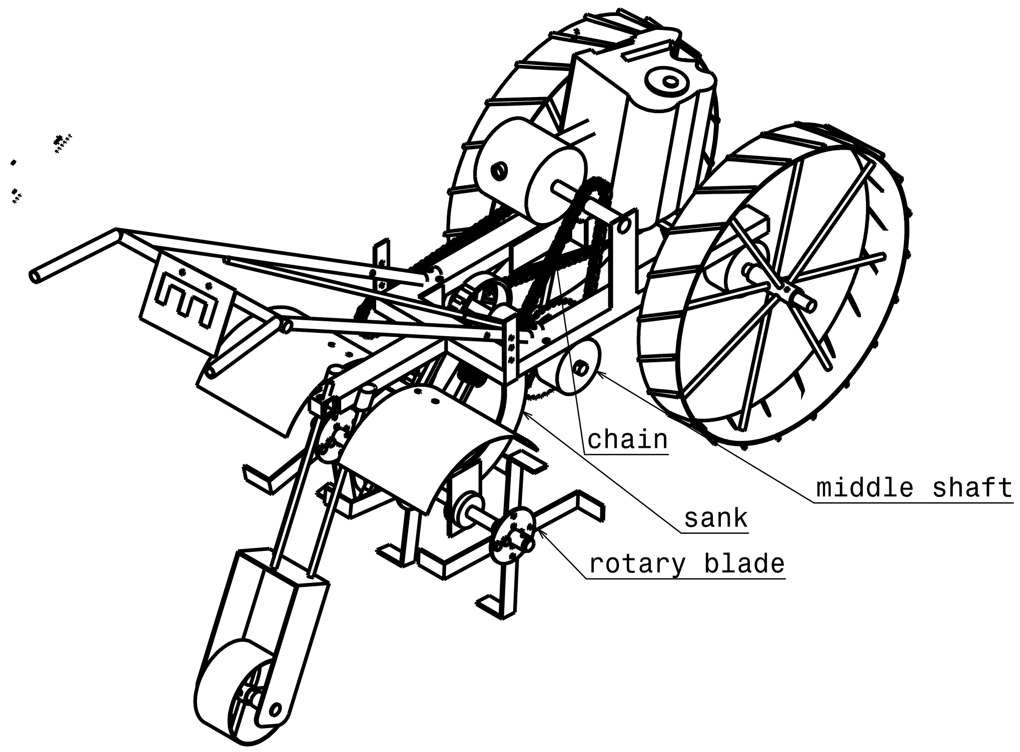


Fig.3.21. Motorized Rotary Weeder machine isometric view

3.4.4.2. Description of the Machine Designed and Developed

Based on design values of different components, an engine operated Motorized rotary weeder is fabricated in the workshop of Asella Agricultural Engineering Research institution and Adama Science and Technology University and Program of Agricultural Machinery Engineering, MVSE Department. A power source of 5 hp, 2200 rpm, two-stroke petrol engine was selected, which was capable of providing the required power. The materials used for fabrication are mostly of mild steel and metal iron. Each of the major components was designed, fabricated and then assembled properly. The technical specifications of the engine are shown in (Table 3.5)

Table 3.5. Technical specifications of the machine

S. N.	SPECIFICATION	VALUE
1	Number of cylinders	One
2	Engine maximum power at 3000 rpm	5 hp
3	Revolution per minutes	715 rpm
4	Weeding speed	17.9 km/hr
5	Travel speed	2.3km/hr
6	Weeding depth	2.5-3 cm
7	Power transmission	Chain and sprocket
8	Fuel tank capacity	3.6 liter
9	Fuel	Gasoline
10	Width of weeding	120-130 mm between one row
11	Materials of blade	Mild steel L- shape blade
12	Materials Frame	Mild steel
13	Materials of shaft	Mild steel
14	Materials of wheel	Mild steel
15	Over all dimension	1230mm×560mm×900mm
16	Total weight	33.4 kg /328.2 N

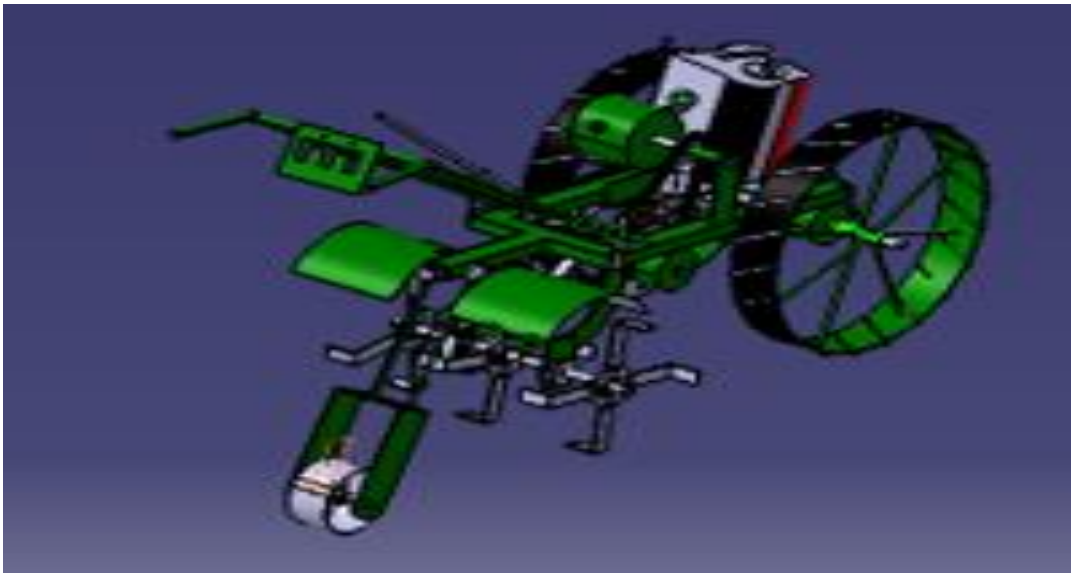


Fig .3.22a. Development of Motorized Rotary Weeder using CATIA V5R20 painted

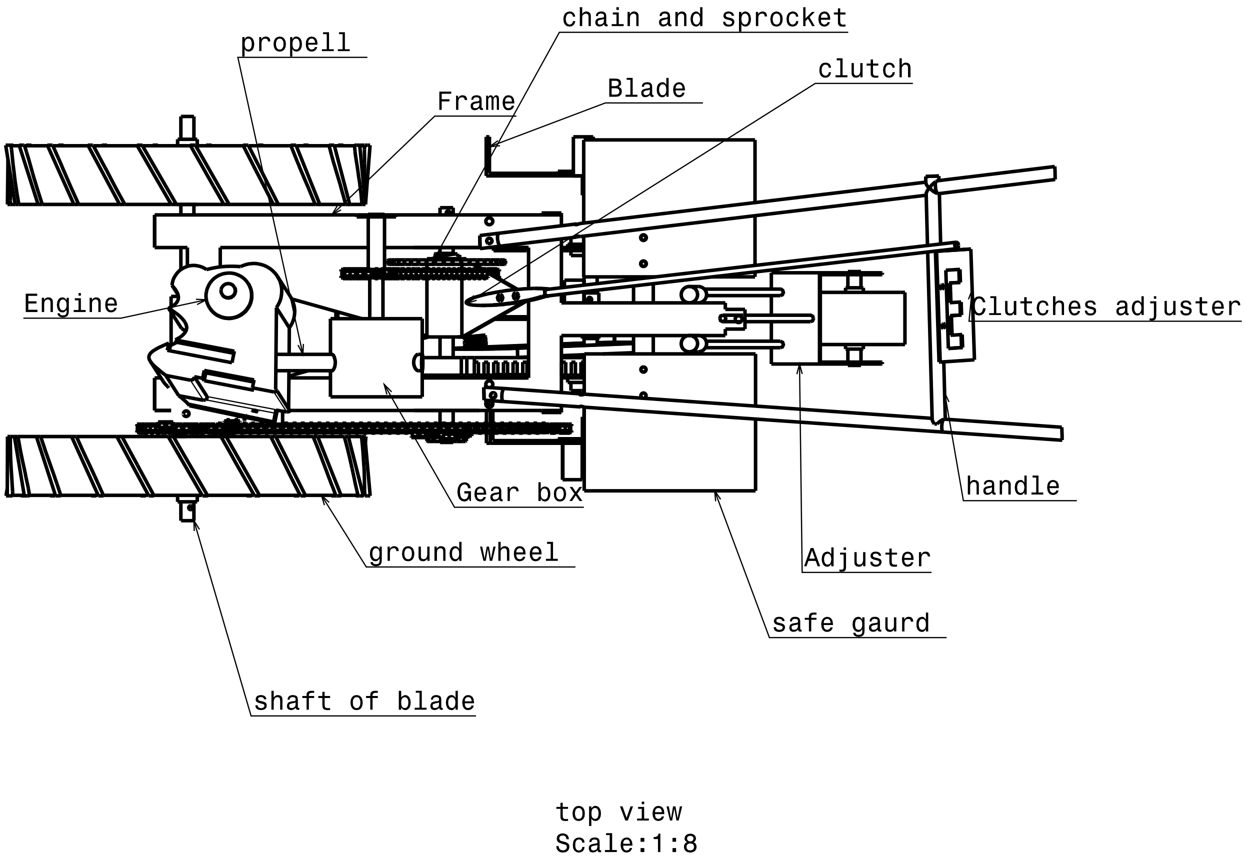


Fig. 3.22b. Top view Motorized Rotary Weeder

The accompanying views and photographs show the general constructional features of the machine. The designed and developed motorized rotary weeder (Fig.3.22)

3.4.4.3. Fabrication of the Machine

CATIA V5.20 design and drawing (Fig.3.22a) was used for the design, development and fabrication of the motorized rotary weeder for cereals crops (Fig.3.22). The different component of the planter mentioned in previously described subheadings was fabricated and assembled in the workshop of Asella Agricultural Engineering Research Institution. Assembled view of mechanical motorized rotary weeder for row planted cereal crops shown in (Fig.3.23). The details of specification of developed machine is given in Appendix-E. and assembled of the motorized rotary weeder.

3.23a.　　　　　　　　　　　　3.23b.

Fig.3.23. Design, development MR Weeder during on the field

3.5. Experimental Factors of Field Test

The weeder was operated and driven by engine power. Three different operating speeds were found out at different sprockets, gear ratio and throttle position. The 1.5 km/h, 1.78 km/h and 2.3 km/h speed were selected for weeding operation and effect of different operating speed on weeding rate, weeding uniformity and crops damage was observed. The best results' giving operating speed was chosen for weeding wheat crops. At each speed three replications were taken. The weeding of different row of wheat was carried out in field. For each row, the weeding space was calibrated, theoretical field capacity, effective field capacity, field efficiency and power requirement were found out. The following parameters were determined before weeding: Type of soil, Soil moisture content in per cent, Bulk density, Depth of weeding, Method weeding and Size of plot.

3.5.1. Observation Recorded

During the testing, field observation as well as machine parameters were recorded for the performance evaluation of three treatments. The field observations recorded are as follows:

3.5.1.1. Plant Population

The total numbers of plants were counted in an area of one square meter by a quadrate of $1m^2$ from randomly chosen places in each plot, before and after every weeding operation to observe plant damage percentage.

3.5.1.2. Weed Population

Weed population per square meter was recorded randomly from each plot with help of 1m^2quadrate, 20 DAS. All the weeds present, in each plot were grouped under grasses, sedges and broad leaf weeds.

3.5.2. Soil Characteristics and Pertinent Properties

The parameters (Soil and site characteristics) record before weeding operation are the crop parameters (plants height and row to row spacing) and field parameters [type of soil, moisture content (MC), bulk density (BD) and cone index (soil strength) of soil and length, skid resistance and width of the field]. For determining the mechanical properties of the soil, samples were collected randomly from each plot of the experimental field at different depths 5 cm and 10 cm with the help of soil auger. Soil samples were analyzed for the mechanical analysis. The physical -structure properties of the soil laboratory result are present in the below diagram Fig.4.24.

