DESIGN OF A TRACTOR OPERATED DRY-SEASON SORGHUM (MASAKWA) TRANSPLANTING MACHINE

BY

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DECLARATION

I, Dada Muhammad Mubarak (2006/24029EA) hereby declare that this project work is a record of a research work that was undertaken and written by me. It was not presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

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CERTIFICATION

This is to certify that the project entitled "Design of a Tractor Operated Dry-Season Sorghum (Masakwa) Transplanting Machine" by Dada Muhammad Mubarak meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its scientific knowledge and literary presentation.

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DEDICATION

This research work is dedicated to my late mother, who died just a few days to my final exams.

ACKNOWLEDGEMENT

There are many individuals that I would like to thank that played a role in this project work, first and for most is my project supervisor, Engr. Dr. A. A Balami, who came up with the concept of the dry-season sorghum transplanting machine. His knowledge and guidance is what made this project work a success.

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ABSTRACT

Agricultural activity is one of the oldest occupations of man, it dates back to the days of Adam, and prominent among the activities is farming. Man has always devised tools so to suit soil types, climatic conditions, crops grown and their peculiar socio-cultural environment. The type of tools used by various farming groups or societies has changed with time and crop types. The machine tool used for the cultivation of Masakwa sorghum is not an exception, from the hand held wooden dibble to the modified dibble. This project intends to present model design of a tractor drawn machine for transplanting of dry season sorghum suitable for vertisol (Firgi) soil type. The machinery is envisaged to have the advantage of higher land cultivation of Masakwa and by extension of higher productivity and better economic advantage to the famer. After due consideration of the implement model a high possibility of building the machine was concluded, and following from results of the general analysis (finite element analysis, cost analysis, economic analysis and performance analysis) and the machine model was built using SOLIDWORKS 2011 and MATLAB 2009 as modeling aid. The possibility was based mainly on the time efficiency to cultivate 10,000 square meters, results from cost analysis and economic analysis.

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CHAPTER ONE

1.0 INTRODUCTION

The focus of this chapter is to give a brief background on the area of study (Design of a tractor operated dry season sorghum transplanting machine), methods and areas of cultivation. Some brief reflection will also be done on the significance and aim of this work. This will prepare a ground for subsequent chapters in my write up.

1.1 Background of study

Dry season sorghum *(Sorghum bicolor L. Moench)* is indigenous to Africa, particularly Sub - Saharan Africa, where it is now widely grown (*Menz et al., 2004*). This cereal crop is grows very well on vertisol (30 – 60% clay), heavy and light alluviums, red, gray, yellow loams and sandy soil (*Pannar - Seed, 2008*). However, the crop is adapted to a wide range of soils provided its fertility is reasonable. Good yield may also be derived on soils with a pH of 4.5 – 7.5 and it can withstand a certain amount of salinity (*Pannar - Seed, 2008*). This variety of sorghum is a short day, low temperature (15 – 30 ^{0}C) and cold night cultivator. It is grown during the dry and cold harmattan period. Due to its uniqueness, it has become a common cereal crop in parts of the world characterized by low annual rainfall. Some countries where it is commonly grown are some parts of: Pakistan, Indian, USA, China, Mexico and Argentina. In Africa, the major growing areas are parts of: Nigeria, Sudan, Ethiopia, Burkina Faso, Egypt, Tanzania, Niger and Mali: of special interest is its wide cultivation around the shores of the lake Chad basin of Borno state, parts of Yobe and Sokoto states nursery sorghum beds are sown and nurtured at the edge of the lake. At the appropriate time on the shores of the lake chad basin in borno state, nursery sorghum seedlings are planted on the lake bed as the water recedes from the lake, an older stand is established very quickly, allowing the crop to mature with the water that is available (*Olabanji et al., 1996*). Plate 1.1 shows a Transplanted Masakwa in a farmer's field in Mashate, Masvingo Province, Zimbabwe

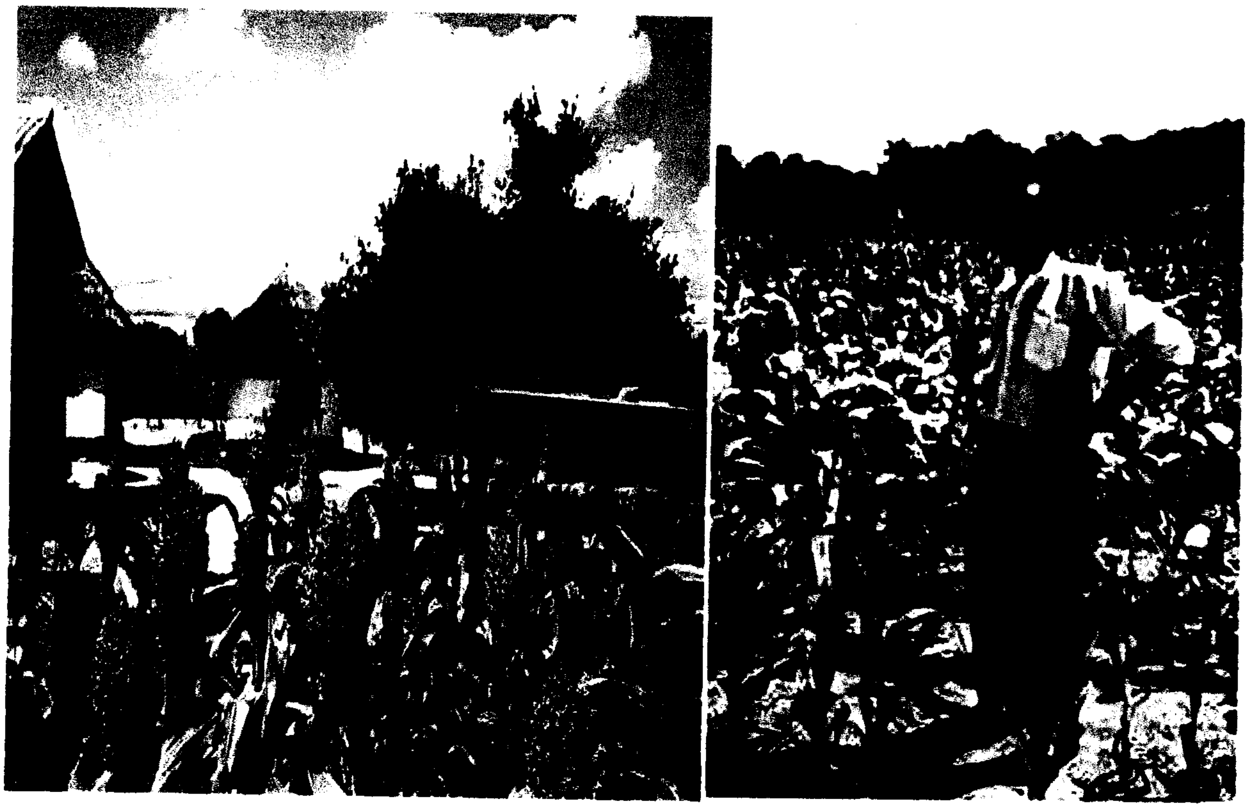


Plate 1.1: Transplanted Masakwa in a farmer's field in Mashate, Masvingo Province, Zimbabwe

The dry season sorghum grows very well on vertisol (30 – 60 % clay) in Northeastern Nigeria, Western Chad Republic and Northern Cameroon. It is cultivated on land mass of 42,915 hectares in Borno state of Nigeria (*Balami and Zanna, 2005*). The yield is from 0.6 to 0.8 t/ha (*Nwaka, 1989*), which can be compared to the yield of wet season sorghum (0.8 - 1.0 t/ha) (*Obilana, 1983*). The crop provides 40 – 80 % of cereal to the people and is mainly used as food and for preparation of local liquor, etc (*Djonnewa and Dangi, 1988*). Table 1.1 shows the comparative yield of rain fed sorghum and dry-season sorghum in the north province and extreme north province of Cameroon.

Table 1.1 Sorghum grown in the two northern province of Cameroon (*Henk and Maurice, 2005*)

Type of Sorghum	North Province (tones)	Extreme North Province (tones)
Rain fed Sorghum	190,000	325,000
Dry season Sorghum	22,000	150,000
Total	**212,000**	**475,000**

Dry season sorghum growing areas under cultivation in Borno State, Nigeria is presented in table 1.2.

Table 1.2 Dry season sorghum (Masakwa) producing areas, under cultivation in Borno State

S/N	L.G.A	Land area (km^2)	Total cultivable land(km^2)	Firgi land (Ha)	Actual Firgi under cultivation(Ha)
1	Dikwa	1,683	37026	29,620	5,924
2	Ngala	3,729	82039	73,834	11,075
3	Monguno	3,926	86372	43,186	4,319
4	Kukawa	6,710	147620	14,762	2,214
5	Bama	6,175	135850	108.680	16.302
6	Gwoza	2,689	59158	118,32	1,775
	Total			**411,915**	**41,609**

In all growing area, Masakwa can be used for any of the many purposes, including, semi-leavened bread, couscous, dumplings, permeated and non- permeated porridges. It is the grain of choice for brewing traditional African liquor (*FAO, 2005*). New products such as instant soft porridge and malt extracts are great success (*Taylor, 2005*).

Vertisol are churning heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out, which happen in most years. Vertisols (in Latin is vertere which means "to turn") refer to the constant internal turnover of soil material. Common local names are 'black cotton soils' (USA), 'regur' (India), 'Vlei soils' (South Africa), 'Margalites' (Indonesia), and 'Gilgai' (Australia). Vertisol become very hard in the dry season and are sticky in the wet season. Tillage is difficult except for a short period at the transition between the wet and dry seasons. Vertisol cover 335 million hectares worldwide. An estimated 150 million hectares is potential crop land. Vertisol in the tropics cover some 200 million hectares; a quarter of this is considered to be useful land. Their agricultural utilization is, however, severely limited by their unfavorable structural characteristics, including excessive swelling and cracking and related characteristics, such as poor drainage and severe soil erosion (*Ben - Dor and Singer, 1987*). Dispersion, swelling, aggregation, and stabilization of all soils are related to the colloidal properties of their clay fractions. Surface reactions of the clay fractions of vertisols are dependent on the nature of the clay species present and are affected by small changes in external factors, such as the amount of exchangeable cations, pH, and electrolyte composition and strength (*Ben - Dor and Singer, 1987*).

1.1.1 Current practices

Transplanting cereal seedlings from irrigated nurseries has been adopted in several areas as a means of improving food security by extending the growing season in areas with patchy and unreliable rainfall, or where the rainfall may not support a second crop. In most rice growing countries, the use of cereal nurseries is commonplace. Linked to accurate sowing rates and input application the process guarantees reasonable crops by reducing risk and affording best use of water. In Vietnam, the National Maize Research Institute has developed a low-cost maize production system on the Red River Delta based on transplanting maize into soils previously used exclusively for rice (*Tran, 1996; Ngo, 1992*).

Of special emphasis is the practice on the shores of Lake Chad in Borno State where, nursery sorghum beds are sown and nurtured at the edge of the lake. When the time is right the seedlings are planted on the lake bed as the water recedes from the lake, an older stand is established very quickly, allowing the crop to mature with the water that is available (*Olabanji et al., 1996*). This activity involves all members of the family, men women and children and the sorghum plantations extend as far as the eye can see.

Similar practice can be seen in the foothills of the Atakora chain near Natitingou, Benin where the Somba tribe cultivate transplanted millet and in the Nampula region of Mozambique where sorghum is transplanted in opportunistic attempts to increase area under cultivation when the rains are good (*Naudin et al., 2004*). A similar practice has been observed in Save Valley, Zimbabwe. In general, indigenous, but largely un-quantified information suggests that where transplanting is practiced a better stand is established, more yield may be obtained per hectare thus a greater degree of food surplus experienced by the people (*Beck et al., 1998*).