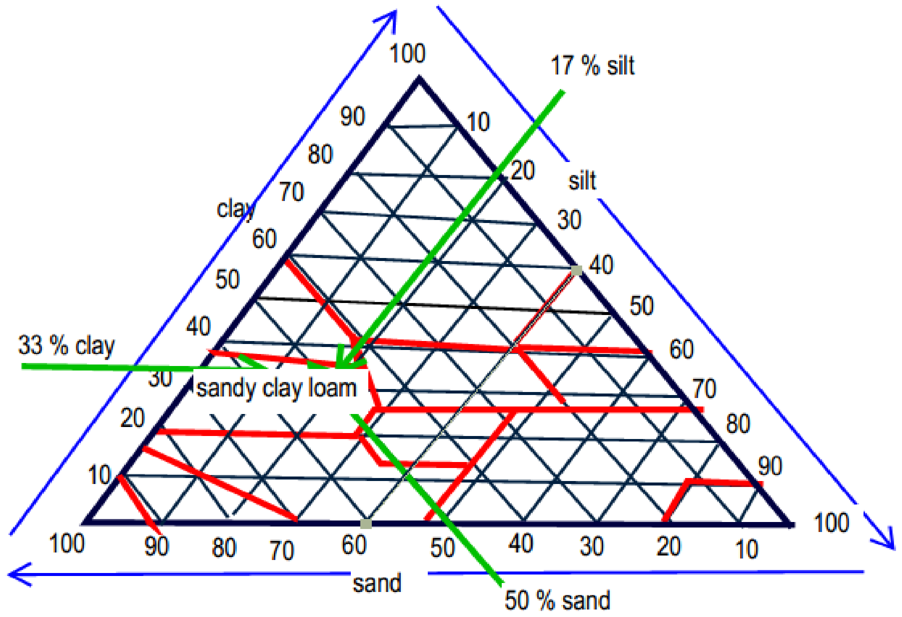


Fig. 3.24. Soil textural triangle diagram from soil laboratory result

Performance indicators used for this experiment includes the following: To determine the MC, BD and cone index of the soil using by equation (3.68), (3.69) (Ojomo *et al*.,2012) are used respectively.

$$MC = \frac{W1 - W2}{W1} \times 100 \quad (3.68)$$

$$\rho = \frac{\text{weight of sampled soil after laboratory drying,gm}}{\text{volume of cylinder core,cm}^3} \quad (3.69)$$

Where: MC = moisture contents (%)

W1 = weight of the wet sample, mg

W2 = weight of the oven dry sample, mg

ρ = bulk density of soil, mg/cm^3

3.6. Performance Test and Experimental Analysis

The performance evaluation of the constructed Motorized Rotary Weeder was conducted on the experimental field of Asella Agricultural Engineering Research Center (AAERC). The site was located 76 km away south of Adama. It's found at an elevation of 2430 m above sea level with point locations of 7° 57' 0" N latitude and 39° 7' 0" E longitude.

The average annual rainfall in the area ranges between 1300 and 1350 mm annually. Sandy clay loam soil textures are the dominant soils of the area. The site has a suitable land and summary rain system. It has also the availability of well-organized laboratory, technician and labor access for the fabrication and testing of the prototype.

3.6.1. Data Collection and Analysis

After field experiment, collected data was analyzed with the help of Design Expert software and statically analysis was also carried out considering factorial design to assess the effect of different parameters on the performance of developed MR weeder.

3.6.1.1. Testing the Prototype

After the machine was constructed, the next activity would have been tested the performance of the prototype. The machine has had been tested in workshops and in actual field condition. In workshop, using by measurement tape (with millimeter graduation) the accuracy all dimension would have been investigated. The actual field tests of the machine were conducted on 10x40 m plot. The experiment will be conducted under a Randomized Complete Block Design (RCBD) and the treatments would be replicated thrice in each block as per layout.

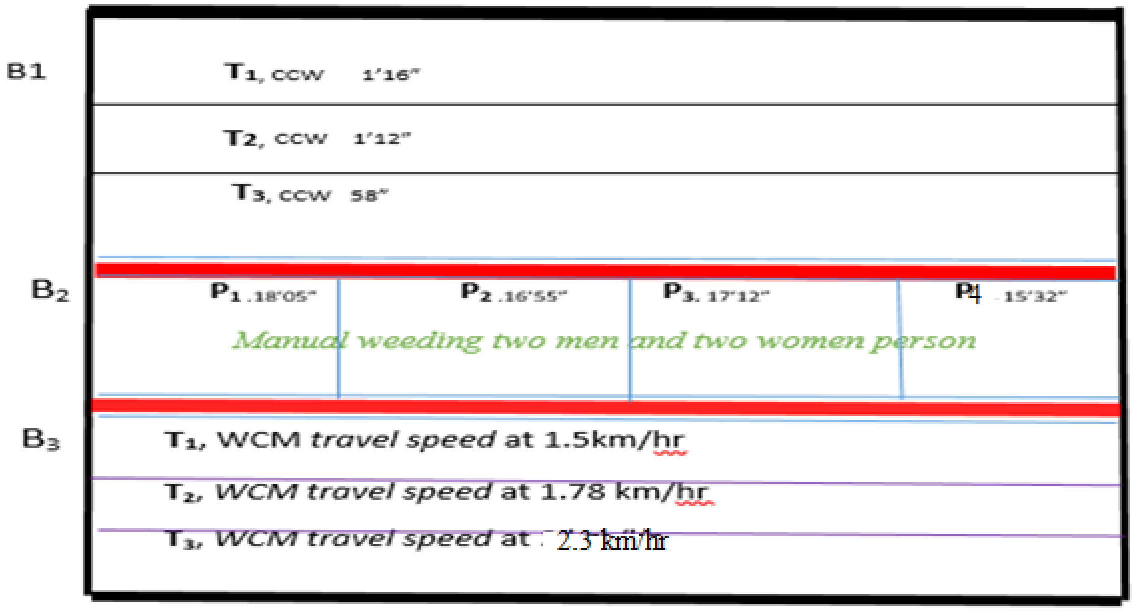
The treatments would be as follows:

Trial-1 =weed control using herbicides
Trial-2 = Manual weeding weed controls
Trial-3 = weed control using mechanical control

During operation the data on pushing force, damage plant, weeding rate, actual weeding time, turning time and adjusting times were collected in order to calculated the effective field capacity, field efficiency, slippage and destroyed weeds. The data recorded from the experiment would be subjected to analysis by using MS. Excel and R -software.

3.6.1.2. Experimental Design

The performance evaluation of the constructed motorized rotary weeder was conducted on the experimental field of AAERC.



Where:- B= block 1, 2 and 3 CCW, MW and WCM respectively

T= Treatment in each block 1, 2 and 3 respectively

‘ P=person 1&2 men and 3&4 women, ’=minute & ”= second

Fig.3.25. Experment design diagram RCBD plot size sample representation

The experimental area was infested mostly with weeds like muja, marga gogori, ballami, sidisa, ada (tufo), cokorsa, bokite, serdo, balwarinte cynosures echinat (thorny pig weed) and others weeds. Prior to each weeding schedule, weed density in each experimental unit was determined by laying-out a squared grid (1m × 1m) in the plot and weeds in the grid were counted. Three such determinations were made for each experimental unit. (Appendix. F. Table F.2)

3.6.2. Performance Evaluation of Weeding Systems

In order to evaluate the performance of developed MR Weeder cereal crops was chosen and experiments were carried out at Asella region Instructional Farm of AAERC, during year 2018. The overall performance of the Weeder was evaluated on the basis of weeding efficiency, crops damage, wheel slippage, field capacity and field efficiency by varying forward speed. The developed weeder was able to weeding three rows at a time placed at 12.5 cm distance. Thus, effective width of the machine was 37.5 cm. The data obtained from the experiments for harvesting losses and machine performance parameters are given in Appendix-F. The effect of different parameters and their interaction was also assessed statistically tables are given in Appendix-H. The effect of different independent parameters on different parameters under study is as discussed as below.

3.6.2.1. Weeding Efficiency and Plant Damages

The performance to evaluates motorized rotary weeder crops field (4 weeks after sowing) at two operating conditions (three row weeding condition) to determine their effects on weeding efficiency, plant damage, effective field capacity, field efficiency and cost economics of weeding operation. The weeding efficiency and plant damage in per cent will be calculate by using formulae equation (3.70), (3.71) (Goel, 2008, Gavali and Kulkarni 2014, Kumar *et al.*, 2014) respectively.

$$\mathrm{WE} = \frac{ni - n2}{ni} \times 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.70)$$

$$\mathrm{PD} = \frac{Q1}{Q2} \times 1OO\% \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.71)$$

Where: WE = weeding efficiency, %

n1 = number of weeds before weeding

n2 = number of weeds after weeding

PD = plant damage, %

Q1 = number of injured plants in 10 m row length after weeding

Q2 = total number of plants in 10 m row length before weeding

3.6.2.2. Effective Field Capacity

Effective field capacity is the actual average rate of coverage by the machine, based upon the total field time. It is a function of the rated width of the machine, the percentage of rated width actually utilized, speed of the travel and the amount of field time lost during the operation. Effective field capacity is usually expressed in eq, (3.72) as hectare per hour (Kepner,1978).

$$\mathrm{EFC} = \frac{A}{Tp + Ti} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.72)$$

Where: EFC = Effective field capacity, ha/hr

A = Actual area covered, ha

Tp = Productive time, h

Ti = Non-productive time, h

3.6.2.3. Theoretical Field Capacity

Field capacity ha/h is computed in equation (3.73) (ANISA, 2017). the area to weed during each trial run in a given time interval with the help of stopwatch time is to record for respective trial run along with are cover if the weeder was operating continuously without interruptions.

$$\mathrm{TFc} = \frac{\mathrm{wd(m)} \times \mathrm{S}\,(\frac{\mathrm{km}}{\mathrm{h}})}{10} \qquad (3.73)$$

Where: w =width of weeding

TFc = Theoretical field capacity

S= speed of operation

10= factor calculated as 1ha/km = 10000/1000

3.6.2.4. Field Efficiency

Field efficiency is the ratio of effective field capacity to the theoretical field capacity, expressed as percentage. It includes the effect of time lost in the field and of failure to utilize the full width of the machine.

$$\eta\mathrm{e} = \frac{\mathrm{EFC}}{\mathrm{TFc}} \times 100 \qquad (3.74)$$

Where: η e = Field efficiency, %

EFC = Effective field capacity, ha/h

TFC = Theoretical field capacity, ha/h

3.6.2.5. Performance Index

The performance index of the weeder should have been calculated by equation (3.75) (Gupta, 1981).

$$\mathrm{PI} = \frac{\mathrm{a} \times \mathrm{q} \times \mathrm{e}}{\mathrm{p}} \qquad (3.75)$$

Where: PI = performance index

a = field capacity of weeder, ha/hr

e = weed efficiency per cent

q = plant damage factor 100-%plant damage

p = power required to operate the weeder, hp.

3.6.2.6. Operating Speed

The operating speed of weeding was carried out by observing the time required for traveling 40 m distance with the help of stop watch along the longest direction.

3.6.2.6.1. Wheel Slip

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

$$\text{Wheel slip} = \frac{m0-m1}{m0} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.76)$$

Where: m_0 = wheel revolution with no push

m_1 = wheel revolution with push

3.6.2.6.2. Wheel Skid

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

$$\text{Wheel Skid} = \frac{L_2-L_1}{L_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.77)$$

where: L1 = Actual distance covered, m

L2 = Theoretical distance covered for the same number of revolutions, m

3.6.2.7. Total Operating Time

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

3.6.2.8. Fuel Consumption

The fuel consumption was measured as per the standard method by observing the fuel required for traveling 40 m long distance. A known volume cylinder was directly attached to fuel tank and was filled up to some level by keeping the motorized rotary weeder on level land and after completing the operation, final measurement of cylinder was noted down. The volume of fuel used was taken into account as fuel consumed for a particular time period.

3.6.2.9. Lubricants

It can be determined depending upon the maintenance cost or depending upon the oil price or oil consumption. Average lubrication cost is taken as 1.5% of 15.54 fuel cost in EB/h.
(Kamboj *et al.,* 2012)

3.7. Energy Consumption

For each weeding treatments, the calculation of energy requirement was done by taking the observation as follows. For hand weeding, only man power was required. The total time taken during the weeding operation was noted. For CCW, time taken for the operation, number of destroyed weeds and number of labor requirement and effective on environment air condition were taken into account. Mechanical Weeding (Motorized Rotary Weeder) For cereals crops motorized rotary weeder, the total time taken for the operation, weight of machine, total fuel consumption and number of labors required was taken for energy calculation. The measurement of fuel consumption in respect of power was done on standard plot size of field. Data collection regarding weeding operations was multiplied by respective energy conversion coefficient as suggested by Mittal (1985). Energy equivalents of different inputs are given in the Appendix-D

3.8. Operational Cost

Cost of weeding operation performed for all treatments was worked out on the basis of the prevailing input and fabrication price of the implements, machinery and rental wages of operator and labours if required. The cost of operation of power weeder is divided into two heads known as fixed cost and operation cost, where fixed cost is independent of operational use while variable cost varies proportionally with the amount of use (Kamboj *et al*., 2012). The fixed cost includes depreciation, interest on the capital cost, insurance and taxes. Operation cost includes, fuel, lubricants, repair and maintenances cost, wages. Cost of weeding operation for power weeder was calculated in 254.67 EB/ha. Operation cost of the power weeder was calculated and given in appendix – E1

3.8.1. Cost Analysis

Cost analysis was done on the basis of fixed and variable costs of equipment. The cost items include purchase price of the machine, salvage value of the machine, machine life (year), interest rate (%), repair and maintenance cost, and labour cost. Straight line method was used for determining the depreciation cost. Salvage value assumed as 10 % of the purchase price. Insurance, taxes and assumed negligible. Repair and maintenance have been assumed as 5% of purchase price per year. Labor charge has been cons as per the prevailing rate per day (8hr work) annual operation cost of the equipment has been considered as 720 hr based on maximum 90 days on daily 8 hr works of actual use of equipment. The following equation was used to determine the cost operation:

A. Fixed Cost

$$Dp = \frac{P-S}{L} \quad (3.78)$$

$$I = \frac{P+S}{2} \times i \quad (3.79)$$

Where: D_p= Depreciation,

P= Purchase price,

S= Salvage value,

L= Life, year

I= Interest on investment

i = Interest rate (%)

B. Variable Cost

Variable cost was calculated on the basis of (i) repair and maintenance cost and (ii) operator charge, Birr/ day.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

The Motorized Rotary Weeder was designed and fabricated to developed, Appendix E shows the specification on the motorized rotary weeder. The performance of developed weeder was evaluated in the in the field also described in this chapter, Appendix H. Field performance test was carried out in control condition as far as possible. The traditional method of weed management practice such as, hand weeding, chemical control and mechanical weeder weed is compared with motorized rotary weeder for controlling weed.