1.2 Statement of Problem

Transplanting of dry season sorghum is done due to two major reasons; extending the growing season by planting indoors, before outdoor conditions are favorable and avoid germination problem by setting out seedlings instead of direct seedling. The manual hand held method of transplanting sorghum either with dibble or hole - maker is very tedious and time consuming. The batch process of transplanting involves high cost of labor and fatigue. It is due to these reasons and more like, accuracy in plant spacing and time taking in transplanting a farm field, that a more efficient machine, with reduced fatigue, time per man hour and cost efficiency is required. Due to the strenuous activities involved in the transplanting of dry season sorghum and to make the farming of this crop sustainable, it is of paramount importance to Introduced a highly efficient transplanting machine.

1.4 Justification of the study

This study wish to buttress the point that, design of a tractor operated machine offers a greater prospect to constructing the machine because the rate of transplanting will be highly increased. This reduces labor time spent on the farm. increases the rate of production to meet commercial demand of sorghum, there-by increasing the standard of living of the people.

1.5 Scope of the problem

The scope of the study is to design, and select materials that can be used to construct the machine with view to ascertain it viability and efficiency.

1.6 Aims of the study

The aims of this project include: to design, simulate and model a tractor operated dry-season sorghum transplanter which will make hole for planting and applying water to the hole in precision, so that the following objectives can be achieved:-

CHAPTER TWO

2.0 LITERATURE REVIEW

Sorghum (*Sorghum bicolor L. Moench*) is the fifth most important cereal crop in the world and second to maize in Africa (*FAO, 1996*). It is widely grown in the subtropics, tropics and Africa continent. Of all Sorghum cultivars available for cultivation by farmers "Masakwa" Sorghum has occupied an important position for some time in the region. This dry-season sorghum is usually grown on vertisol from the end of the rainy season in September to January. Blench reported that Masakwa was first developed to Asia and spread in Nigeria from the Nile Valley with Borno and Adamawa States representing the western limits to its distribution. The major areas of cultivation in Borno state is bet.ween Lake Chad in the north and part of Mandara hills in the south. Other areas in Borno state include Dikwa, Bama, Ngala, Gwoza, Mungono and Marte Local Government Areas. In his areas cultivation state is by small scale peasant farmers (*Olabanji et. al, 1996*). Other locations in Borno State are contained in Table 2.1. Masakwa or Firgi sorghum is drought and cold tolerant short day sorghum cultivar that has been cultivated in the Lake Chad over centuries (*Zach et. al; 1996*). It is grown under residual moisture in vertisols of northeastern Nigeria during the harmattan period (*Ogunlela and Obilana, 1983; Akposae. et. al, 1986; Olabanji. et. al, 1996; Zach et. al, 1996; Gworgwor, 2001 and Tabo, et. al, 2002*). The total area under cultivation in the Lake Chad basin area of Nigeria is 102,584 Km^2 (*Olabanji, et. al; 1996*). The crop is also cultivated in northern parts of Cameroon and in the Chad Republic (*Djonnewa and Dangi, 1988*). Its relative short growth cycle allows it to develop and mature on the available residual soil moisture on the rather heavy deep vertisol (Black cotton soils).

i. To reduce the time required in transplanting a field as compared to using hand reduce dibbles or hole maker.

Table 2.1: Dry-season Sorghum Producing Areas in Some Parts of the World

S/No.	Race of Sorghum	Regions/Country
1	*Sorghum bicolor race Bicolor*	Nigeria. Uganda and Southwest Et.hiopia
2	*Sorghum bicolor race Caudatum*	Northeast Nigeria and Southwest Et.hiopia
3	*Sorghum bicolor race Durra*	India and North Africa
4	*Sorghum bicolor race Guinea*	Sahelian west Africa
5	*Sorghum bicolor race Kafir*	Eastern Africa, Southern Africa and Northern Nigeria

The most important natural factors for this specialized dry season cropping is the presence of soils with high clay content locally termed Firgi (*Zach et. al, 1996*). Furthermore, Masakwa sorghum cultivation is based on the following preconditions.

i. Knowledge of a water management system using wells and ditches.
ii. Knowledge of the soil characteristics
iii. Knowledge of breeding of appropriate sorghum races.

The Firgi is a distinctive clay plain of black cotton soil. These fertile vertisols are flooded in the rainy season and ret.ain moisture during the dry cool period from September to January (*Zach et. al, 1996*). They have high water holding capacity but low in organic carbon and nitrogen (*Mordi et. al, 1991*). However, because of their high clay content, poor drainage and low-hydraulic conductivity in the swollen state, vertisols are very hard when dry and extremely sticky and difficult to manage when the rain commences (*Swindale and Miranda, 1984*). They are therefore largely under utilized by farmers in the tropics and are left fallow during the rainy season. During the dry season, it is common practice by farmers to grow the crop on these soils.

Masakwa sorghum contributes significantly to the economic livelihood of the people in the northern parts of Borno State, Nigeria (*Ogunlela and Obilana, 1983; Gworgwor, 2001), Cameroon and Chad (Djonnewa and Dangi, 1988*). It is an important cereal crop with high nutrient value. It provides supplementary supply of grains and forage during the dry season for both human and livestock consumption respectively.

2.1 Cultural Practices

The cultural and management practices for Masakwa sorghum production are different from those of regular grain sorghum in many aspects. Some of these differences are mainly due to the nature of the soil texture.

2.1.1 Cultivars

Masakwa cultivars belong to at least the races durra, Caudatum and Kafir (*Zach et. al. 1996*). This race of sorghum has been found to exist in some parts of the world (*Barret.eau et. al, 1997*) which is as shown in table 2.1. The major Masakwa sorghum land races grown by farmers in Borno State are presented in Table 2.2. The common land races grown across the four Local Government Areas are Burugukhime (red grain), Bul-walana (white grain), Adja'ana (cream grain) and Tumbuna (milk grain). Based on their relative popularity in the communities and their market.ability, land races can be ranked in decreasing order of preference as follows: Bul-walana, Adja'ama, Tumbuna and Burugukhime. However, in Bama Local Government Area, Burugukhime was the most preferred landrace.

2.1.2 Nursery Management

Nurseries for the seedlings are prepared during the wet. season (July to September) on sandy soil near the field where they will be transplanted (*Ogunlela and Obilana, 1983; Zach et. al, 1996; Yakamba, 1992*), seed should be treated with Apron Star 42WS at the rate of one sachet (10 g) to one Kg of seed. Ash from the grass burning is spread over the area prior to sowing. Seeds are broadcasted in the nurseries in August. When the seedlings have reached a height of 30 to 40 cm (6 - 8 weeks old), they are transplanted to the clay field (main field) (*Zach et. al. 1996*).

Table 2.2: Masakwa Sorghum Landraces Grown in Some Local Government Areas in Borno State Nigeria.

Local Government Area	Village/Town	Masakwa Sorghum Predominant type
Ngala	Ngala	Bul-walana
	Bugda	Burugukhime
	Dagala	Tumbuna
	Dikwa	Adja'ana'
Monguno	Mashila	Bul-walana
	Njinne	Tumbuna
	Old Marte	Adja'ana'
		Burugukhime
Bama	Iza	Burugukhime
	Arikarari	Tumbuna
	Mbuliya	Burugukhime
	Keri mbaga	Adja'ana'
	Walasaloderi	Adja'ana'
	Jagoriri	Burugukhime
	Banki	Adja'ana'
	Vialiya	Burugukhime
	Maimiliri	Adja'ana'
Gwoza	Ngige	Burugukhime
	Dorie	Tumbuna
	Gwoza	Burugukhime

2.1.3 **Field Management:**

The field should be bunded (20 - 40 cm) high as the rain starts so as to allow water to collect and penet.rate the soil prior to transplanting (*Zach et. al, 1996*). Field clearing commence in September as flood water in the field recedes and grasses in the field begin to turn brown. Grasses and shrubs in the field should be constructed to store water for transplanting, seedlings should be uprooted in the evening and the roots inserted in water pond to stay overnight. Hole are dug with wooden dibbles. The holes should be 20 cm deep, 6cm wide and space 1.0 m × 1.0 m to 1.5 m × 1.5 m. About 200 mm (two handful of water) should be poured into each hole before seedlings are inserted into the holes to recharge the soil profile to field capacity and ensure proper anchorage and seedling establishment (*Zach et. al, 1996*). The leaf tips of seedlings are snipped off before transplanting in order to reduce transpiration and consequently increase chances of survival, these holes are then left uncovered. No further irrigation or fertilization is necessary (*Zach et. al, 1996*).

2.1.4 Plant Population

Plant density is one of the major contributing factors towards the attainment of potential growth and yield (*Tabo et. al, 2002*). The spacing for Masakwa sorghum production appears to be very wide (*Ogunlela and Obilana, 1983; Yakamba, 1992; BOSADP, 1993 and Gworgwor, 2001*). The interplant spacing ranges from 96 cm to 126.6 cm with a mean of 114.4 cm; while the intra-row spacing varied from 97.6 cm to 143.3 cm with mean of 120.0 cm (*Gworgwor, 2001*). Therefore, there is the need to establish an optimum spacing for Masakwa sorghum production bearing in mind the limited soil moisture which makes extremely high plant densities not only impractical but also unadvisable to adopt.

The effects of plant population on the productivity of the plant have been reported by several researchers (*Akposae et. al, 1986; Yakamba, 1992 and Tabo et. al; 2002*). Yakamba, 1992 recommended 31,000 plants per hectare as optimum plant density for Masakwa sorghum grain yield; while BOSADP (1993) recommended 20,000 plants/ha in another related experiment.

2.1.4 Weeds

Weeds are not serious constraints in Masakwa Sorghum production (*Ogunlela and Obilana, 1983 and Gworgwor, 2001*). However, one or two hoe spot weeding operation is recommended depending on the level of weed infestation of the field (*Zach et. al, 1996*).

2.1.5 Fertilization

The plant in question is cultivated without mineral or organic fertilizer (*Ogunlela and Obilana, 1983; Zach et. al 1996 and Gworgwor, 2001*). This situation is probably not too surprising in the view of the difficulties posed by limited soil moisture and lack of precipitation which makes the application of solid fertilizer difficult and risky. In addition, the heavy clay is inherently fertile, liquid fertilizer may be more convenient to apply but then it has its associated inherent socio-economic problems and cost.

2.1.6 Harvesting

Harvesting is done from late December to January. This should be carried out early enough to avoid bird damage at physiological maturity (when seed grain cannot be crushed by pressing between two fingers). Stalks are cut at the ground level and left on the field to allow panicle to dry properly (*BOSADP, 1998 and Zach et. al, 1996*). Thereafter panicles are severed from straws with a knife or sickle and threshed on a hard surface (*Zach et. al, 1996*).

2.1.7 Storage

Threshed grains are stored in earth granaries dug into the Firgi soil outside the village (*Zach et. al, 1996*). The remaining grain is stored in 100 kg bags.

2.2 Uses

Masakwa sorghum provides supplementary supply of grains and forage during the dry season for both human and livestock consumption (*Ogunlela and Obilana, 1983*) in the drier land marginal rainfall areas of the semi-arid tropics. It is also processed into flour used in the preparation of Tuwo, Porridge, Pap and other local delicacies (*Zach et. al, 1996*).

2.3 Constraints to Masakwa Sorghum Production

The major constraints to high production rate in Masakwa production include:

I. **Pest and Diseases:** The major pests of Masakwa sorghum are birds, grass hoppers and stem borer (*Olabanji et. al, 1996 and Gworgwor, 2001*), Quelea birds is also a major yield reducing agent in the sahel. Covered smut or ear smut and long amut are diseases that are found in Masakwa sorghum fields.

II. **Labour Constraints:** There are two main sources of farm labour, namely family and hired. There are on average four family members per household available for farm work in the Masakwa producing areas. Hired labour is the most important source of farm labor and is mostly for clearing (i.e. cutting shrubs, and grasses), for building, making holes for seedlings transplanting and harvesting. At transplanting hired labour is scarce and the cost are high.

III. **Planting Holes:** Planting holes are prepared with a special digging stick (Sharawa). This operation requires a lot of labour and it is difficult to open a large new area for Masakwa sorghum cultivation.

IV. **Weed Control:** Weeds are not major problems in Masakwa sorghum production. However one or two weeding operations may be required depending on the infestation of the field. Any delay in weeding at appropriate period becomes detrimental to Masakwa sorghum growth and yield.

V. **Rainfall:** Insufficient rainfall during the wet. season to flood the area could be detrimental to Masakwa production.

VI. **Future Research Needs:** There is the need to improve available land races of Masakwa sorghum through selection and hybridization, while potential avenue for improving its productivity. Some desirable traits in some of the 'regular' sorghum variet.ies can be transferred to Masakwa land races in order to improve them. Also, farmers plant Masakwa at low plant population and consequently obtain low grain yield. There is need to conduct investigation on plant density in order to det.ermine the optimum plant density in order to det.ermine the optimum plant density for Masakwa production in the Chad Basin Area. Appropriate birds control measures need to be developed too.

2.4 The Dibble

A dibble or dibber is a pointed wooden stick for making holes in the ground so that seeds, seedlings or small bulbs can be planted (*Wikipedia, 2011*). The oxford mini reference dictionary defined dibber as "a tool used to make holes in ground for young plants"(*Hawkins,* *1995*). The dibble is locally called "Gafgal" or "Gafkal" in Kanuri language and Tuman or by other tribes in some localities. The tool is made from a popular thorny descent plant, Balanite Egytica (called Aduwa in Hausa) (*Haque and Audu, 1998*). An elderly and experienced farmer assessed that the tree has a quality of being chiseled into different shapes when wet. and very hard and strong when dry, it last longer and is not easily attached by most woods pests. Dibbles come in a variet.y of designs including the straight dibber, T-handled dibble (fig 2.1), trowel dibber, and L-shaped dibber. For the transplanting of dry-season sorghum a straight dibber is mostly used, a sket.ch of the dibble made using SolidWorks 2011 is as shown in fig 2.2.

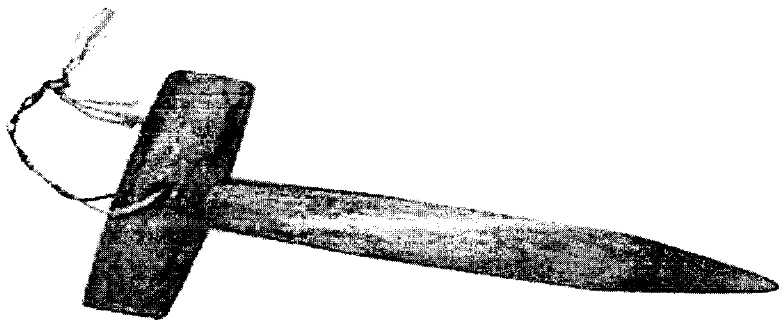


Fig 2.1 T-Handled Dibble

2.4.1 Description of the Traditional Dibble

The dibble was first discovered in Roman times and has remained mostly unchanged over years. In the eighteenth and nineteenth centuries, farmers widely use long-handled dibbles of met.al or wood to plant crops. One man would walk with a dibble making holes. and a second man would plant seeds in each hole and filling it with water. It was not until the renaissance that dibbles became a manufactured item, some made of iron for penet.rating harder soils and clay.

The dibble is usually about 1.2 - 1.6 m long depending on the height of the farmer-use (*Haque and Audu1998*). It is shaped into three distinct parts: the head, the neck and the long tapered pointed end i.e. the upper unshaped part (the head), the middle slandered cylindrical gripping portion (the neck) and the long (about ¾ of whole length) lower tapering pointed – tip. For soil insertion, the pointed end on the diddle is about 20 – 30 cm from the slendered cylindrical neck approximately 4 - 6.5 cm (*Haque and Audu. 1998*) the middle part (which is shaped to uniform diamet.er) is used to hold the dibble firmly with both hands for forceful insertion into the soil. The upper unshaped part which may or may not be peeled is used as a stopped for the hands as well as to make the dibble 10 - 20 cm long and has a diamet.er of 10 - 13 cm. The dibble varies in size as shown below (fig 2.2) and the weight range from 5 - 7 kg. A dibble is carried and handled by one person. It can be made at home by the farmer themselves or purchased from the local market. (at prevailing market. prices); it can be used for several seasons (Haque and Audu 1998).

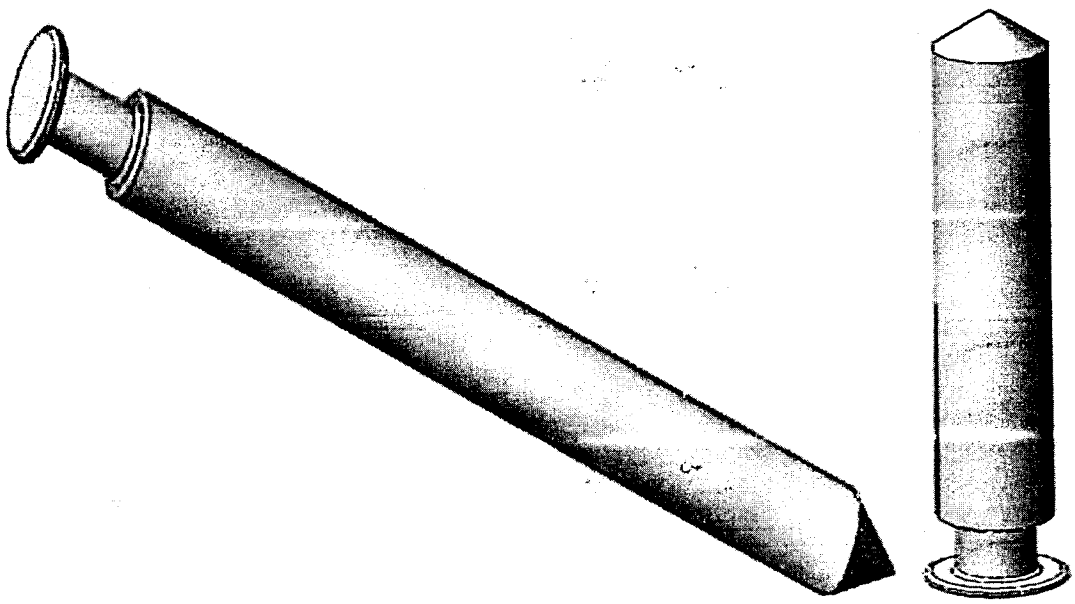


Fig 2.2: The Traditional Dibble

2.4.2 Transplanting Procedure Using the Traditional Dibble

Two persons usually work together as a team to carry out the job. One person handles the dibble and digs the hole at an interval of about 100 – 120 cm long and between the rows. The second person carries the seeding in one hand and a container with water in the other. The container may be an empty engine oil gallon, jerry can, a bucket. or a bowl. The first person holds the middle of the dibble with both hands and raises it about 50 cm above the ground and using force, he insert it upright into the soil to make the hole. The farmer makes two to three such efforts before being able to make a hole of 20 – 30 cm deep and 4 - 6.5 cm (*Haque and Audu, 1998*). After the hole is made, the second farmer pours a small quantity of water, 100 – 200 ml or 2 - 3 handfuls of water (*Ogunlela and Obilana, 1983*) and puts two to three seedlings into the hole. Otherwise a single farmer performs the task of sequentially. The root of seedlings are usually pushed slightly into the bottom of the hole with a short stick of about 40 – 50 cm long and about 2 cm more if normal pushing is not satisfactory (*Olabanji, 1992*). The holes are covered with soil after transplanting the seedling possibly to enhance germination. Usually two third of the hole is filled with water, the farmer makes 120 - 150 holes in an hour and it takes him 60 -80 hours to transplant one hectare (*Haque and Audu, 1998*). The problems identified with the present transplanting system are:

i. Low output (i.e. about 0.015 ha/h)
ii. Extension of transplanting period, this allows the soil to drop its moisture level.
iii. Non-uniformity of transplanting holes depths and plants spacing typical of any manual operation (i.e. inconsistency).
iv. Lack of water at the proximity. The available water source may dry up if transplanting period is unnecessarily extended (*Haque and Audu, 1998*).

2.5 The Mechanized Hole Maker

The dry season sorghum hole maker have been undergoing several design changes over the years since 1998 when it was modified by Madanga Philips in the University of Maiduguri, Nigeria. This tool gave a reasonable efficiency and gave a promise of further study into the design modification of the hole maker. Philip came to the conclusion that:

i. The hole maker provides a means of making a hole with ease.

ii. The technology used in making this tool is well understood and can be adopted to ease the farmer's difficulties.

iii. The weight of the tool is negligible such that it can be carried by the farmer from one place to the other.

With this conclusion, the tool has provided a more ergonomically design tool at its time, but this has not real success for producing the sorghum in this age of agricultural mechanization where time and precision is of paramount.

Later in 2005 at the Federal University of Technology Minna, Abdu Zanna made a modification and performance evaluation of the hole maker. His work gave a bet.ter result as compared to the work of Philip in 1998; he was able to perform farm experiment with the tool and proving that the tool can perform properly when used by prospective farmers. The result to Zanna's field experiment is as shown in table 2.3.

Table 2.3 The Result to Field Experiment.

S/N	Plot of Land		No. of Holes	Time (hours)	Quantity of water (Liters)	No. of 20-Litre Jerri cane
	Acre	Ha				
1	1	0.405	4,050	17	510	26
2	1.5	0.607	6,070	25	765	38
3	2.47	1	10,000	42	1,260	63

2.5.1 Design Criteria of the Hole Maker

The basic information required to start the design of a mechanical device for Masakwa transplanting is as follows:

i. Distance between two adjacent rows and successive plant in a row (i.e. inter and intra row spacing).

ii. Allowable plant deviation from the axis of the row (agronomic statistical analysis/research).

iii. Transplanting depth.

iv. Allowable quantity of lost plant (agronomic research).

v. Quantity of water required in each hole for plant by different soil moisture. Usually, about 2/3 of the hole is being filled with water (*Haque and Audu, 1998*).

Table 2.4 List of Parts of the Modified Hole Maker.