The performance of the motorized rotary weeder and other different weed management practices are expressed in terms of weeding efficiency, plant damaged, field efficiency, fuel consumption, energy consumption, cost of operation and energy cost ratio. The field test results of development motorized rotary weeder are depicted in Appendix. G1and G2. In motorized rotary weeder, the power transmission mechanism, (chain and sprocket), rotary cutting blades ("L" shaped), rotary shaft supporter, handle height adjustments for convenient operation, weeding depth adjustments and other accessories such as throttle system for engine speed control are the developmentation of the available motor weeder.

Due to these developed the motorized weeder worked satisfactorily than previously designed. The designed power weeder is well suited for cereal crops planted in row. By using the chain and sprocket system the power transmission was adequate to work in the 26 to 38% moist soil (wb). The behind mounted, three units of cutting blades fulfilled the weeding process satisfactorily by cutting and uprooting weeds. The sharpened ends provided on the cutting blades helped to cut the soil and provided a minimum tillage in between the crop rows. By raising and lowering the gauge wheel, the depth of cut was significantly contributed the weeding operation of the weeder.

4.1. Field Performance Test of Motorized Rotary Weeder

The machine was tested on the experimental plot of Farm land wheat crops of AAERC. It was observed that the machine worked satisfactorily for weeding in 38% to 42% moisture content (db) in the field. The field test result of the developed power weeder is furnished in Table B.1. (Appendix B. Table.1).

4.1.1. Physical Properties of Soil of Experimental Site

4.1.1.1. Moisture Content and Bulk Density of Soil

During carrying out the experiments, the soil conditions of the experimental field were studied and different parameters indicated in the table 4.1 below.

Table:4.1. Moisture content and the bulk density of the soil

Observation	Weight of a soil (gm)	Weight of soil after oven dry (gm)	MC		Volume (cm^3)	Bulk density (gm/cm^3)
			Wet base (Wb %)	Dry base (Db%)		
1	361	254	29.63	42.12	192.42	1.32
2	390	279	28.48	39.78	192.42	1.45
3	376	263	30	42.96	192.42	1.37
4	380	275	27.63	38.18	192.42	1.43
5	390	279	28.48	39.78	192.42	1.45
CV	3.2	4.3	3.7	5.3		4.2
Average	376.75	267.75	28.93	40.76	192.42	1.39
S. D	12.038	11.413	1.084	2.184	0	0.059

Moisture content on dry basis of soil was measured by oven dry method. Five soil samples were taken randomly at 5 different locations in the plot using core sampler of 7.0 cm diameter and 5 cm height. Moisture content at 5 different places was found to be 29.63%, 28.48%, 30%, 27.63% and 28.45% on wet basis respectively. The average moisture content of the experimental field was 28.9%. Bulk density of soil was measured by core sampler. Bulk density of soil was found to be 1320 kg/m^3,1450 kg/m^3,1370 kg/m^3,1430 kg/m^3 and 1450 kg/m^3 respectively. Average value of moisture content and bulk density of experimented plot was found 28.9% (Wb) and 1390kg/m3 respectively.

4.1.1.2. Population of Weed

In general, it was observed that the broad-leaved weeds are contributed the maximum of weed followed by grasses and sledges. Weed population at 20 DAS were studied. The common weed species were observed those broad-leaved weeds were: Tufo, bokite, baldima, sidisa, balwarente.

In sedges, margasare, margagogori, balami, Cyprus rotundus and in grasses, Echinochloa colona and other weed were present in test plots. It is evident from (Appendix F. Table 2.) that, the weed population before weeding operation at 20 DAS was maximum as 321 weeds square meter in block B_1 (CCW) which was followed by B_3 (motorized rotary) and B_2 (manual weeding) in each of three treatments as 280 and 304 weeds per square meter respectively.

After weeding operation, observed in B_3 (motorized rotary) and B_2 (manual weeding). In B_3 (motorized rotary) the weed population for T_1 reduced from 304 to 22, T_2 reduced from 219 to 32 and T_3 reduced from 315 to 64 weeds per square meter respectively. In case of treatment B_1 (CCW) after five days in each treatment the average weed reduced from 304 to 115. Also, in B_2 (MWC) the weed population reduced from 238 to 11 weeds per square meter from (Appendix.G1. Table:1).

4.1.1.3. Weeding Efficiency

Weeding efficiency for different weeding operations for 20 DAS are depicted in (Appendix F. Table 3b). It reveals that, for 20 DAS, the weeding efficiency was observed as 94.7 % under the average of three treatments (motorized rotary weeder) and 92.43 % for treatment (T1), 95.85 % for treatment (T2) and 96.19 % for treatment (T3) respectively. The linear regression indicated that the positive relation between weeding efficiency of MRW at different travel speed of the thee treatment showed in Fig. 4.1. The data obtained from the testing were analyzed and the linear regression showed good relation between the travel speed increased in high coefficient of determination (R^2 = 0.9558) were observed at travel speed 1.5 km/hr, 1.78 km/hr and 2.3 km/hr. When were compared the three method of weeding control in Fig.4.2 the maximum weeding efficiency was delineated as 95.4 % B1(for Hand weeding) and the minimum weeding efficiency was 62 % B2(Chemical control weeding) in (Appendix. G. Table: G1)

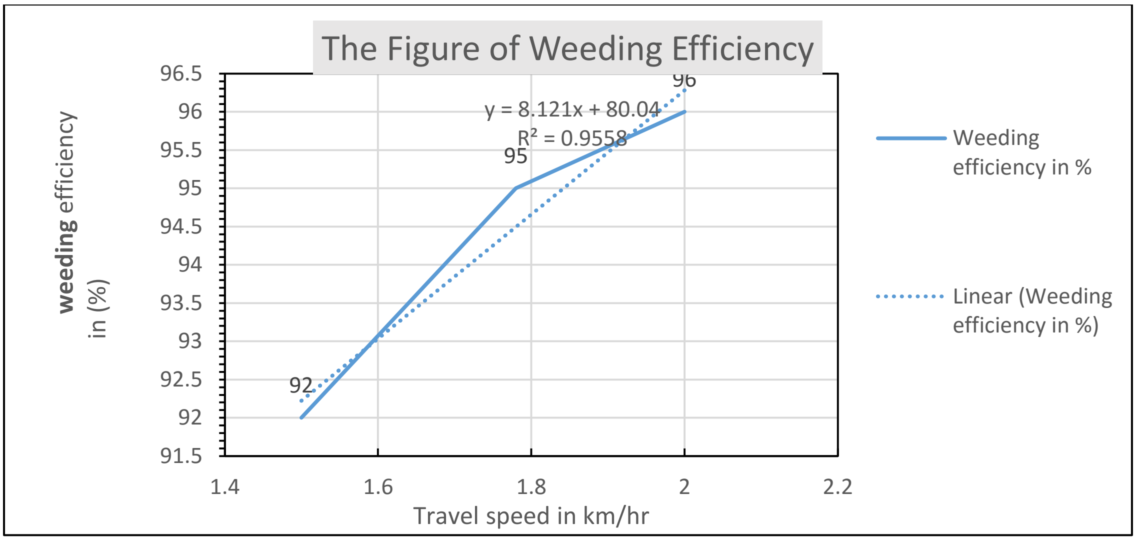


Fig. 4.1. Weeding efficiency in one block of the three treatment of MRW.

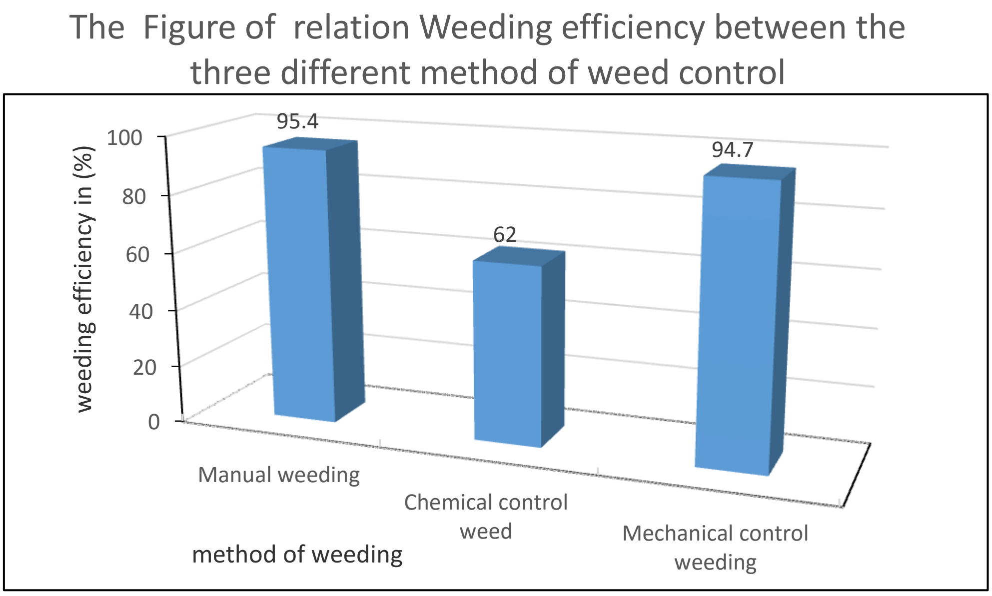


Fig. 4.2. Weeding efficiency, the three blocks of different method of weeding treatment.

4.1.1.4. Plant Damaged

The plant damaged for different treatments are depicted in (Appendix. F. Table: F.3). It indicated that the maximum plant damaged for MR Weeder at 20 DAS was observed as 6.0% under treatment T1, followed by 9.0% for treatment T2 and 18% for treatment T3 (motorized rotary weeder) respectively. The plant damaged for different treatments with in different speeds are given in Fig.4.3

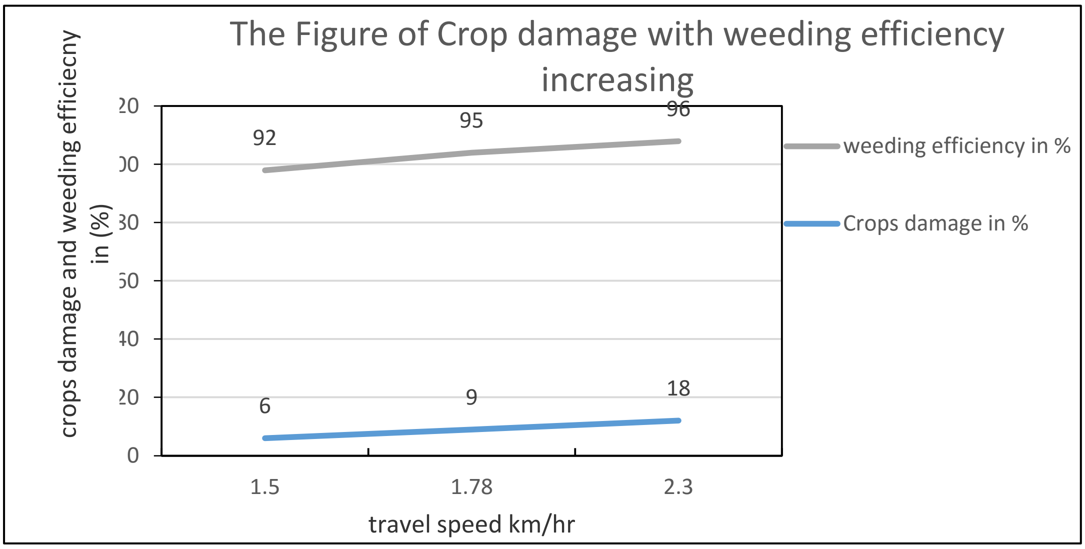


Fig. 4.3. The crops damage with related to weeding efficiency.

4.1.2. Field Capacity

The field capacity for different weeding operations in the three different techniques is delineated in (Appendix G. Table 1). The highest field capacity, for 20 DAS were 0.046 ha/hr in theoretical field capacity and 0.035 ha/hr in effective field capacity for manual weeding, 2.85 ha/hr in theoretical field capacity and 2.56 ha/hr. in effective field capacity for CCW and 0.85 ha/hr theoretical field capacity and 0.73ha/hr for MRW respectively observed. The theoretical field capacity and effective field capacity in different block for different techniques are given in Fig.4.4.

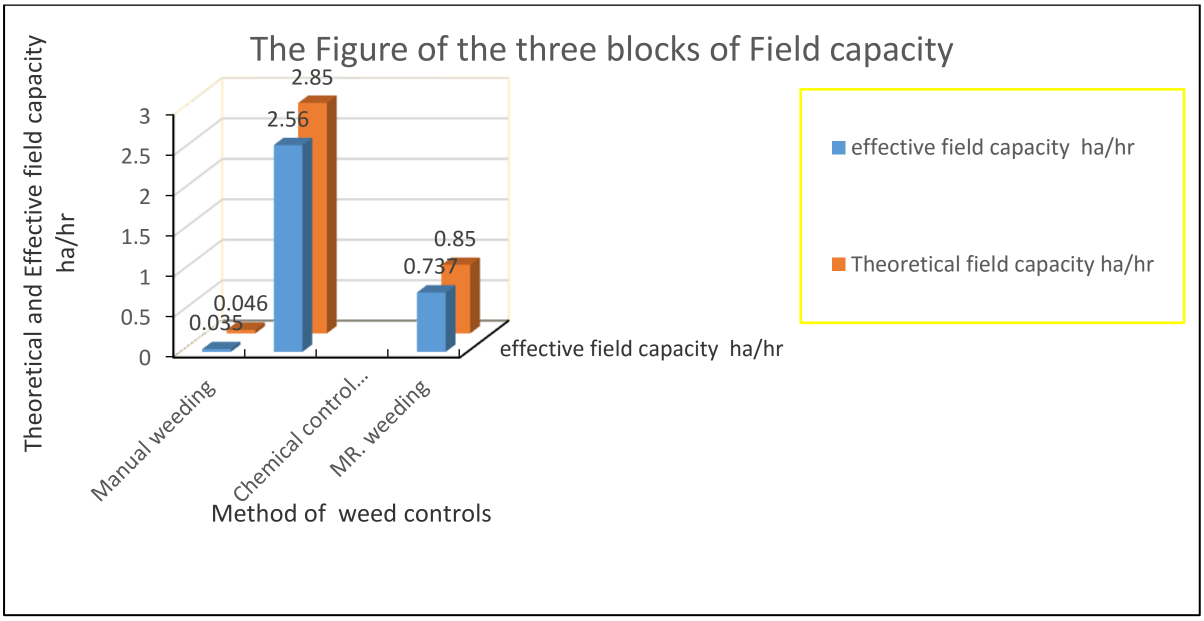


Fig.4.4. The field capacity of the three different techniques

Also, the field capacity for different weeding operations in MRW delineated in (Appendix. G2. Table.1). The highest field capacity, for 20 DAS Treatment T1 were 0.75 ha/hr in theoretical field capacity and 0.65 ha/hr in Effective field capacity, Treatment T2 were 0.86 ha/hr in theoretical field capacity and 0.74 ha/hr in Effective field capacity and Treatment T3 were 0.99 ha/hr in theoretical field capacity and 0.85 ha/hr in Effective field capacity respectively observed. The field capacity was 0.224 ha/hr in (Appendix. H. Table.1). The relation theoretical and effective field capacity of one block with different travel speed given in Fig.4.5.

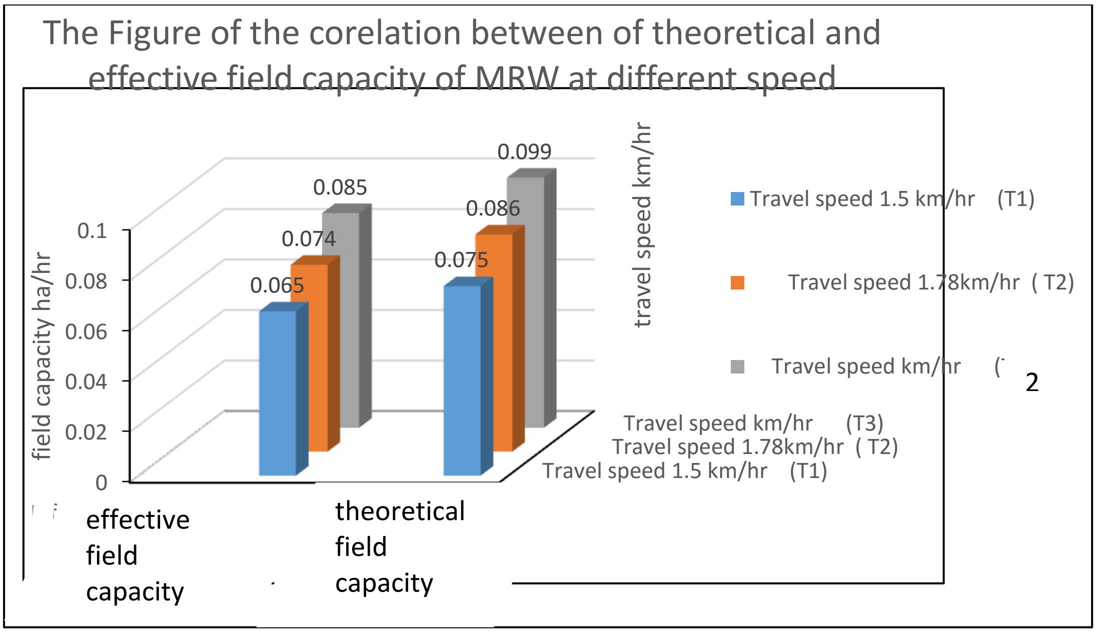


Fig.4.5. The theoretical field capacity and effective field capacity of MR Weeder with different travel speed.

4.1.3. Field Efficiency

The field efficiency for different weeding operations in the three different technic is delineated in (Appendix. G. Table. G.1). The highest field efficiency, for 20 DAS were 76% in manual weeding B2, 90% in CCW B1 and 86.7% in MRW B3 were observed respectively. It also was observed 87% in the treatment (T1) 1.5 km/hr, 86% in treatment (T2) 1.78 km/hr and 85% in the treatment (T3) 2.3 km/hr respectively in (Appendix G2. Table 1). In this regarded as more ideal method in which no machine parameters are included and weeds were CCW and manual weeding, so those method of weeding regarded as 100% efficient which depends on the efficiency of the laborers. But in CCW affected on environmental and manual weeding was labour intensive.

The field efficiency for different treatments are given in Fig.4.6 and Fig 4.7.

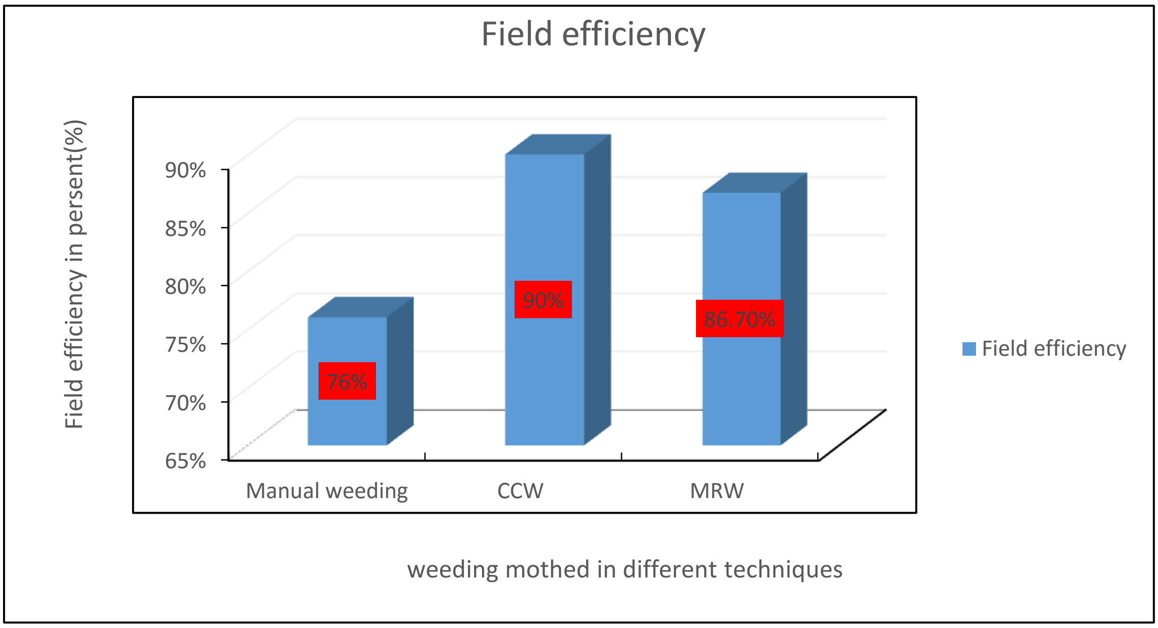


Fig.4.6. Field Efficiency in Different Method of Technique

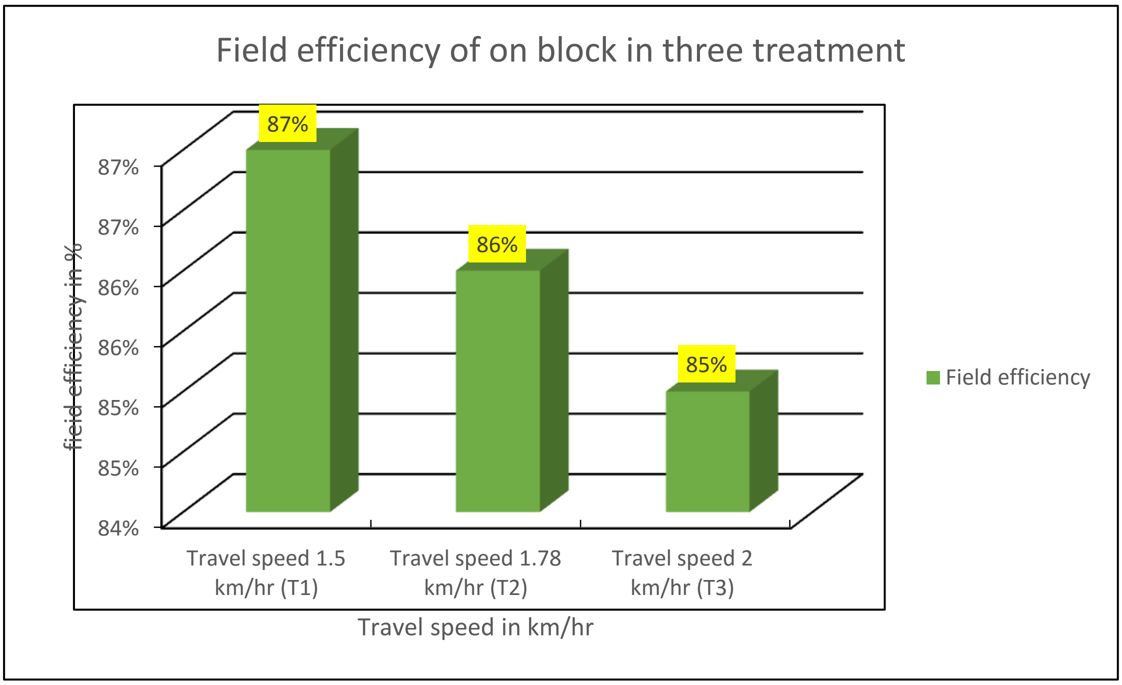


Fig. 4.7. Field efficiency of MRW in three different treatments

4.2. Performance index

The performance index of the MRW machine using equation (3.75) was the same with in the different travel speed expressed in Appendix. G2 Table:1 that PI = 0.31 in three treatments

4.3. Wheel Slip

The wheel slip in present and power required in (kw) to driven of the MRW Machine drawn weeding was determined by using the method mentioned earlier and the results obtained for wheel slip data obtained at different operating speed in power required were shown in (Appendix. F. Table: B.1). The wheel slip and power increased with increase in speed. The data obtained from the testing were analyzed and the linear regression showed the positive relationship between power required and wheel slippage at the different travel speeds increased in high coefficient of determination (R^2 = 0.9995 R=0.8147.) were observed at the both trails respectively. The data showed the concerning effect of speed on wheel slip and power. The minimum wheel's slip i.e. 6.59 % and 1.76 kw, i.e. 6.65% and 2.02 kw and maximum wheel slip i.e.7.28 % and 2.26 kw was observed at speed of 1.5 km/h,1.78 km/hr and 2.3 km/h, respectively. The Fig: 4.8 show that the wheel slip increased with increase in speed and power.

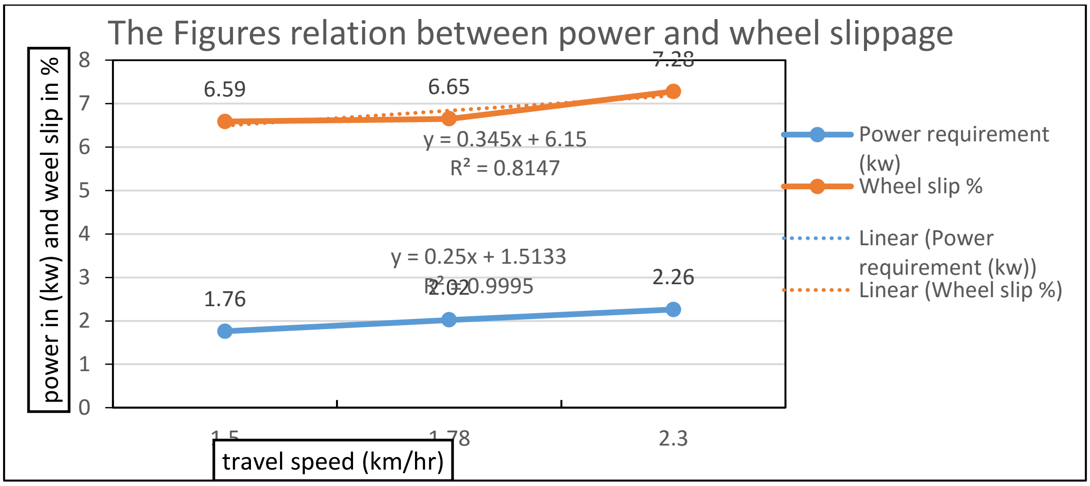


Fig. 4.8. Wheel slips percentage determination with power requirement in different speed

4.4. Total Operating Time

Total operating time for the complete operation of weeding during performance test of the MRW machine was measured actual operating time and time losses from adjustment, rest and turning at headland expressed by minutes in (Appendix. H Table: H.1)

4.5. Fuel Consumption

The fuel consumption was measured as per the standard method by observing the fuel for MRW to traveling 40 m long distancefrom Appendix G2 Table 3. A known volume cylinder was directly attached to fuel tank and was filled up to some level by keeping the motorized rotary weeder on level land and after completing the operation. The data showed in Fig.4.9. the testing was analyzed and the linear regression showed positive good relation between power required and wheel slippage with the operation speed increased in high coefficient of determination (R^2 =0.9995. R^2=0.893) were observed at different speed operation respectively.