S/No.	Materials	Quantity	Purpose
	6 cm diameter galvanized water pipe	1	Hole Making Portion
	2.5 cm Square-section hollow pipe (300 mm long)	1	Stand gives shape to tool
	5 cm * 2.5 cm rectangular section hollow pipe (500 mm long)	1	Foot press pedal
	Semi-circular hollow pipe (500 mm long)		Handles
	Small bicycle brake and cable (set.)	1	Opens water valve
	Open/Close water tap	1	Water flow valve
	Union/nipple water pipe connections	4	Water flow regulating
	20 cm diamet.er water hose (2 m length)	1	Siphoning water from container
	10 cm diamet.er water hose (1 m length)	1	Delivers water to hole
	Hose clip	9	Tightens connections
	Bicycle jack spring		Closes water valve
	Water valve connection/extension	1	Holds spring and cable
	Bolts, nuts & washer		Holds spring to stand pipes
	Plastic jerry can	1	Contains water
	Spray paint		Protection from rusting
	Labour		Assistance in cutting and welding
	Strap (10 m length)	1	Holding water container

2.5.2 Analytical Design Guide that was carried out on Modified Hole Maker

The following guide was followed in the design of the dry season sorghum hole maker:

i. Height of convenient holding position at relaxed standing posture = 1080 mm. Therefore, 1080 + 130 = 1210 or 1200 overall height from the tip is taken for convenience i.e. breast height of the person.

ii. Thrust exerting device: - Pressure/force to be applied by both hands (using the handles) and a foot (through the foot pedal) - the other foot being used to support oneself.

iii. The farmer makes two or three of such efforts before he is able to make a hole of about 15 – 20 cm deep and 6cm wide (*Olabanji, 1992*), which are expressed as $Y \leq 20$ cm:

The overall acceptable figure (fig 2.3) that was used for designing a hole maker becomes:

$20 \leq Y \leq 30$ cm and $4 \geq X \leq 6.5$ cm for the depth and surface diamet.er respectively:

Tapering hole depth = points D = 17 to 27 cm

Hole surface diamet.er = points $\Phi = 6.05$ to 5.41 cm.

This diamet.er tapers to 2.86 cm or lower at the tip (end point of D).

Therefore approximate volume of hole (cone-Shape) made with dibble given as:

$$\frac{\pi \times d^2 \times h}{12} \quad (1)$$

Where:

d = Surface diamet.er of hole maker = 6 cm,

h = depth of hole maker = 20 cm

The volume is then given as 188.50 cm^3 from equation 1

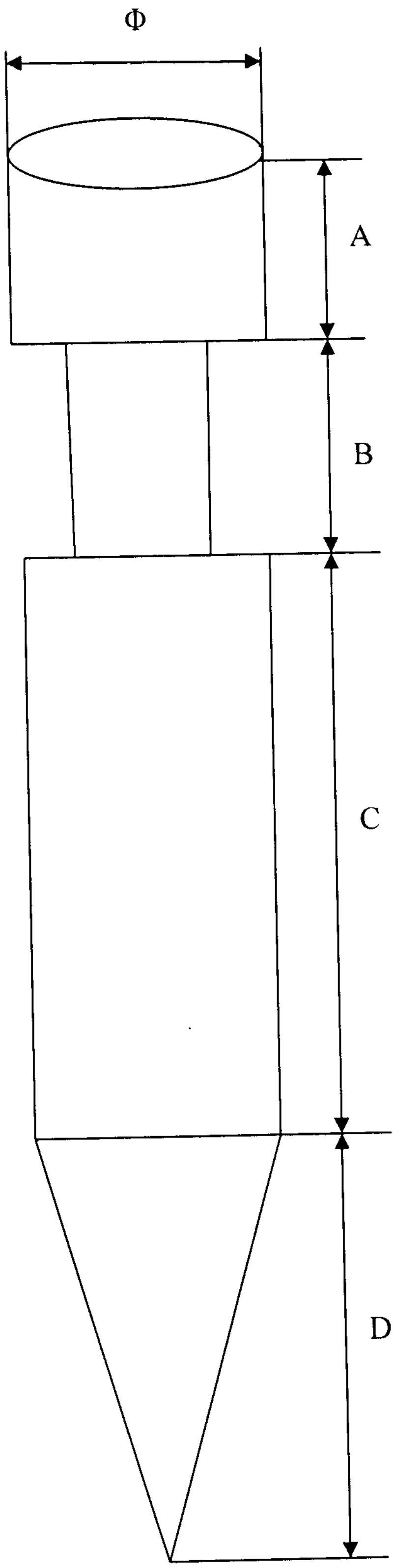


Fig 2.3: Simple Sket.ch of a Hole Maker

Φ = Diameter of head

A = Length of head

B = Length of handle

C = Length of body

D = Length of sharp end

i. Quantity of water being poured into each hole:-

About two third of the hole is being filled with water, which is about 100 – 200 ml of water (*Haque and Audu, 1998*). And two third of the hole volume is 126 ml, which falls in the range (100 – 200 ml) giving 2 - 3 handfuls (*Ogunlela, 1993*).

The modified hole maker was tested at the experimental vegetable farm of Yobe state College of Agriculture, Gubja along Biu Road, which has similar soil characteristics with the dry-season sorghum producing areas. With a total weight of 4.04 Kg it also boosts 40 % efficiency as compared to the use of manual dibble. Also the experiment results are as given in table 2.3 and the materials used for the construction of the hole maker in Table 2.3.

With the above research on design and fabrication for dry-season sorghum it has not yet achieved great efficiency, due to the following reasons:

ii. Accuracy in plant spacing: the space between the plant can't be accurately taken or noticed by the famer since he is still using the own visual intuition to determine the spacing. This setback can increase or decrease the plant density creating a deviation from a density that will provide optimum yield.

iii. Time required for cultivation: the time of transplanting seedlings is still not sufficient (table 2.3), it takes about 42 hours to transplant one hectare of land which is about 5 days if the famer is to work for 8 - 9 hours per day which is tedious and time consuming for the famer to transplant the field.

iv. Stress of carrying water jerry can and the hole maker by hand: the carrying of water container for such a long hour of work can be very tiring and backbreaking, which does not make it fit for the famer.

The major aim of mechanizing any farm operation is to save labour, time and energy as much as possible; these key issues are what this research work will focus on.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The CAD model was done using SOLIDWORKS 2011. This project was guided by a strict list of requirements from its conception. Most of the requirements focused on the functional and technical capabilities of the MATLAB computer program. On the other hand, the purpose of this project was to guide in the design of a tractor operated dry season sorghum transplanting machine. Therefore, the safety, performance, and environmental impact of the implement had to be considered during the selection of materials. This implement is to carry out the following functions: make holes to a required depth, apply required quantity of water to the holes made, and ensure that the spacing for inter-row and intra-row conform to that of the crop. The design parameters selected allowed for the method used and also a satisfactory use of CAD (SOLIDWORKS 2011) software in the design process.

3.1.0 Design Parameters

3.1.1 Agronomic Parameters

i. Distance between two adjacent rows and successive plant in row (i. e. inter and intra row spacing), which is 1.0 meters (Zach *et al.*, 1996)

ii. Allowable plant deviation from the axis of the row, which is ± 0.2 m (Gworgwor)

iii. Transplanting depth, which is 0.2 m (20 cm) (Zach *et al.*, 1996)

iv. Diameter of hole, which is 5 – 6cm (Zach *et al.*, 1996)

v. Quantity of water required in each hole. Usually about 2/3 of the hole is being filled with water (Haque and Audu, 1998)

The volume of water occupied by the hole is gotten as:

$$\frac{\pi \times d^2 \times h}{12} \qquad 1$$

Where:

h = height of the hole made by dibble,

d = Diameter of the hole made by dibble

3.1.2 Standard parameters

The selection of this set of parameters is based on the type of tractor which the implement will be attached through the Three Point Linkage (TPL). A massy Ferguson MF 260 and MF 275 diesel tractor of category 1 and 2 was chosen for all design model verifications and simulations. This series of tractor was selected because it is available in the university and also available for heir in the state Agricultural Development Programs (ADP) offices. The standard specifications of the selected tractor are as given in Table 3.1.

Table 3.1: Standard specification of the selected tractors

Hydraulic		Weight and Dimension		Transmission		Capacities	
Function	Draft control, Response control, Constant Pumping	Gross Wt	1 809 Kg	Type	Sliding Spur	Fuel tank	47.5 l
Pump type	Reciprocating Ferguson pump	Wheel base	1890 mm	Number of gears	8 forward, 2 reverse	Engine sump	6.8
Maximum oil flow	16 l/min	Overall lenght	3.260 mm	Forward 1	2.7	Cooling system	10.2
Maximum Pressure	19.25 MPa at normal operating temperature	Width (minimum)	1,753	Forward 2	3.9	Hydraulic system	33.0
Max. lift capacity with lower	1415 Kg Cat. 1 & 2 with interchangeable balls	Height over exhaust	2,145 mm	Forward 3	5.4	Steering box	0.9

links horizontal						
	Height over steering	1,410 mm	Forward 4	7.2	Oil bath air cleaner	0.5
	Turning circle with brakes	5,970 mm	Forward 5	10.7		
	Turning circle without brakes	6,700 mm	Forward 6	15.6		
	Ground Clearance	338 mm	Forward 7	21.3		
			Forward 8	28.7		
			Reverse 1	3.6		
			Reverse 2	14.5		

The parameters (i.e. the standard dimensions) for the hitch was taken from the ASAE S217.12 DEC01 (ISO+730-1:1994) titled Three-Point Free-Link Attachment for Hitching Implements to Wheel Tractors and are shown in Table 3.2.

Table 3.2: Standard dimension for category I and II three point linkages

Dimension	Description	See appendix	Category	
			1	2
Upper hitch points				
D_1	Diameter of hitch pin	B	19mm	25.5 mm
b_1	Width of ball	B	44 mm max	51 mm
b_2	Linch pin hole distance	B	76 mm min	93 mm min
Lower hitch points				
d_2	Diameter of hitch hole	B	22.4 mm	28.7 mm

d_3	Width of ball	B	35 mm	45 mm
l_1	Lateral distance from lower hitch point to centerline of tractor	B	359 mm	435 mm
l_2	Lateral movement of lower hitch point	B	100 mm min	125 mm min
L	Distance fron end of power take-off to center of lower hitch point, with the lower link horizontal.	B	500 to 575 mm	550 to 625 mm

3.1.3 - **Functional Requirements**

The proposed machine model covers both hydraulic and mechanical domains. The model must be able to simulate dynamic operation, which includes lifting and dropping of the actuator, and other moving parts. Model must be able to export simulation data for plotting and further analysis.

The machine consists of the following components:

a) Hollow square beam

The hollow beam is made from plain steel iron. arranged in such a way that it serve as the machine frame and supporting all the loads resting on it and the forces transferred from the dibble. On this part rest the weight of all other parts.

b) Cylinder

This is the enclosure where compression takes place and the water is afterwards send through the delivery pipe and transferred delivery nozzles. This cylinder has a piston which transfers the pressure to course the flow of the fluid.

c) Piston

This part is used to transfer energy to the water in the cylinder through the actuator. The piston is made to be of lesser diameter compared to the internal diameter of the cylinder; this is to allow free movement of the piston.

d) Connecting rod

This component transfers motion from the actuator to the piston by providing a downward and upward displacement to the piston.

e) Actuator

The actuator is used by the operator to for moving the connecting rod up and down, the force applied by the operator serve as the source energy.

f) Actuator support

This serve as an edge support for the actuator to efficiently move about an axis, and it rest on the frame of the machine.

g) Water tank

This is the containment that holds the water to be used by the machine during field operations.

h) Gusset plate

Then is the connector to the tractor and it transfers the whole weight of the machine to the three point linkage.

i) Dibble.

This is the major part of the machine, which makes the hole where water is applied and the seedling is planted afterwards.

g) Pipe.

This is the hollow circular parts of the machine which conveys water from the tank to the various discharge points.

3.2 System Model

The model cover the mechanical frame, implement attachment and the hydraulic pump system. This model equation shows the links between different components that interact with each other. Elements used with the implement are also put into consideration. The following parts and elements were considered to fully organize the system model:

i. Hollow square beams

The hollow square beam was made using a hollow plain carbon steel of 80 × 80 mm for the two end members and 60 × 60 mm for the four center members.