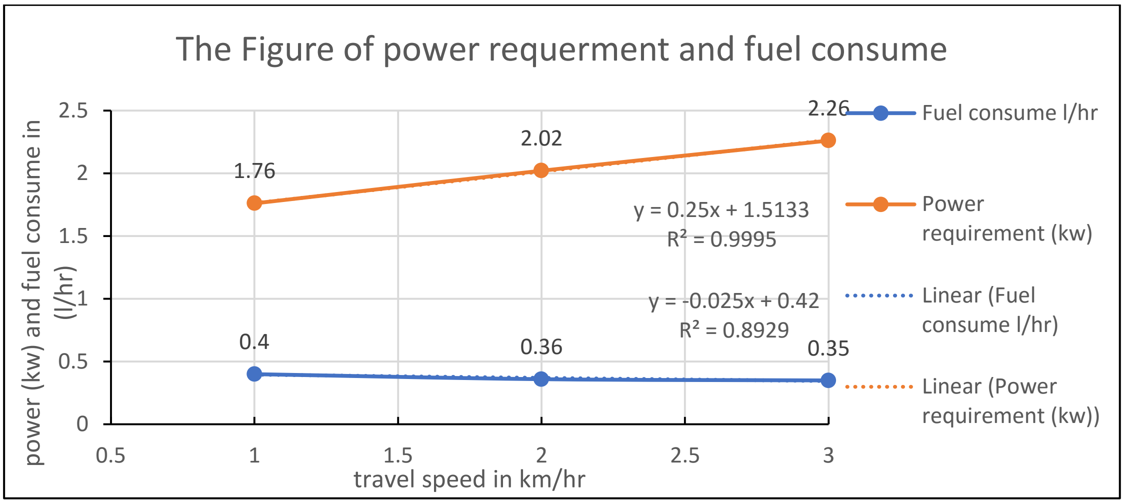


Fig. 4.9. Effect power and operation speed 0n wheel slippage

final measurement of cylinder was noted down in three different treatments 1.1 l/hr the volume of fuel used was taken into account as fuel consumed for a particular time period. In (Appendix H. Table 1).

4.6. Performance Evaluation of MRW

Field performance tests were carried out to obtain actual data on overall performance of the of MRW machine. The field test was done in the experimental farm of (AAERC). The performance of the MRW weeding row planted wheat crops in terms of weeder Agricultural machine parameters was assessed at different forwards speeds of 1.5,1.78 and 2.3 km/h. Since, variety of weed has no effect on weeder, therefore, weed variety was not considered during this test. During field performance test, the parameters determined was theoretical field capacity, effective field capacity, field efficiency, fuel consume, operated time, labor required, energy consume covered area and with three replications of each. The detail data of these seed drill parameters are given in Appendix-H. Table:1)

But under the correlation the machine with energy consumed and the man hours were the negative correlation between operation speed shown in Fig. 4.10. The value of the coefficient of linear regression determination (R^2 =1 in the three of graphs) were suggestion a strong, negative association between energy of machine, energy of human and man hour with the operation speed.

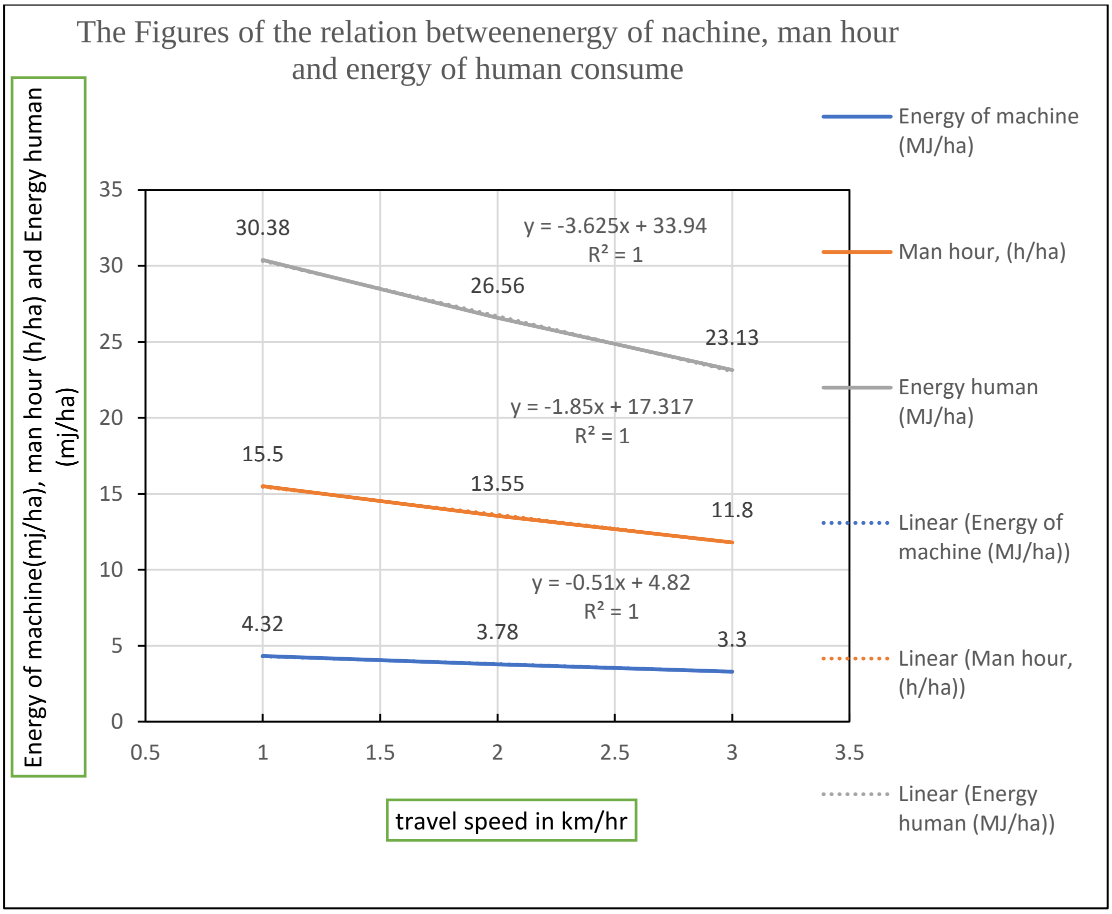


Fig. 4.10 effect of energy consume with the operation speed

Table: 4.2. Mean of Measured Performance Evaluation of MRW during Field Test

Parameters	Operating speed, km/hr		
	1.5	1.78	2.3
Effective field capacity, (ha/h)	0.065	0.074	0.085
Theoretical field capacity, (ha/h)	0.075	0.086	0.099
Field efficiency, (%)	87	86	85
Field capacity	0.224	0.224	0.224
Performance index	0.31	0.31	0.30
Fuel consume, l/hr	0.4	0.36	0.35
Energy of machine, (MJ/ha)	4.32	3.78	3.3
Man hour, (h/ha)	15.5	13.55	11.8
Cost operation, (EB/ha)	254.67	254.67	254.67
Energy human, (MJ/ha)	30.38	26.56	23.13
Energy of fuel, (MJ/ha)	286.44	225.5	190.8
Energy cost, EB/ha	0.96	0.96	0.96

4.7. Cost Estimation and Cost of Operation

The unit cost of a MRW drawn three row weeding in row planted cereals crops was determined by calculating the cost of different components and their fabrication cost as given in (Appendix-E. table:1) The estimated cost of the one unit of a MRW drawn three row weeding in row planted cereals crops determined as 17787.30 EB

Table:4.3. The total summary of cost.

S. N.	COST OF VARIABLES	SUMMARY IN (ETHIOPIAN BIRR)
A	Raw materials cost	10651.50
B	Materials wastage (2.5%)	2662.60
C	Machine cost	594
D	Labor cost	1457.50
E	Overhead cost 5% (C+D)	102.60
F	Profit cost 10%(A+B+C+D+E)	1546.70
G	Selling tax 15%	2320.10
	Selling price	17787.30

CHAPTER FIVE

5. SUMMARY AND CONCLUSION

The designed and development of Motorized Rotary Weeder for row planted cereals crops conducted have been fabricated and constructed in AAERC work shop. The MRW Machine weeding between in three row planted wheat weeding operation suitable for medium farmers and to evaluate its performance. The machine was powered by 5hp.engine. The rotary blade was made up of mild steel. The capacity total energy of weeder 262.94 MJ/h 1.32 for kinematic velocity of the forward and peripheral velocity ratio. The blade motion mechanism, fitted in the unit shaft blade which supported by sank, gets the drive from middle shaft through chain and sprocket system which the power transmitted from engine. The spacing between in each three-blade holder was designed 20 cm and fixed shaft blade which has a depth control mechanism on gauge wheel.

It is known that Ethiopian wheat weeding system was carried out using manual weeding but this technique is mostly labor and time-consuming operation. The other one was chemical control weeding this technique also effect on environmental and global warming. Based on these constraints and as a result of its rectification an attempt was done to design and developed the MR W weeder. The MRW weeder was tested in summer season wheat crop to assess the technical and economic. performance and compared with the traditional hand weeding and operation with CCW for weeding operation at 20 days after sowing.

The potential of the MRW weeder was compared on the basis of weeding efficiency, plant damaged, field efficiency, energy consumption. The study revealed many meaning full findings, which may provide a magnitude of substitution or replacing the existing methods by Manual weeding and CCW system operated. These properties were considered and accordingly a MRW three row weeder was developed. The developed accordingly a MRW three row weeder is consisting of frame, blade, engine, ground wheel, wheel, wheel shaft, blade shaft, middle shaft, sank, wheel gauge, adjuster, gear box, propeller shaft, chain and sprocket and etc. device. A depth adjustment was made for wheel gauge with the help of bolts and nuts. It gives ease of attachment and adjustment, uniform depth and stability.

The field testing of MRW weeding wheat crops field was carried out at the field of AAERC. Three plots of 1 m × 40 m (size) in each were selected for field test. The field was well prepared which was 15 cm deep, firm, fine structure, smooth and level, relatively free of surface trash. In Preliminary test MRW weeding wheat crop was operated with 1.5, 1.78 and 2.3 km/h speed. MRW was operated on these three speeds and its effect weeding rate and crop damage was observed. At the 2.3 km/h operating speed weeding rate as well as weeding spacing between the crops was properly maintained as per requirement and was selected for weeding operation as its gives better results than the other operating speed. Field performance tests were carried out to obtain actual data on overall performance of MRW. The theoretical field capacity, effective field capacity and field efficiency was observed 0.86 ha/h, 0.74 ha/h and 86 % respectively during 2.3 km/h operating speed. The power required for to operating the weeding in the field found 2.63 hp. the wheel slip was 6.84% occurred. Also, when it compared with manual weeding and CCW the theoretical field capacity 0.046ha/hr, 2.85ha/h, 0,86 ha/hr, effective field capacity 0.035 ha/hr, 2.56 ha/hr, 0.74 ha/hr and field efficiency 76%, 90%, 86% manual weeding, CCW and MRW respectively was observed. The increasing clean productivity and in terms of saved man hour were justified.

Thus, on the basis of information secured through the study, the following conclusions could be inferred.

5.1. CONCLUSION

1. The motorized rotary weeder was developed by taking the standard technical of ASBE consideration and specifications.
2. The motorized rotary weeder for row planted cereal crop was tested in the experimental plots and it was compared with traditional hand weeding and CCW operation). It was observed that the machine works satisfactorily for weeding at 20 DAS.
3. The theoretical field capacity, effective field capacity and field efficiency was observed 0.86 ha/h, 0.74 ha/h and 86 percent respectively during 2.3 km/h operating speed.
4. Energy-cost was lowest for Motorized rotary weeder and there was no significant difference for treatment T1, T_2 and T3 for 20 DAS.

5.2. RECOMMENDATION

Weeding by Motorized Rotary weeder was found satisfactory for weeding at 20 DAS for row planted cereal crops due to the higher weeding efficiency and field efficiency, lowest; plant damage, operational cost and energy-cost. However, it can be thoroughly tested in AAERI line sown wheat crops for further analysis. The following points may be considered for future line of work

- Studies may be carried out for different soil types and different cereals crops
- Scope for study on noise and vibration and using easy steering system
- Specific work method

REFERENCE

Aditya Srmour.*et al.,* (2016). design and development of single weeder for rice, Agricultural Engineering (Farm Machinery and Power Engineering) Roll No. 220114010.

Agarwal, J.P. and Singh, O.P. (1968). All about weeds. *Actual Publishing House,* Aligarh.

Ahmed R. (2014). Performance Evaluation of Draught Animal Power Cultivator. *Asian Journal of Applied science and Engineering*, **3**(4): 111-115.

ANISA.G, (2017) Performance testing of the rotary paddy weeder with different angle of blade International *Journal of Agricultural Engineering | **Vol.** 10 | Issue 1. 86-91.*

Bajwa, A.A. (2014). Sustainable weed management in conservation agriculture. *Crop protection, **65***:105-113.

Balachand, C.H. (2006). Design, development and evaluation of animal drawn weeder suitable for non-descript bullock of **C.G.** region. *M. Tech. Thesis, Indira Gandhi Krishi Vishwa Vidyalaya,* Raipur.

Bernacki, H., Haman, J. and Kanafojski, C.Z. (1972. Agricultural machines, theory and construction. US Department of Agriculture and National Science Foundation, *Washington D.C.*

Bin Ahmad, Mohd Taufik, (2012). "Development of an Automated Mechanical Intra-Row Weeder for Vegetable Crops" Graduate. *Thesis and Dissertations*. *Paper* 12278.

Biswas, H.S. Soil tool interaction for mechanical control of weeds in black soils. Unpublished Ph.D. thesis, Indian Institute of Technology, Kharagpu. (1990).

Bosai, E. S.; O. Verniov, Simmov and Sultanshal. (1987). Theory, construction and calculation of agricultural machines. **Vol. I**, *Amerind Publishing* Co. Pvt. Ltd. **New** Delhi.

Chauhan, B. S., Abeysekera, A.S.K., Wickramarathe, M.S., Kulatunga, S.D. and Wickrama, U.B. (2014). Effect of rice establishment methods on weedy rice (Orizya sativa L.)

infestation and grain yield of cultivated rice (O. sativa L.*) in Sri Lanka*. *Crop Protection*, **55**:42-49.

Datta, S.K., Aragon, K.L. and Mlabugoe, J.A. 1974. Varietal difference in culture. *Seminar Proceeding In. Rice breeding and varietal environment.* West Africa Rice Development Association, Manorovia bilaria: 35-73.

Duff, B. and Orcino, N., (1971). Economic research in the department of agricultural engineering. *IRRI Seminar*. Los Banos, Philippines:**9**

Fagade, S.O. (1980). Performance of some herbicides in the control of upland rice weed in Nigaria. *WARDA Technical News Letter*, **2**(2):9-10.

Ferreno, (2008). Failure analysis of a lift gear shaft*: application of the FITNET FFS procedure fatigue module, Engineering fracture analysis* **15** Pag. (970-980).

Greg Bowman. *Sustainable Agriculture Research and Education, United States Department of Agriculture Sustainable Agriculture Network*. Steel in the Field: a farmer's guide to weed management tools. (2001).

Gite, L.P. and Yadav, B. G. (1990). Optimum handle height for push-pull type manually operated dry land weeder. *Ergonomics,* 33.

Goel, (2008). **Gavali and Kulkarni**, (2014), "Development of rotary weeder blades by Finite Element Method*" International Journal of Scientific Research Engineering & Technology* (IJSRET), ISSN 2278 – 0882 Vol. 3, Issue 6.

Gogoi, A.K. (1995). Weed management in transplanted *(Oryzasativa). Indian Journal of Agronomy*, **40**(3):415-419.

Harrison, S. A. (1990). The Fate of Pesticides in the Environment, *Agro chemical Fact Sheet* # 8, Penn, USA.

Håkansson, S. (2003). Weeds and weed management on arable land: *An ecological approach*. CABI *Publishing, Cambridge*, MA.

Hasanuzzaman M, Ali MH, Alam MM, Akhtar M, Fakhrul Alam K. (2009). Evaluation of pre-emergence herbicide and hand weeding on the weed control efficiency and performance of transplanted rice. *American –Eurasian J*. Agron.,**2**(3): 138-143.

Hegazy, R.A., Abdelmotaleb, I.A., Imara, Z.M. and Okasha, M.H. (2014). Development and evaluation of small-scale power weeder. *Misr. J. Ag. Eng*. **31**(3): 703-728.

Helweg, C.*et al*., (2003). Fate of pesticides in surface waters, Laboratory and Field Experiments; *Ministry of Environment, Danish Environmental Protection Agency,* Pesticides Research No. 68.

Hertz, H.R., (1882**).** Mechanical engineering and tribology. Solved the contact problem curved surfaces. (*Collected work),* **vol**.1, Leipzig, Germany.

J. O. Olaoye, O. D. Samuel and T. A. Adekanye Performance Evaluation of an Indigenous Rotary Power Weeder in Energy and Environmental Engineering *Journal Department of Agricultural and Mechanical Engineering,* Olabisi Onabanjo University, Ibogun Campus, Ogun State, Nigeria Vol. 1, Issue2, September, 2012.

Kepner, R.A., Bainer, R. and Barger, E.L. (1978). Principles of farm machinery. *3rd edition, CBS Publications and Distributors,* **New** Delhi.

Kefyalew S., (2014). Pull performance of draught animals under arid climatic condition of afar region, Ethiopia. Haramaya University.

Khodabakhshi A, Kalantari D, Mousavi SR. Effects of design parameters of rotary tillers on unevenness of the bottom of the furrows. *International Journal of Agronomy and Plant Production.* 2013;**4**(5):1060- 1065.

Khurmi, R. S. and Gupta, J. K. Reprint. 1995. *A text book of machine design* (M.K.S. and S.I. units). *Eurasia publication House* (**Pvt.**) LTD. **New Delhi**.

Khurmi, R. S. and Gupta, G. K. (2005). A text book of machine design. *Eurasia Publication House Pvt. Ltd.* Ram Nagar, **New Delhi.**

K. K. Singh Mahilang, Swapnil Choudhary V. M. Victor, Naresh and Khilendra Kumar Sonboier. (2017). *Department of Farm Machinery and Power Engineering,* ***Journal***

of Applied Science & Technology, *SVCAET&RS, IGKV Raipur, India ISSN: 2231-0843*.

Lavabre, E. M. (1991). Weed Control. *Macmillian Education* Ltd., London

Mahilang, Kumar, K. and Kanwar, G.R. (2013). Design and development of power operated rotary weeder for rice. B. Tech. Thesis, *Indira Gandhi Krishi Vishwa Vidyalaya*, Raipur.

Mittal, V. K., Mittal, J. P. and K. C. Dhawan. 1985 In A jay, K. V and M. L. Dewanganb (eds.). Digest on energy requirement *in agricultural sector*. pp. 100-10. Efficiency and Energy use in puddling of lowland rice grown on verti sols in central India.

Nabibagh.*et al*., (2009) Berasia Road, Bhopal thin wheel hand hoe published by *Central Institute of Agricultural Engineering*-462038, September,2009.

Nagesh Kumar, T. (2014). Sujay Kumar, A., Madhusudan Nayakand Ramya, V. Performance of evaluation weeders *Department of Agriculture Engineering,* Vol. 3, No 6, 2160 – 2165.

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

Nkakini, S.O., Akor, A.J., Ayotamuno, M.J., Ikoromari, A and Efenudu, E.O. (2010). Field performance evaluation of manual operated petrol engine powered weeder for the tropics. *Agricultural mechanization in Asia, Africa and Latin America,* **41**(4):68- 73.

Olaoye, J.O. and A. dekanaye, T.A. (2011). Analysis of the motion of weeding tools and development of rotary weeder. *Journal of Agricultural Engineering and Technology*, 19(2):9-25.

Ojomo, A.O., Ale, M.O. and Ogundele, J.O. (2012). Effects of moisture content

on the performance of a motorized weeding machine. *Journal of Engineering*. 2(8):49 -53

Panwar, J.S. 1999. Design and development of small engine operated weeder cum seeder. Presented. Annual Convention of ISAE, C.S. *Haryana Agricultural University*, Hissar:16-18.

Parish S. (1990) A review of non-chemical weed control techniques. *Biological Agriculture and Horticulture***, 7,** 117-137.

Patel and Pandey (1983). Development Agricultural machinery. *Reported that the hand weeding treatment was superior to chemical method of weed control.*

Rangapara Dineshkumar J. (2014): Development of mini tractor operated picking type pneumatic planter and *agricultural university*, Godhra,

Ragesh. K. T. ***et al.,*** (2015). Design modification of power weeder for paddy crop. *department of farm machinery and power engineering in* indira gandhi krishi vishwavidyalaya raipur (chhattisgarh)

Raut, V.D., and Dekate, D. 2013. Review paper on various aspects of weeders for economical cultivation. *International Journal of Modern Engineering Research,* **3**(5):3296-3299.

Reece A.R., (2002). The Mechanics of Tractor Implement Performance. *Publishers R. H. Macmillan, Melbourne, Australia*.

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

Sahay, J. (2006). Elements of Agricultural Engineering. *Standard Publishers Distributors,* 1705-B, Nai Sarak, Delhi (INDIA).

Sakai, J. (2000). Two-wheel tractor engineering hand book. Shin-norinsha *Publisher, Tokyo, 310 p. (in English- Japanese).*

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

Silas, O.N. and Abu, H. (2015). Development and evaluation of wheeled long-handle weeder. The *West Indian J. Eng*., 37(2): 37-44.

Singh, G. (1988). Development and fabrication techniques of improved grubber. *Agricultural Mechanization in Asia, Africa and Latin America,* 19(20): 42-46.

Singh, (Gyanendra,1989). Ergonomic consideration in development and fabrication of manual wheel hoe weeder. *Indian Journal of Agricultural Engineering*. **2**(4):234-243.

Singh, R. and Sahay.et.al., (2001). Studies on rotary weeder in wheat crop. M. Tech. Thesis, *Punjab Agricultural University, Ludhiana*.

Smith, R.J. 1961. 3–4 Dichloropinalide for control of barnyard grains in rice field. Weeds, **1(2):**381-322.

Starkey. P. and Simalenga. T (ends), (2000). Animal power for weed control. A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA). *Technical Centre for Agricultural and Rural Cooperation* (CTA), Wageningen, for details of ATNESA and its resource publications see. The Netherlands.ISBN92-9081-136-6.

Tamrat Gebiso, Ayalew Bekele, Ephrem Boka. (2017). Role of Agricultural Mechanization Technologies in Transforming Agriculture: The Case of Wheat Row Planter in Ethiopia. *AJB. and Environmental Statistics*. Vol. 3, No. 1, 2017, pp. 10-19.

Varshney, A.C., Tiwari, P.S., Narang, S. and Mehta, C.R. (2004). *Data book for Agricultural Machinery Design*. CIAE**,** Bhopal.

Victor, V.M. and Verma, A. 2003. Design and development of power-operated rotary weeder for wetland paddy. *Agricultural Mechanization in Asia, Africa and Latin America*, **34**(4):27-29.

Yenish, J. P., & Ball, D. A. (2004*).* Herbicide-resistant grass weed development in imidazolinone-resistant wheat: Weed biology and herbicide rotation. *Weed Technology*, 18(3), 860-868.

Prof. Wakchaure. B. Parhad Kalpana. R, Arote Dnyaneshwar. (2017). "Design and Development of Automated Farm Weeding Machine*" Mechanical Department,* S.V.I.T, Chincholi, Nashik, Maharashtra, **V ol-**3 Issue-2 2017. India IJARIIE-ISSN(O)-2395-4396

Zoltan Gobor, (2013) Mechatronic "System for Mechanical Weed Control of the Intra-Row Area in Row Crops*" Springer-Verlag Berlin Heidelberg*. DOI 10.1007/s13218-013-0265-0.