The dimensions of end members are as given:

l = length of end member = 2500 mm

b = breadth of end member = 80 mm

w = width of end member = 80 mm

t = thickness

ρ = Density of plain carbon steel = 7800kg/m^3 (Shigley and Mischke, 1996)

m = mass of member

The volume of the end member becomes:

V_{member} = External volume of end member – Internal volume of end member (1)

$= (l \times b \times w)_{external} - (l \times b \times w)_{internal}$

$V_{member} = 16{,}000{,}000 - 9{,}000{,}000 = 7{,}000{,}000mm^3 = 0.007\ m^3$

Mass of first member, $M_1 = \rho \times V_{member}$

$M_1 = 7800 \times 0.007$

$M_1 = 54.60$ Kg

Since the two end members M_1 and M_2 has the same dimension and materials, then M_2 = 54.60Kg

For the four centre members:

The dimension of the four center members are as follows:

Length, (l) = 1840 mm

Width (external), w_e = 60 mm

Breadth (external), b_e = 60 mm

Thickness, t = 7.5 mm

From equation (1) the external volume of the centre member becomes:

$V_{member(ext)} = (l \times b \times w)_{ext} - (l \times b \times w)_{int}$

$V_{member} = 6624000 - 5071500 = 1552500\ mm^2$

$= 0.0015525\ m^3$

The mass(M) of the beams using plain carbon steel becomes:

$M = \rho \times V_{member}$

$M_3 = 7800 \times 0.0015525 = 12.11$ Kg

Since all the center beams has the same dimensions and are made from the same material, then $M_3 = M_4 = M_5 = M_6$.

Therefore: M_4, M_5, and $M_6 = 12.11$ Kg

ii. Cylinder

The statement made by Ogulela (1993) that the volume of water to be filled in the hole ranges from 100 – 200 ml was also confirmed by Haque and Audu, (1998) which gave the volume of water required per hole as 126 ml, and lies in the range of 100 – 200 ml (100,00 – 200,000 ml).

Based on the above stated facts, the volume of cylinder is calculated as follows: Designing for 126 ml (126,000) and using a confidence range of 100 – 200 ml, we can calculate the volume of required for the nine holes.

For nine holes (V_{9holes}) = 126,000 × 9 = 1,134,000 mm^3

V_{9holes} will be the minimum volume of water required for nine holes.

The cylinder was divided into three compartments.

Volume above piston control ring = V_{ac}

$$h = \frac{4 \times V_{ac}}{\pi \times d^2}$$

Taking V_{ac} = 1,134,000 mm^3, which is equivalent to the volume of the 9 holes.

Diameter of cylinder = d

d = 200 mm

h = height of cylinder

h = 36.09 mm

The volume below suction (V_{bc}) is measured to be 40 mm

Leaving 10 mm below pipe entrance at both suction and delivery ends of the cylinder and 20 mm above the pipes gives the height below piston control ring to be 70 mm.

The volume below control ring = V_{bc}

$$V_{bc} = \frac{\pi \times d^2 \times h}{4}$$

d = 200 mm

h = 70 mm

V_{bc} = 219,940 mm^3

Volume at control ring:

Taking 10 mm thick control ring, with 10 mm height. d = 10 mm, h = 10 mm

The volume at control ring equals:

$$V_{acr} = \frac{\pi \times d^2 \times h}{4}$$

V_{acr} = 254502 mm^2

The total volume of water to be contained in the cylinder is given to be:

Total internal volume of cylinder = V_{total}

$V_{total} = V_{ac} \times V_{bc} \times V_{acr}$

= 113400 × 21994004 × 254502

V_{total} = 3587902 mm^3

iii. **Piston**

The volume of piston is given as:

$$V_{piston} = \frac{\pi \times d^2 \times t}{4}$$

Diameter, d = internal diameter of cylinder = 200 mm

Thickness = 40 mm

Volume of piston = V_{piston}

Density, ρ = 1300 Kg/m^3

V_{piston} = 1256800 mm^3 = 0.0012568 m^3

The mass (M) of piston becomes:

M = $\rho \times V_{piston}$

M = 1.63Kg

iv. **Water pipes**

Suction pipe:

Using $V = \frac{\pi \times d^2 \times l}{4}$

Length of pipe, l = 0.2 m = 200 mm

Diameter of pipe, φ = 40 mm

Thickness, t = 2 mm

$V_{suctionpipe}$ = External volume – Internal volume

$V_{suctionpipe}$ = (251360 – 203601) m^3

= 47758.4 mm^3 = 4.78×10^{-5} m^3

Delivery pipe:

Length, l = 0.8 m = 800 mm

Diameter, d = 40 mm

Using the same steps as that for suction pipe

$V_{deliverypipe}$ = 23879.20 mm^3 = 2.39×10^{-5} m^3

For distribution line

Total length of line, l = 8.25 m = 8250 mm

Diameter, φ = 10 mm

Thickness, t = 1 mm

Density, ρ = 7800 Kg/m^3

Volume of pipe = $V_{external} \times V_{internal}$

$$= 648037.5 \times 414744.0 = 233293.5\ mm^3 = 2.33 \times 10^{-4}$$

Mass, M = $\rho \times V$

M = 0.3029Kg

v. **Connecting rod**

Considering the length of cylinder before the lower piston control ring = 46.09 mm

Adding the thickness of the piston and the 10 mm thickness of the upper control ring which the adds up to give 50 mm.

Total height (H) in the cylinder above lower control ring = 96.09 mm ≈ 96 mm.

To satisfy for the actuator which is suspended at 40^o, will give a height of:

Height, H = $l \times \sin 40^o$

Where length of actuator support, l = 1000 mm

$$= 1000 \times \sin 40^o$$

$$= 650.73\ mm \approx 651\ mm$$

H, is the height from the upper end of the frame to the base level.

Using Pythagoras theorem to find the horizontal distance covered, and taking the distance as x:

$X^2 = 643^2 \times 1000^2$

X = 651 mm

Taking 400 mm for the connecting rod, for convenience in the displacement of the piston without hitting the walls of the cylinder:

Length of connecting rod = 400 mm

Breadth, b = 60 mm

Width, w = 40 mm

Density, $\rho = 7800\ Kg/m^3$

Volume of material, $V_{rod} = l \times b \times w$

$V_{rod} = 400 \times 60 \times 40 = 1200000\ mm^3$

Mass, $M = \rho \times V_{rod}$

M = 9.36 Kg

vi. Actuator support

Total length of support, l = 1600 mm

Width, w = 20 mm

Breadth, b = 20 mm

Thickness, t = 4 mm

Density, $\rho = 7800 kg/m^3$

Calculating the volume of support material

$V_{supportmaterial} = V_{external} - V_{internal}$

$= (1600 \times 20 \times 20) - (1600 \times 16 \times 16)$

$= 230{,}400\ mm^3 = 0.0002304\ m^3$

Mass, $M = 7800 \times 0.0002304 = 1.8Kg$

vii. Actuator

Length, (l) = 0.8m = 800 mm

Diameter, (d) = 40 mm

Thickness, (t) = 20 mm

Density, (ρ) = 7800 Kg/m^3

$V_{actuatormaterial} = V_{external} - V_{internal}$

$= 191033\ mm^3 = 1.910\ m^3$

Mass, $M = \rho \times V_{actuatormaterial}$

M = 1.5Kg

Fig. 3.4: Actuator

viii. Water Tank.

For the water container, the following dimensions were taken after due consideration of the mass of the water and also the container material itself;

$$V = \frac{\pi \times d^2 \times l}{4}$$

d = diameter of tank = 740 mm

l = length of tank = 1500 mm

ρ_{water} = density of water = 980 Kg/m^3

$V = 663209700mm^3 = 0.663\ m^3$

Mass of water M

$M = \rho \times V$

M = 632.22 Kg

Force that will be acting internally around the containment

$F = m \times g$

Where:

F = force will be exerted by the water

g = acceleration due to gravity = 9.81 m/s^2

F = 6202.08 N = 6.20 kN

The pressure (P) that will be exerted internally per unit area on the wall of the container is given by:

$$P = \frac{F}{A}$$

Where:

P = pressure exerted by the water when the container is filled,

F = Force exerted by the water when the container is filled,

A = Internal area surface area of the container.

$$P = \frac{6202.08}{1.97 \times 10^{-3}}$$

$P = 3.1483 \times 10^{-3}$ N/mm^2

The mass of the tank (M_t becomes:

$$M_t = \rho \times V_t$$

Where:

V_t = volume tank material

$V_t = V_{out} - V_{in}$

$$V_t = \frac{\pi \times d^2 \times l}{4}$$

Where:

Therefore the volume of the two ends of the tank, becomes:

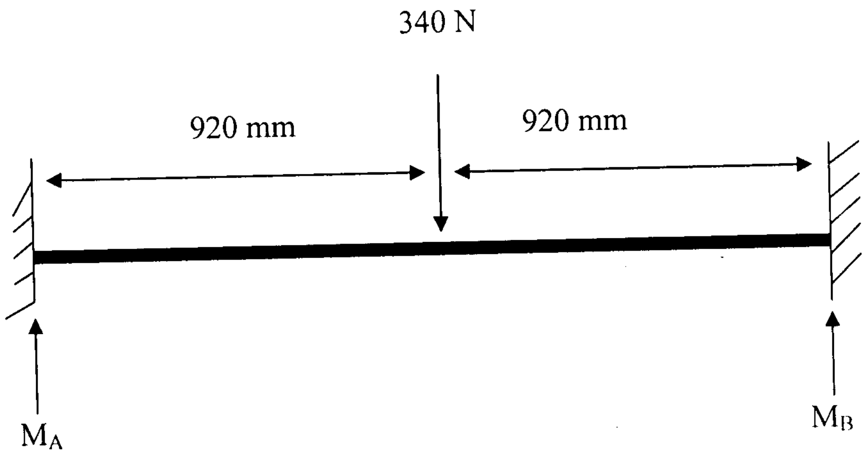
V_{total} = 5212892.20mm^3 = 0.00521289m^3

$M = 1300 \times 0.00521289 = 6.7968\text{Kg}$

3.2.0 Bending Moment Diagrams

Since the two side beams have the same dimensions and carry the same load and are also welded at both ends, they are said to be fixed at both ends.

The force required to make one hole = 340 N (Zanna, 2004), i.e. at each dibble end there will be an upward force of 340 N on the beam.