Appendix A:

Materials Properties

Apply a load to a material and measure the response to obtain Mechanical Properties such as yield strength, Young's modulus, elongation, hardness, impact resistance, and fatigue life. All other properties are called Physical Properties. Use standards published by ASTM, ASABE, et al., for materials property values before designing anything Metals

Table A.1. Materials Properties at Room Temperature (U.S. Customary units)

Material	Specific weight γ (lb./in.^{3})	Yield strength (tension) σ_{YS} (ksi)	Ultimate strength (tension) σ_{UTS} (ksi)	Ultimate strength (compression) σ_{UCS} (ksi)	Ultimate strength (shear) τ_{ult} (ksi)	Young's modulus E (10^6 psi)	Shear modulus G (10^6 psi)	Thermal expansion coefficient α (10^{-6} in./(in.°F))	Poisson's ratio ν -
Steels									
ASTM A36	0.284	36	58	-	-	30	12	6.5	0.25
ASTM A992 (HSLA)	0.284	50	65	-	-	30	12	6.5	0.25
AISI 80X (HSLA)	0.284	80	100	-	-	30	11.6	6.5	0.28
AISI 1020, annealed	0.284	43	57	-	-	30	12	6.8	0.25
AISI 1020, cold rolled	0.284	48	65	-	-	30	12	6.8	0.25
AISI 1040, annealed	0.284	51	75	-	-	30	12	6.3	0.25
AISI 1040, cold rolled	0.284	60	90	-	-	30	12	6.3	0.25
AISI 4140, annealed	0.284	61	95	-	-	30	12	6.8	0.25
AISI 8620, annealed	0.284	56	78	-	-	30	12	6.2	0.25
Stainless steels									
Type 304, annealed	0.290	30	75	-	-	28	12.5	9.6	0.29
Type 304, cold rolled	0.290	110	150	-	-	28	12.5	9.6	0.29
Type 409, annealed	0.280	30	55	-	-	29	11.3	6.5	0.28
Cast irons									
Grade 4 austempered ductile iron	0.260	155	200	-	-	24.4	9.4	5.9	0.25
Class 35 gray cast iron	0.260	-	35	125	48.5	10.9	6.4	7.2	0.29

Table A.2. Materials Properties of Bolts in Bolted Joints

Bolt Specification	τ_{all} (ksi)	τ_{all} (MPa)
ASTM A307 low-carbon steel	12.0	82.5
ASTM A325N, threads in the shear plane	24.0	165
ASTM A325X, threads excluded from the shear plane	30.0	207
ASTM A490N, threads in the shear plane	30.0	207
ASTM A490X, threads excluded from the shear plane	37.5	260

Appendix B:

Soil texture

Table B. 1. Soil Texture Analysis

	Types of soils	Wait time	Mark height	
			H	M
1	Sand	**1** minutes	30	30
2	Silt	1 hour	10	10
3	Clay	24 hour	20	20
	Total (1+2+3)		60	60
	% sand		50%	50%
	% silt		17%	17%
	% clay		33%	33%
	Soil type		Sandy clay loam	Sandy clay loam

Appendix C1

Table C1.1. Layout of chain drives

1) Chain speed:	$v = \frac{d \cdot \pi \cdot n_1}{60000}$	$= \frac{172,79 \cdot \pi \cdot 20}{60000}$	$= 0,18 \frac{m}{s}$
2) Chain pull:	$F = \frac{1000 \cdot P}{v}$	$= \frac{1000 \cdot 0,96}{0,18}$	$= 5333\ N$
3) Centrifugal force:	$F_f = q \cdot v^2$	$= 3,32 \cdot 0,18^2$	$= 0,11\ N$
4) Total pull:	$F_G = F + F_f$	$= 5333\ N$	Centrifugal force ignored
5) Bearing pressure arithmetic:	$p_r = \frac{F_G}{f}$	$= \frac{5333}{2,94}$	$= 1813,9 \frac{N}{cm^2}$
6) Bearing pressure permissible:	$p_{zul} = \frac{p_v \cdot \lambda}{f_s \cdot f_s}$	$= \frac{3027 \cdot 0,77}{1 \cdot 1}$	$= 2240 \frac{N}{cm^2}$
The arithmetic bearing pressure should not exceed the permissible value. The approx. Value p_v and the friction travel λ are determined by interpolation from the tables on page 35.			
7) Static breaking load safety factor:	$\gamma_st = \frac{F_B}{F_G}$	$= \frac{100000}{5333}$	$= 18,7$ higher than the recommended minimum value 7
8) Dynamic breaking load safety factor:	$\gamma_d = \frac{F_B}{F_G \cdot Y}$	$= \frac{100000}{5333 \cdot 2}$	$= 9,4$ higher than the recommended

Appendix C2:

Design and construction Chain sprocket

The shape of the chain wheels is determined by the chain size, number of teeth and the torque to be transmitted. Wheels with hubs allow the transmission of a higher torque, whereas plate wheels may be used only for the transmission of smaller torques. The tooth form is designed in accordance with DIN 8196. The calculation of the required values is summarized below. p chain pitch

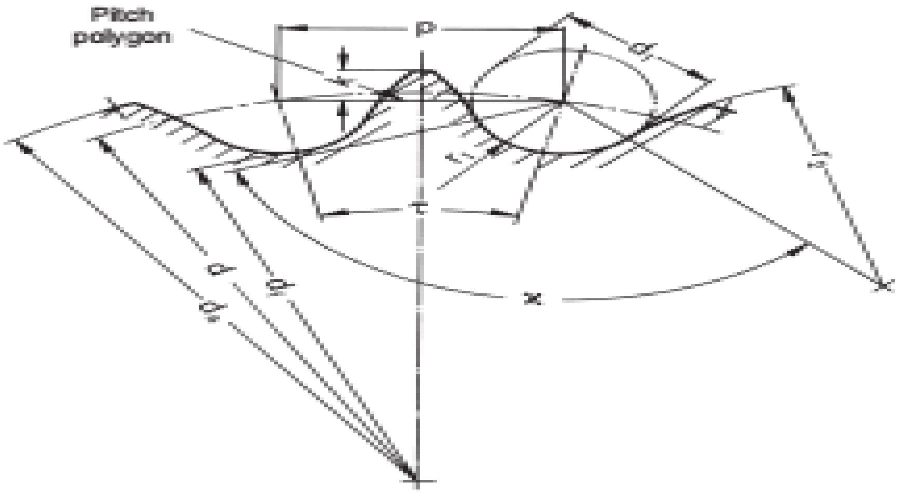


Fig. C1 pitch and diameter of sprocket

Pitch circle diameter, $\mathrm{d} = \frac{\mathrm{p}}{\sin\frac{\tau}{2}}$ $\qquad \frac{\tau}{2} = \frac{180}{\mathrm{z}}$

Root circle diameter, $\mathrm{df} = \mathrm{d} - \mathrm{d1}$

Top diameter, $\mathrm{da\ max} = \mathrm{d} + 1.25\mathrm{p} - \mathrm{d1}$ $\qquad da\ min = d + (1 - \frac{1.6}{z})p - d1$

Tooth height, $kmax = 0.625p - 0.5d1 + \frac{0.8}{2}p$ where, d1 = roller diameter max.

$kmin = 0.5(p - d1)$

$r1\ max = 0.505d1 + 0.069\sqrt[3]{df}$

$r1min = 0.505d1$

$r2max = 0.008d1(z^3 + 180$

$r2min = 0.12d1(z + 2)$

$xmax = 140 - \frac{90}{z}$

$xmin = 120 - \frac{90}{z}$

d= pitch circle diameter

df= root circle diameter

da = top diameter

r1= tooth radius

τ =tooth angle

χ =roller contact angle

r2= tooth profile radius

k =tooth height above pitch polygon

z =number of teeth

Tooth width

Tooth width B1 is narrower than the inner width b1 of the chain pitch B1 p < 12,7 p > 12,7 for Single chain wheels 0,93. b1 0,95. b1/-+008 for Double and Triple chain wheels 0,91. b1 0,93. b1 for Quadruple chain wheels and over 0,88. b10,93. b1(b1inner width of the chain)

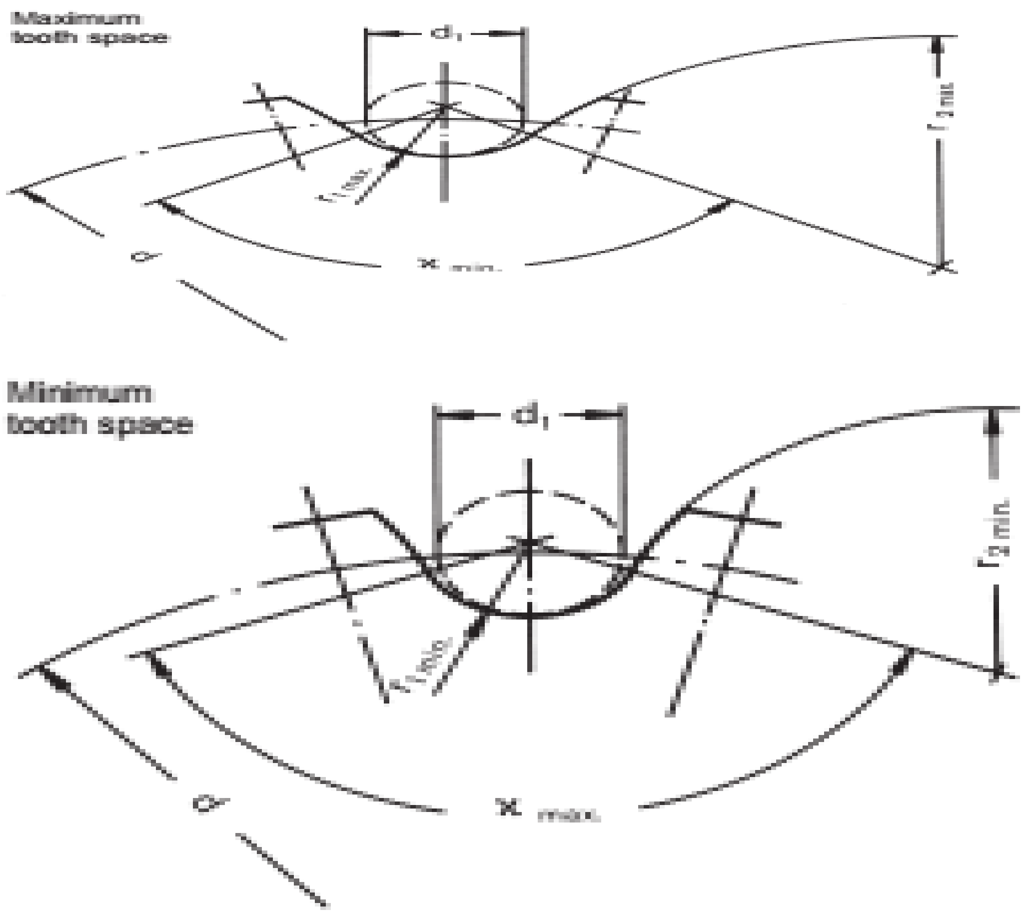


Fig. C2 The Tooth width sprocket.

The parameters of chains

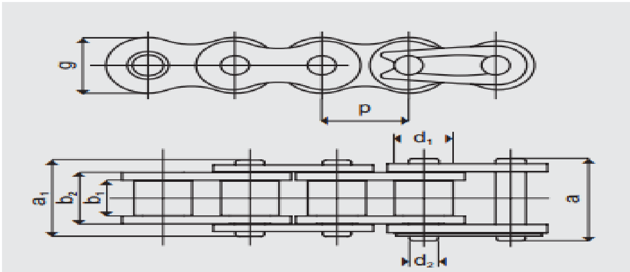


Table C2.1.The standard of chain Based on IWiS R oller chains complying with DIN 8187

DIN ISO no.	Ref.no. IwiS	Pitc p'	H P (mm)	A (mm)	B (mm)	D (mm)	Simplex Chain θ (mm)	G (mm)	i (mm)	L (mm)	Threaded insert M (mm)	m max.(mm)
Shape 102.1												
08 B-1	L 84ML"	$\frac{1}{2}$,	12.7	13,0	19,0	4,2	11,6	5,4	-	18,0	4	5,2
10 B-1	M106ML"	$\frac{5}{8}$,	15,875	16.3	24,3	5,2	13,6	6,8	-	24,0	5	5,3
…….												
Shape 103.1 and 103.2												
08 B-1	L85ML"	$\frac{1}{2}$,	12,7	17,0	23,0	4,2	11,6	25,5	12,7	23,6	4	5,2
…												

Appendix. D1

Table D1.1. Energy equivalent of different input.

S.N	Input forms Human labour	Units	Equivalent energy in (MJ)	Remark
	a) Adult-men b) Adult-women c) Child	Man- hour Women-hour Child-hour	**1.96** **1.57** **.98**	1 Adult- women= 0.8 Adult –men 1 Child = 0.5 Adult men

Source: Mittal.et.al, 1985.

Energy Calculation

Energy Equivalents for different inputs Human = 1.96 MJ/ man- hours

Fuel (Kerosene) = 46.2 MJ/l

Iron = 60 MJ/Kg

Human Energy = Time of operation (h/ha) × Energy equivalent × Number of persons required

= 13.6 × 1.96 × 1 = 26.68

Machine energy (Me)

$$\textbf{Me}= \frac{60\times Wmc\times Tr}{AWH\times L}$$

Where, Me = Machine Energy (MJ/ha)

Wmc = Weight of the machinery (Kg)

Tr = Time required (h/ha)

AWH = Annual working hours (h)

L = Useful life (years)

Me = (33.454× 13.6 × 60)/ (720 x 10) = 3.79

Fuel Energy Fuel consumption = .37 l/h

Fuel consumption for 13.6 h/ha = 13.6 × 0.37 = 5.03 l/ha

Fuel energy = Fuel consumption × Energy equivalent of fuel

= 5.03× 46.2 = 232.478

Total energy for motorized rotary weeder = Human energy + Machine energy + Fuel energy

= 26.68 + 3.79 + 232.478 = 262.94 MJ/h

Appendix D2:

Conditions for cutting off a soil slice:

The equations given in (3.46) describe the absolute motion of the share to trace the locus of $A_{1'}$ over time as sketched in fig.3.14. Let $A_{1,0'}$ denote the position of A_1 as it begins to cut through the soil. Denoting the depth of cut by (h), the angle through which (AI) rotates to get to $A_{1,\,0'}$ is given by (po) which equals ($\omega_{t0)}$ such that from equation,

$$\sin po=1-\frac{h}{R} \qquad \sin po=1-\frac{3\ cm}{12.3\ cm}=49°$$

X$= v_{ft} + R\cos wt$ ………………………………………………………………………(3.46)

X$= 65cm/s + 12.3cm\cos 49$°= 77.3 cm

$y = R(1 - \sin wt)$ ……………………………………………………………………….(3.47)

$y = 12.3(1 - \sin 49°)$ = 3cm

As (AI) starts to penetrate the soil at $A_{1,0'}$ its direction of motion is vertically down. Afterwards, its motion will be opposite to the direction of implement forward travel as it cuts off a soil slice. This means that there is a point of inflexion in the locus traced by at (A1) at which the absolute velocities of the share in the x direction is zero and may be given by

$$\frac{dx}{dt} = v_f - Rw\sin po \qquad \frac{dx}{dt}$$

$$= 65\ cm/s - 12.3cm \times 5.28\sin 49 = 16.29\text{cm}$$

and

$$\sin po = \frac{v_f}{RW} = 1/\lambda$$

which defines λ as, $\lambda = \frac{Rw}{v_f}$

$\lambda = \frac{R}{R-h}$ From this equation, then = $\frac{12.3}{12.3-3}$= 1.32

$\lambda = \frac{1}{1-Q}$ may be given as

where Q is the ratio of a/R.

The above expressions give the necessary condition for cutting off a soil slice. If the relative magnitudes of the peripheral velocity of the shares, $\mathbf{V_{ft}}$ and the implement forward speed, V are such that **dx/dt** has the same direction as the implement travel after penetrating the soil, then the share withdraws from the soil without cutting off a soil slice.

The different possible paths of a share through the soil for various values of λ are illustrated in fig.3.15. which shows that cutting off a soil slice is possible only when λ is greater than unity. Therefore, for any weeding to occur with a rotary weeder, the ratio Rw/Vf must be greater than unity. Kinematics velocity **(λ)** at these forward and peripheral velocities was,

Kinematics velocity, λ= 1.32.

Appendix E:

Production and Operational Cost of the weeder

Table E1. Materials for construction of Motorized rotary weeder and its cost

S. N.	Component	Quantity	Total mass (kg)	Materials	Size (mm)	No. unit	market rate (EB/unit)	total cost (EB)
1	Frame	1	2.36	Mild steel	35×35×5	10 kg	43.5	435
2	Wheel	2	1.2	Sheet metal	80×4000×3	2 kg	43.5	87
3	Engine	1	14		52(bore) 46(stroke)	14 kg	6000	6000
4	Gear box	1	1.02	Steel	140×80	2 kg	500	1000
5	Shaft	3	1.4	M.S	50	3 kg	45	135
6	Blade	12	1.224	M.S	123×1476×3	4 kg	34	136
7	Sank	2	0.72	M.S	70×1000×3	2 kg	45	90
8	Handle	2	0.24	M.S. pipe	20×4000	1 kg	75	75
9	Chain	3	1.94	Standard	13 pitch	3	280	840
10	Sprocket	6	1.244	Cast iron	Different	6	80	480
11	Safe guard	2	0.206	Sheet metal	1.5 thick	2	32	64
12	Adjuster	1	0.12	M.S			123	123
13	Wheel of adjuster	1	1.2	Sheet metal	80×540×3	1	43.5	43.5
14	Clutches	1	1.78	M.S		1	200	200
15	Clutches handle	1	0.37	M.S	700	1	35	35
16	Engine set	1	0.21	M.S	160×200	1	43.5	43.5
17	Bolts and nuts	46	2.34	M.S	750g	67	50.5	50.5
18	Spokes	20	0.58	M.S	1.5kg	16	20	320

19	Bearing	9	1.05	Chrome alloy steel	62.05 and 64.05	9	35	315
20	Hub	3	0.25	M.S	25dia	2	35	70
21	Rotary shaft	1		M.S	20dia	1	43	43
22	Accessories and cable	1		Cable type	Standard	1	65	65
Total cost (EB) = 10650.5								

Calculation of Operational Cost of Motorized rotary Weeder

The initial cost of motorized rotary weeder has been calculated by adding up the cost of individual components involved in the fabrication at the prevalent market price.

These were then added to a reasonable percentage for fabrication cost and marginal profit of manufacture as discussed below. The unit cost was calculated by adding the fixed cost and variable costs.

Initial Cost of Machine The initial cost of the power weeder was calculated on the basis of total materials used in fabrication and the detail account is given in Appendix – E. Cost of fabrication, as 25% of the total cost was assumed.

The fabrication cost of the power weeder is $= \frac{(10{,}650.5 \times 25)}{100} = 2662.63$ EB

Hence the total cost of the power weeder = 10650.5+2662.63 = 13313.13 EB

Economic Analysis

Following assumption was made for economic analysis of power weeder:

i. Expected life of weeder = 10 years.

ii. Annual use of weeder can be calculated as follows

Weeding period for wheat crop per year = 90 days

Total annual used = 720 h/year, when working hour is 8 h/day

Salvage value of the power weeder = 10% of the initial cost

Fixed Cost

1. Annual depreciation (by straight line method)

$$D = \frac{C - S}{L} = \frac{13313.13 - 1331.313}{10} = 1198.18\ EB$$

2. Interest on investment at 10% of initial cost.

$$I = \frac{C+S}{2} \times \frac{i}{100} = \frac{13313.13+1331.313}{2} \times \frac{10}{100} = 732.22 \text{ EB}$$

3. insurance and tax cost @ 1.5% of initial cost = 13313.13×1.5)/100 = 199.70 EB/ year

Therefore, Total Fixed cost per year = 1198.18 +732.22 +199.70 = 2130.1 EB / year

Hence, total fixed cost per hour =2.96 EB / hour.

Variable Cost

1. Repair and maintenance cost @2.5% of initial cost

= (2.5 × 13313.13)/100 = 332.82 EB/ year

Cost per hour = 332.82/720 = 0.463 EB/ hour

2. Fuel consumption = 0.37 l /h Cost of fuel per litre = 16 Fuel cost = 16 × 0.37 = 0.59 EB/ hour

3. Lubrication cost = 1.5 % of fuel cost = 0.088 EB/ hour

4. Wages of operator = 120 per day

Wages per hour = 120/6= ` 15 EB/ hour

Total operating cost = .463+ .59 + 0.088 + 15 = 16.14 EB/ hour.

Therefore, total cost of weeding with developed Motorized rotary weeder per hour

= Fixed cost + Variable cost

= 2.96 + 16.14 = 19.1 EB/hour

Average effective field capacity of power weeder was taken from the experimental data.

Hence the operational cost of Motorized rotary weeder per hectare

= (Total cost of weeding per hour)/ Effective field capacity

= (19.1/0.075) = 254.67 EB/ ha

Table E.2. The cost of machine and labour in the working hour.

S. N.	Types of machine	Machine cost/hr	Working hour	Cost	Labour cost/hr	Working hour	Total prices
1	Universal metal cutting	12	4	48	26.5	4	154
2	Welding	8	2	16	26.5	2	69
3	Lath machine	12	12	144	26.5	12	462
4	Bending machine	5	1	5	26.5	1	31.5
5	Rolling machine	5	1	5	26.5	1	31.5
6	Drilling machine	12	6	72	26.5	6	231
7	Grinding machine	5	3	15	26.5	3	94.5
8	Compressor	5	1	5	26.5	1	31.5
9	Radial drilling	8	4	32	26.5	4	138
10	Assembly	12	21	252	26.5	21	808.5
						Sub total	2051.5

Appendix F:

Field Test

Table F.1 The duration of operation time during field test.

S. N	Travel speed	Time taken to completed	No. turning	Area	Length	No. plant damage in Ave.	Time loss	Actual time operating	Total time operating
1	1.5 km/h	3’12”	2	40 m^2	40 m	22 amount/m^2	30”	3’12”	3’42” or (0.06167 hr)
2	1.78 km/h	2’47”	2	40 m^2	40 m	32 amount/m^2	28”	2’47”	3’15” or (.0542 hr)
3	2 km/h	2’25”	2	40 m^2	40 m	64 amount/m^2	25”	2’25”	2’50” or (0.0472 hr)

Table F.2. The types of weed population.

S. N	Types of weeds	No. weeds before weeding, (1 m^2)	No. weeds after weeding, (1 m^2)	Efficiency of weeding (%)
1	Mujjaa	23	2	91.30
2	Marga sare	21	3	85.71
3	Tufo (hada)	73	3	95.9
4	Balami	49	4	91.8
5	Marga gogori	12	2	83.33
6	Baldima	45	1	98
7	Sidisa	23	2	91.3
8	Bokite	15	0	100
9	Bal-qore	9	1	88.88
10	Others	34	5	85.29
	Total	304	23	91.15

Table F.3. Plant damage and weeding efficiency in different treatment at 20 DAS

S. N	Speed of travel (km/h)	Different treatment	No. of crops before weeing, in ($1m^2$)	No. of crops after weeding, in ($1m^2$)	No. of crops damage	Crop damage in (%)
1	2.1	T_1	372	350	22	6
2	2.2	T_2	356	324	32	9
3	2.3	T_3	361	297	64	18

Weeding efficiency in different treatment.

S. No	Speed of travel (km/h)	Different treatment	No. of weeds before weeing, in ($1m^2$)	No. of weeds after weeding, in ($1m^2$)	Weeding efficiency, (%)	Time in (hr)
1	1.5	T_1	304	23	92.43	0.056
2	1.78	T_2	217	9	95.85	0.052
3	2.3	T_3	315	12	96.19	0.0488

Table F. 4. Wheel slips percentage determination

Replication	Speed km/hr	Distance covered in 10 revolution		Wheel slip %	Power requirement (kw)	Fuel consumption (l/hr)	Wheel skid, m
		Under no load, m	Under load, m				
1	1.5 km/hr	16.96	15.87	6.43			
2		16.89	15.76	6.66			
3		16.95	15.82	6.66			
Mean		16.933	15.817	6.59	1.76	0.4	.0674
1	1.78 km/hr	16.92	15.81	6.56			
2		16.86	15.75	6.65			
3		16.84	15.73	6.59			
Mean		16.873	15.763	6.65	2.02	0.36	.0685
1	2.3 km/hr	16.12	14.92	7.44			
2		16.05	14.89	7.23			
3		16.02	14.87	7.18			
Mean		16.0633	14.893	7.28	2.26	0.35	.0976

Table F.5 The table show the relation power transmission during design consideration

Rpm at engine	Rpm at gear box	Rpm at middle shaft	Rpm at blade shaft	Rpm at ground wheel	Travel speed
2000 rpm	500 rpm	83 rpm	650 rpm	21 rpm	2.1 km/hr
2100 rpm	525 rpm	88 rpm	682 rpm	22 rpm	2.2 km/hr
2200 rpm	550 rpm	92 rpm	715 rpm	23 rpm	2.3 km/hr

Given here is the unit conversion formula for converting values from RPM to km/hr.

RPM stands for revolutions per minutes. = It is a measure of the frequency of rotation.

km/hr stands for kilometer per hour = it is the unit of speed.

RPM can be easily converted to km/hr with help of the radius of the rotating object.

Convert radius to diameter by dividing the value by 2. RPM to km/hr conversion formula is given by multiplying the diameter and rpm and the constant 0.001885.

Formula:

$$k = d \times r \times 0.001885$$

Where,

k = Kilometer Per Hour(km/hr)

d = Wheel Diameter(cm)

r = Revolution Per Minute (RPM)

Appendix G1:

Table G.1. Weeding performance of weeding with different technic.

Parameter	Different technic		
	Manual weeding	Chemical control weeding	Motorized rotary weeding
Length, m	40 m	40 m	40 m
Width, m	3 m	3 m	3 m
Area, m^2	120 m^2	120 m^2	120 m^2
No. weeds before weeding, g/m^2	238	304	280
No. weeds after weeding, g/m^2	11	115	39
No. plant before weeding	356	372	363
No. plant after weeding	356	372	324
% of damage plant	-	-	11 %
% weed remain	4.6 %	38 %	5.3 %
Weeding efficiency	95.4 %	62 %	94.7 %
No. pass	-	3	6
Total operating time in, hr.	15’41”	1’9”	0.073
Turning loss in, hr.	-	-	0.014
Operating actual time	15’41”	1’11”	0.0488 8’21”
Walking speed	-	2.15 km/h	2.3 km/h
Theoretical field capacity	0.046 ha/hr	2.85 ha/hr	0.085 ha/hr
effective field capacity	0.035 ha/hr	2.56ha/hr	0.0737ha/hr
Field efficiency	76 %	90 %	86.7 %
Labor requirement	4	1	1
Fuel consumption			1.11 l/hr

Appendix I:

LIST OF SYMBOLS

Ø	Diameter
d	depth of cut
kgf/cm2	kg. newton per cent meter square
Lab.	laboratory
Ms	Mild Steel
Rpi	rated power of the source, kW,
R^2	Linear regression
RPM (rpm)	Revolution per minute
SR	Soil resistance, kgf/cm^2
S_1, S_2, S_3, S_4, S_5, S_6	Number of Sprockets

Appendix:J appendix of picture

The figures of clutches

Figure gear box arrangement

Fig. The Arrangement of Bevel Gear