M_A = Fixed moment at A

M_B = Fixed moment at B

W = Load on the beam = 340 N = 0.34 kN

L = Span of the beam = 1840 mm = 1.84 m

But moment at A equals to that of B:

$$M_A = M_B = -\frac{W \times l}{8}$$

$$= -\frac{0.34 \times 1.84}{8}$$

= -0.078 kN-m

Computing for deflection of the beam from (Khurmi, 2006), we get the deflection (y_c) as:

$$y_c = \frac{W \times l^3}{192 \times E \times I}$$

Where:

I = Moment of inertia of the beam

E = Elastic modulus of the beam = 210,000 N/mm^2

$$I = \frac{b_b \times d_b^3}{12} - \frac{b_{ib} \times d_{ib}^3}{12}$$

b_b = Breadth of beam

d_b = width of beam

i = the corresponding internal dimension of the beam

$$I = \frac{0.08 \times 0.08^3}{12} - \frac{0.072 \times 0.072^3}{12}$$

I = 1.1738 × 10^4

$$y_c = \frac{1.6 \times 1{,}840^3}{192 \times 210{,}000 \times 1{,}173{,}845.33}$$

$$y_c = 4.48 \times 10^{-2}\ mm$$

For the beams supporting the drum and other auxiliary parts:

Neglecting the force exerted by the dibble and assuming that the weight of the drum, water, cylinder, piston, and supports are equally distributed on the two beams and 0.5 m of the end beam:

Summing the forces that will be exerted,

Mass of water = 632.22 Kg

Mass of tank = 6.80 Kg

Mass of actuator = 1.5 Kg

Mass of piston = 9.8 Kg

$$\sum mass = 652.12\ Kg$$

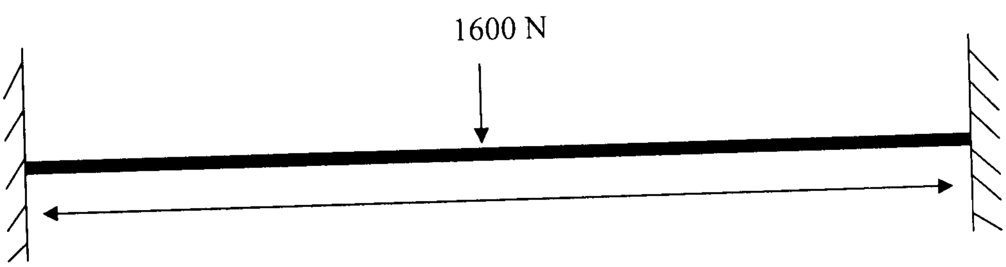
= 651.12 Kg × 9.81 m/s^2

= 6397.30 N = 6.4 KN

On each part of the beams where the loads rest, we have:

$$= \frac{6.4\ KN}{4}$$

= 1.6 KN



1,840 mm

The maximum negative bending moment of the beam is given by Khurmi, (2006):

$$M_A = M_B = \frac{W \times l^2}{12} = \frac{1600 \times 1840^2}{12}$$

$= 451413333.33\ N - mm = 0.451\ KN - m$

The maximum positive bending moment of the beam is obtained as given by Khurmi, (2006):

$$M_c = \frac{W \times l^2}{24} = \frac{1600 \times 1840^2}{24}$$

$M_c = 451413333.33\ N - mm = 0.4514\ KN - m$

The maximum deflection (y_c) of the beam, from (Khurmi, 2006) is as given:

$$y_c = \frac{W \times l^4}{384 \times E \times I}$$

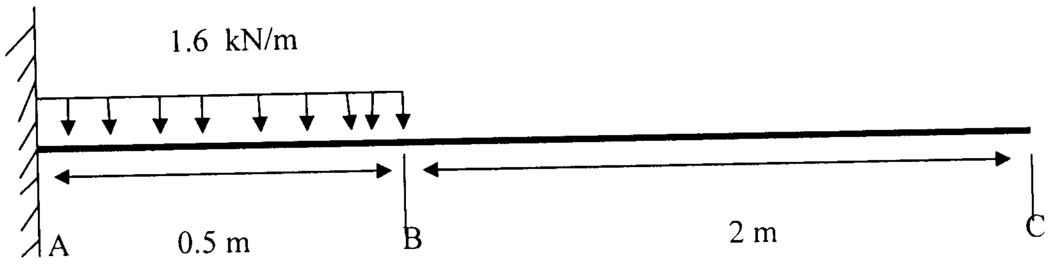
$$I = \frac{80 \times 80^3}{12} - \frac{66 \times 66^3}{12}$$

$I = 3255210.53\ mm^4$

$$y_c = \frac{1600 \times 1840^4}{384 \times 210000 \times 3255210.53}$$

$y_c = 1.39\ mm$

Taking the two end beams as cantilevers fixed at one end and neglecting forces exerted by dibble, the bending moment diagram of the beam is as given below:



Span, l = 2.5 m

Uniformly Distributed load, W = 1.6 kN/m

Length of cantilever carrying load, (a) = 0.5 m

Shear force:

$F_C = 0$,

$F_B = -W \times a = -1.6 \times 0.5 = -0.8$ kN-m

Bending moment:

$M_C = 0$;

$$M_B = -\frac{W \times a^2}{2} = \frac{1.6 \times 0.5^2}{2} = -0.2\ kN - m$$

$$M_A = -[(1.6 \times 0.5) \times \left(2 + \frac{0.5}{2.5}\right)]$$

$$M_A = -0.32\ kN - m$$

Flow of water through pipes and also to distribution pipes:

Different pipe dimensions were chosen for different distribution points, and they are as identified below:

d = diameter

P = pressure

F = force

v = velocity

V = volume

A = Area

ρ = Density

From our previous calculations we deduced that the volume of water required for 9 holes is 1134000 mm^3, which has a mass of 1.134×10^{-7} Kg. Also assuming that the pipes are already filled with water:

From continuity equation of fluid (Merle and David, 2005) the discharge (Q) is obtained as:

$$Q = v.A$$

Mass of water for discharge, $M = \rho \times V$

Where:

Q = discharge in m^3/s

v = Velocity of water in m/s

A = Surface area of hole in m^2

$$A = \frac{\pi \times d^2}{4}$$

d = 200 mm = 0.2 m

A = 31415.93 mm^2 = 0.031415 m^2

M = Mass of water in Kg

V = Volume of water in m^3 = 1.134×10^{-7} m^3

ρ = Density of water in Kg/m^3

Force exerted by the piston = F_{piston}

$$F_{piston} = M_{piston} \times g$$

M_{piston} = Mass of piston = 1.63 Kg

g = Acceleration due to gravity = 9.81 m/s^2

F_{piston} = 16.03 N

Assuming a man applies a force of 10 N to the pump, and adding this to the downward force exerted by the piston. The total force applied on the piston is then given as:

$F_{applied}$ = 10 N + 16 N

$P_{applied}$ = the applied pressure to the water in the cylinder.

$$P_{applied} = \frac{F_{applied}}{A}$$

$P_{applied} = 5.093 \times 10^{-4}$ N/mm^2 = 509.3 N/mm^2

For the other pipes:

$d_{deliv} = 40$ mm

$d_{lat} = 20$ mm

$d_{dist} = 10$ mm

$P_{deliv} = 1.27 \times 10^{-1}$ N/mm^2

$P_{lat} = 5.09 \times 10^{-2}$ N/mm^2

$P_{dist} = 6.79 \times 10^{-2}$ N/mm^2

Therefore pressure at each outlet is = P_{out}

$$P_{out} = \frac{P_{dist}}{9}$$

$P_{out} = 7.544 \times 10^{-3}$ N/mm^2

3.3 Material Selection

The materials selected for each of the component are based on their strength. ability to withstand environmental conditions and their economy. The materials selected for each part and reason(s) for their selection are as tabulated in Table 3.3.

Table 3.3: List of parts, material and reason(s) for selection

Part	Material	Reason
Frames	Plain carbon Steel	- Ability to withstand long stress and does not easily cracking.
Piston	Rigid PVC	- Non-corrosive nature - Ability to withstand harsh environmental conditions. - Its light weight
Tank	Rigid PVC	Same as above
Pipe	Rigid PVC	Same as above
Actuator	Plain carbon steel	Same as frame
Actuator support	Plain carbon steel	Same as frame
Connecting rod	Plain carbon steel	Same as frame

3.4 Modeling Analysis

The plates which are to be attached to the three point linkage are analyzed with SOLIDWORKS 2011 based on the weight of the implement when the water tank is filled. This weight is 7947.67 N = 7.93 kN and is the total weight of the implement. Plain carbon steel was selected based on the stress and strain result is as given below using Von-Mises stress with 2916 Jacobian point mesh. The solid mesh of the plate is shown in fig. 3.6.

steel was selected based on the stress and strain result is as given below using Von-Mises stress with 2916 Jacobian point mesh. The solid mesh of the plate is shown in fig. 3.6.

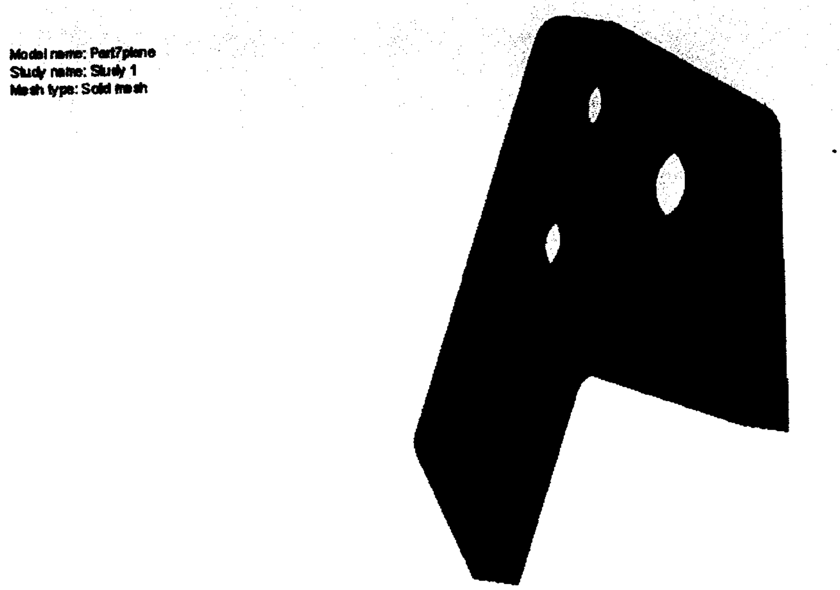


Fig 3.6: Meshed plate for connection to three point linkage

In carrying out the stress and strain analysis, the plate dimensions and material properties were changed several times to make sure it can withstand the applied stress and strain which will be carried the applied weight of the implement. The analysis of the plate was carried out by fixing the bottom curve of the plate and load equivalent to the weight of the implement beimg applied to the top and right side. The static strain and static stress distribution of the plate are shown in fig. 3.7 and 3.8.

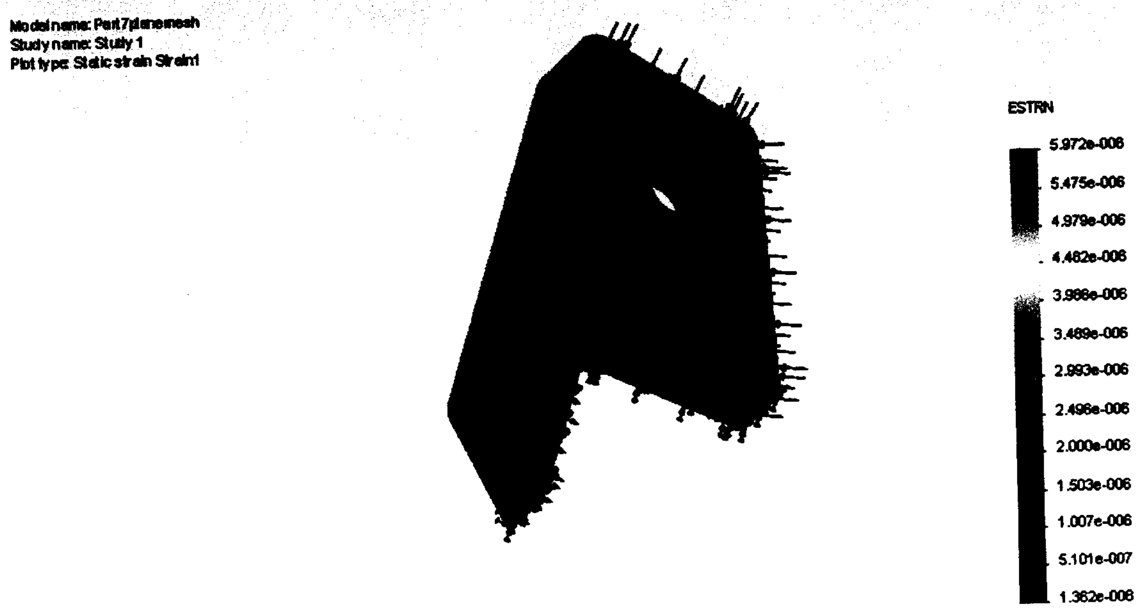


Fig 3.7: The static strain analysis of the gusset plate

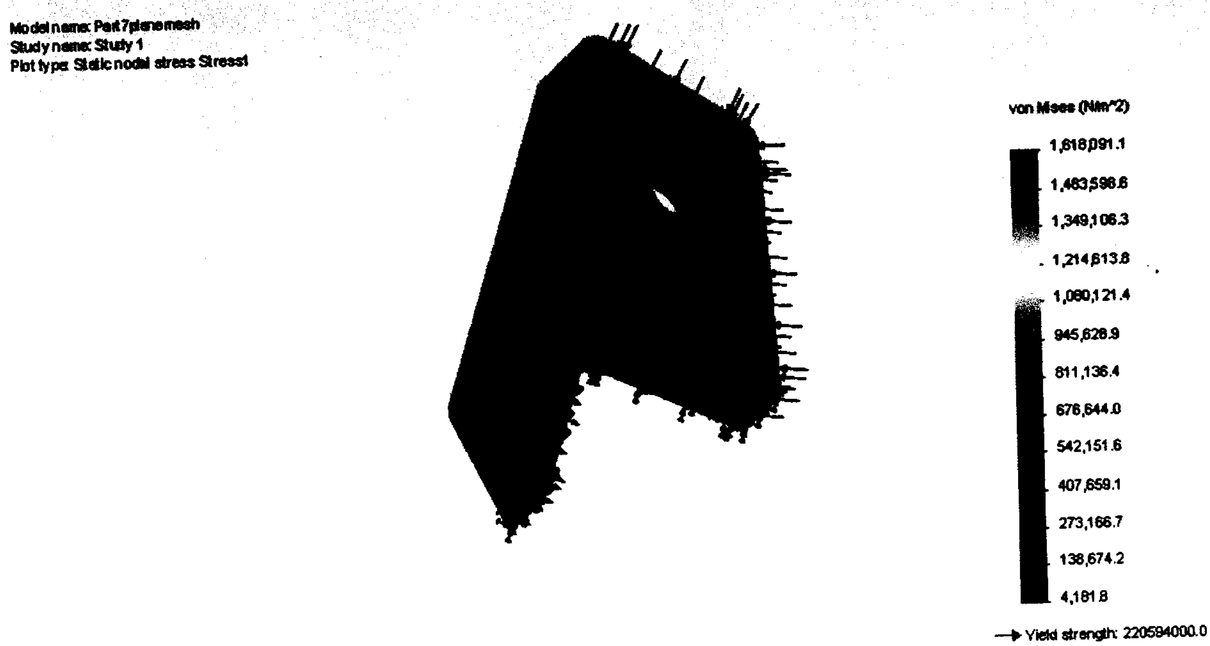


Fig 3.8: The static stress analysis of the gusset plate

3.5 Computer Aided Design (CAD)

The built assembly of the implement and part list are as shown in Fig 3.9 while the pictorial graphics is shown in Fig 3.10. All other drawings are given in appendix B.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	frame		1
2	Handle support		1
3	Link bar		1
4	Bed		1
5	Dibble		1
6	Cylinder		1
7	Piston		1
8	Handle		1
9	Platform		1
11	link bar1^complete design		1
12	PIPe^complete design		1
13	outlet pipe^complete design		1

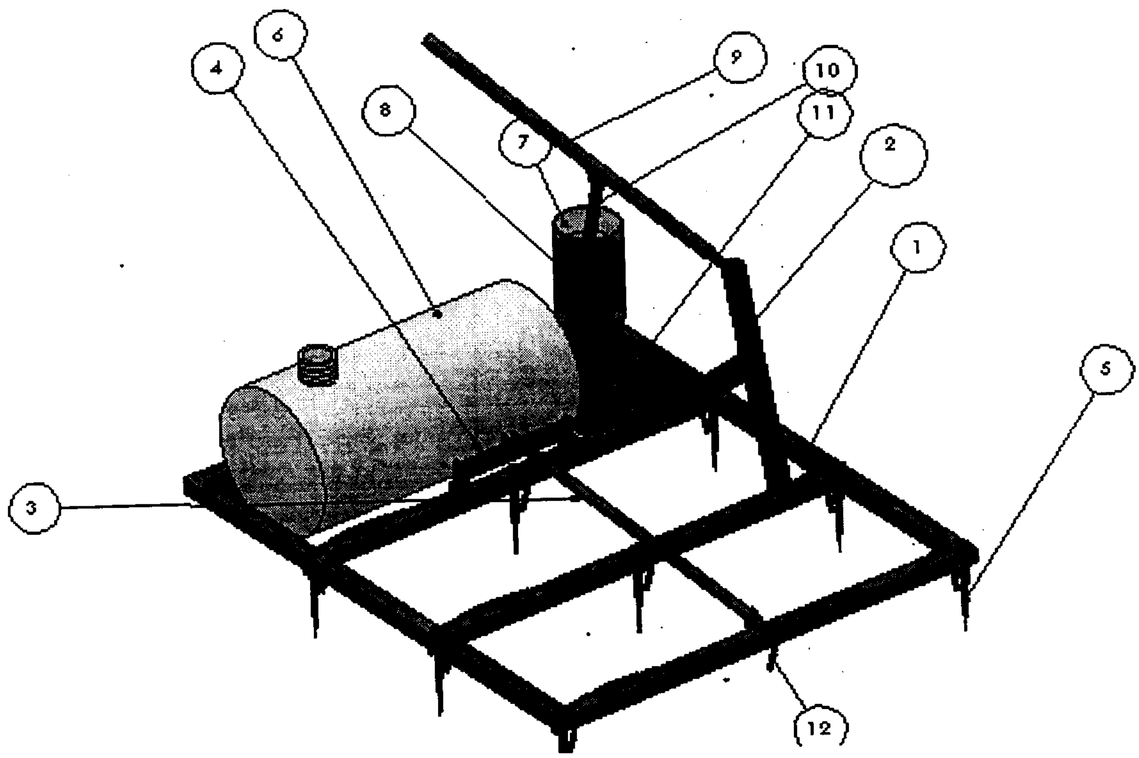


Fig 3.9: Full 3D model of implement showing the part lists

iii. Pumping the water contained in the cylinder through the actuator.

a) **Field operation analysis**

The model was evaluated based on the data used in generating its model and measured variables from the tractor. These variables were taken from Marcey Fergusson MF 260, obtained from the Agricultural Development Project (A.D.P.) Minna. Assuming no time was wasted during the operation, the following computations were carried out based on the measurement from the tractor.

i. It takes approximately 8 seconds to drop and lift the three point link to its minimum and maximum respectively without stopping.
ii. The time taken by the tractor to travel a distance of 3 m was gotten by varying the speed of the tractor from 1 m/s to 7 m/s.
iii. From the force and discharge relation, it was deduced that a minimum of 5 seconds is taken to discharge 126 ml of water into the holes.

Based on the above measurements and taking it as a cycle time, it was found that it took a total of 11 - 22 seconds to perform one circle. In a hectare, there are 10,000 holes of 1 meter equidistance, at low plant density to reduce risk of water stress and produce bigger panicle (Olabanji, 1992). Taking into cognizance the dimension of the machine part that makes the holes which is 2 × 2 m, making the area of the machine 4 m^2. Using the area of the machine, the number of sets made by the machine per drop and other computation is found to be (for ease of computation, variables were assigned to different requirements).

$$N_{hectare} = \frac{A_{land}}{A_{machine}}$$

Where:

Number of drops made by the machine in one hectare = $N_{Hectare}$

Area of land in square meter (A_{Land}) = 10000 m^2

Area of machine in square meter ($A_{Machine}$) = 4 m^2

$$N_{hour} = \frac{3600\ seconds}{T_{circle}}$$

Where:

Number of drops made by the machine per hour = N_{Hour}

Time taken to complete a set of hole and move to the next set = T_{Circle}

$$N_{holes} = N_{hour} \times 9 = 2025\ holes\ are\ made\ per\ hour$$

Where:

Number of holes made per hour = N_{Holes}

$$T_{hectare} = \frac{N_{hectare}}{N_{holes}}$$

Time taken to complete an hectare of land = $T_{Hectare}$

Table. 3.4. Shows transplanting operation on the field with speed been varied.

Speed variations							
Speed (m/s^2)	1	2	3	4	5	6	7
T_{Circle} (s)	22.63636	15.81818	13.54545	12.40909	11.72727	11.27273	10.94805
$N_{Hectare}$	159.0361	227.5862	265.7718	290.1099	306.9767	319.3548	328.8256
N_{Hour}	1431.325	2048.276	2391.946	2610.989	2762.791	2874.194	2959.431
$T_{Hectare}$ (hr)	6.986532	4.882155	4.180696	3.829966	3.619529	3.479237	3.379028

b) Water Requirement:

Due to the considerable weight of the machine considered in the design of the implement, a water tank with 0.66 m^3 (663 litres) volume was used. This means that the tank has to be filled twice to satisfy the water required in the 10,000 holes per hectare. The water required for a hectare of land was found as follows:

Volume of water required per hole = 126 *ml*

Number of hole per hectare = 10,000

Volume of water required for one hectare = 126 × 10,000 = 1,260,000 *ml* = 1.26 m^3 (1260 *litres*)

But we already know that the volume of our tank is = 0.66 m^3 = 663.00 *litres*

Cost Analysis

The price of the components and miscellaneous cost from investigation of what it will cost to construct the machine are given in Table 3.4. It is estimated that □ 88,870 can successfully construct the transplanter.

Table. 3.5. Shows the quantity and price list of each component.

Components	Specification	Quantity	Price (□)
Piston		1	900
Frames	80 × 80 mm	2.5 m × 2	7,500
	40 × 40 mm	2 m × 4	8,000
Water Tank		1	8,000
Pipe	4 mm	0.4 m	100
	2 mm	2.3 m	250
	1 mm	6 m	600
Actuator	40 × 20 mm	0.8 m × 1	300
Actuator support	40 × 20 mm	0.2 m × 1	60
Connecting rod	40 × 20 mm	0.4 m × 1	120
Gusset plate	See appendix	6	4,000
Cylinder	See appendix	1	3,000
Dibble	See appendix	9	2,700
Construction			14,811.6
miscellaneous			14,811.6
Total			**88,869.6**

a) **Economic Analysis:**

The economic analysis for the machine was carried out for one hectare of land and with result from market survey.

Labour cost per hectare = □ 7,000

Cost of machine = □88,869.6

Cost of maintenance per year = □675

Cost of tractor hiring per hectare = 1000

Tax rate for income above □160,000 = 20%

The average yield per hectare is 1000 Kg which is equivalent to 1 tone as stated by Obilana, (1983) and the cost of Masakwa sorghum per bag (80 Kg) as gotten from market survey is □14,000.

Income per hectare = □280,000

Table. 3.6. Below is the financial situation of this equipment through its intended life.

Year	Income (□)	Expense (□)	Operational Net Income (□)	Depreciation (□)	BK (□)	Taxable (□)	Tax (□)	Income After Tax (□)
0		88,869.6	-88,869.6					-74058
1	175000	33350	141650	14811.6	59246.4	126838.4	25367.68	116282.32
2	173250	33683.5	139566.5	14811.6	18538.4	124754.9	24950.98	114615.52
3	171517.5	34017	137500.5	14811.6	18871.9	122688.9	24537.78	112962.72
4	169802.3	34350.5	135451.825	14811.6	19205.4	120640.2	24128.05	111323.78
5	168104.3	34684	133420.302	14811.6	19538.9	118608.7	23721.74	109698.5614
6	166423.3	35017.5	131405.759			131405.8	26281.15	105124.607

The result from Table 4.1 shows that considerable profit is made with the machine after 5 years.

LTW = Lifetime Worth of the machine, and is computed using the formula as given by Ardala, (2000).

$$LTW = -P + P_t\left(\frac{P}{F}, i, N_t\right) \quad 1$$

t = 1, 2, 3, … n

n = 6.

LTW = -74058 + 116282.32(P/F, 12, 1) + 114615.52(P/F, 12, 2) + 112962.72(P/F, 12, 3) + 111323.78(P/F, 12, 4) + 109698.56(P/F, 12, 5) + 105124.61(P/F, 12, 6)

LTW = □602,199

After taking into consideration detail cost (expense) procured to cultivate a hectare of land, it was noticed that considerable profit is made after a five years lifetime worth (LTW).

Machine efficiency:

From the computed results in the last section, this showed that it takes approximately 1 hour 14 minutes to cultivate a hectare of land. This is a short time as compared to modified dibble which can make and fill 10,000 holes in 42 hours, and the traditional dibble which transplant a hectare in 60 – 80 hours, that is the famers make 120 to 150 holes in a hour (Haque and Audu, 1998).

Since the area covered by the machine with respect to time is higher than that of the modified dibble and the hand held traditional dibble, a transplanting efficiency of 90 % was gotten over the modified dibble and 83 % over the hand held traditional dibble. The efficiency was found as follows:

Efficiency at 7 hours per hectare:

$$\square_{md} = \frac{70 - 7}{70} \approx 90\ \%$$

$$\square_{mm} = \frac{42 - 7}{42} \approx 83\ \%$$

Efficiency at 3.4 hours per hectare:

$$\square_{md} = \frac{70 - 3.4}{70} \approx 94\ \%$$

$$\square_{mm} = \frac{42 - 3.4}{42} \approx 92\ \%$$

Where:

$\square_{md}$ = Efficiency over traditional dibble,

$\square_{mm}$ = Efficiency over modified dibble.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

From the machine model, using both agronomic and mechanical parameters suitable results were obtained to effectively obtain a suitable design and graphical concept model for a tractor operated dry season sorghum transplanting machine. The bases results and for the results are as presented below:

a) **Parameters for selection of materials.**

Materials to be used for the machine were selected from the design calculation, which serves as specification. The selection was done based on:

i. Weight: due consideration was made concerning the weight of the machine.

b) **Component parameters**

The component parameters were obtained from design calculation, the parameter gave the machine an area of 5 m^2 with area having dibble as 4 m^2, and a total of 9 dibbles were attached to the machine model. Water tank attached to the model frame has a volume of 663 litres and a weight of 650 Kg.

c) **Stress analysis**

Using SOLIDWORKS, stress analysis was conducted on the principal component that will be carrying large amount of the machine weight. The stress analysis was carried out using Von-Mises stress; this analysis gave a following stress and strain results:

$\tau = 94{,}562$ N/mm^2

$\sigma = 4.482 \times 10^{-6}$ N/mm^2

Where:

τ = Maximum shear stress

σ = Maximum shear strain

d) Field operation analysis

A projection was made for the field operation using the selected tractor parameters; the selected tractor has eight forward gears with 1 – 4 being used as starting gears. The speed are shown in Table 3.1, simulating using a speed range of 1 – 7 m/s an effective working time ranging from approximately 3.4 – 7 hours was obtained. At this time the water tank will be filed twice to cover the 10,000 holes.

e) Economic analysis

The cost analysis of the machine shows that total of □88,870 will be required to construct the machine, using this cost an economic analysis was carried out and it shows that the lifetime worth (LTW) of the machine after five year is considerably high at □602,199. The LTW portrayed that the machine will still be effective even after five years.

f) Efficiency

After simulating the planting operation a time frame of 3 – 7 hours was found to be the total time it will take the machine to transplant a hectare of land when attached to the tractor. This time gave and efficiency ranging from 90 – 94 % over the wooden dibble and 83 – 92 % over the modified dibble.

4.1 Discussion of Results

The design model of tractor operated dry season sorghum presented here was based on several parameters both agronomic and mechanical. The approach used in the design gives the machine a simple working principle, resulting in a high efficiency compared to the hand held wooden traditional dibble and the modified dibble. The planting operation shows fast transplanting rate compared to other form of dibble used for transplanting this crop. The short time in this operation was obtained mainly due to the number of dibbles used and also because it was operated by a tractor. This large amount of holes made between a short time was not hindered by water requirement, since the water tank will only be filled twice to effectively fill the holes in a hectare of land with water.

Also due to this short timing a high economic value was obtained for the machine which gave the machine a very high lifetime worth after five years compared to it construction cost and also cost require for labour during growing life and harvest time of the crop.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The research work shows an easy model form to see how viable the fabrication of a tractor operated dry-season sorghum transplanting machine will be. Based on the model design and analysis carried out in the course of this work, the following closures were drawn:

I. The time that will be taken by the machine to transplant a hectare of land, considerable efficiency was found as compared to other hole maker for transplanting this variety of sorghum, given that no time was wasted during the transplanting operation.

II. Amount of labor used in other forms of hole making and water application equipment has been considerably reduced in this machine given a better economic value and efficiency.

III. The economic values projected for the machine shows that considerable profit will be made from the use of the machine after using it for an assumed cropping season.

5.2 Recommendation

Following from the conclusions drawn here, the following recommendations are suggested.

i. After effectively building this model, it is recommended that a true visible model of the machine be built to verify its efficiency and operation mode.

ii. One limitation of this work, is the non provision of moving parts that will synchronys the making of holes and accurate discharge of water into this holes, it is strongly recommended that effective synchronic model be built to provide more plating efficiency and reduce stress on the tractor hydraulic system.

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APPENDIX I

The Von-Mises Stress

For a ductile material, the stress level is considered to be safe, if

$\sigma_e \leq \sigma_y$

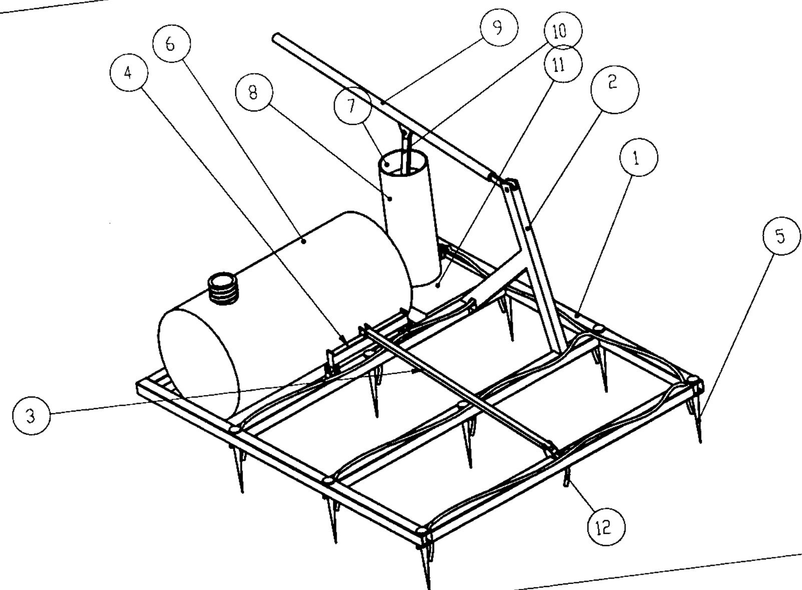
Where σ_e is the Von-Mises stress and σ_y the yield stress, Then Von-Mises stress is given by:

$$\sigma_e = \frac{1}{\sqrt{2}}\sqrt{(\sigma_1 \times \sigma_2)^2 + (\sigma_2 \times \sigma_3)^2 + (\sigma_3 \times \sigma_1)^2}$$

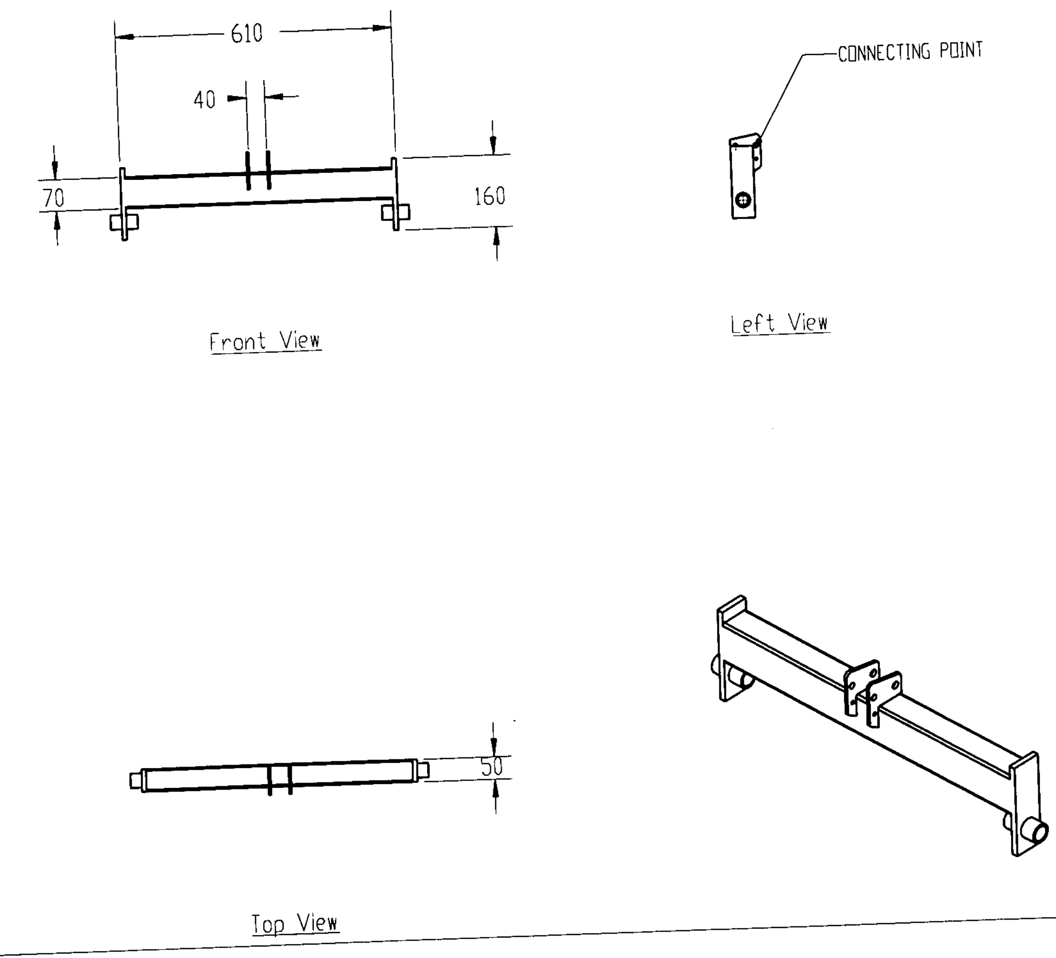
In which σ_1, σ_2 and σ_3 are the three principal stresses at the considered points in a structure.

PART LIST

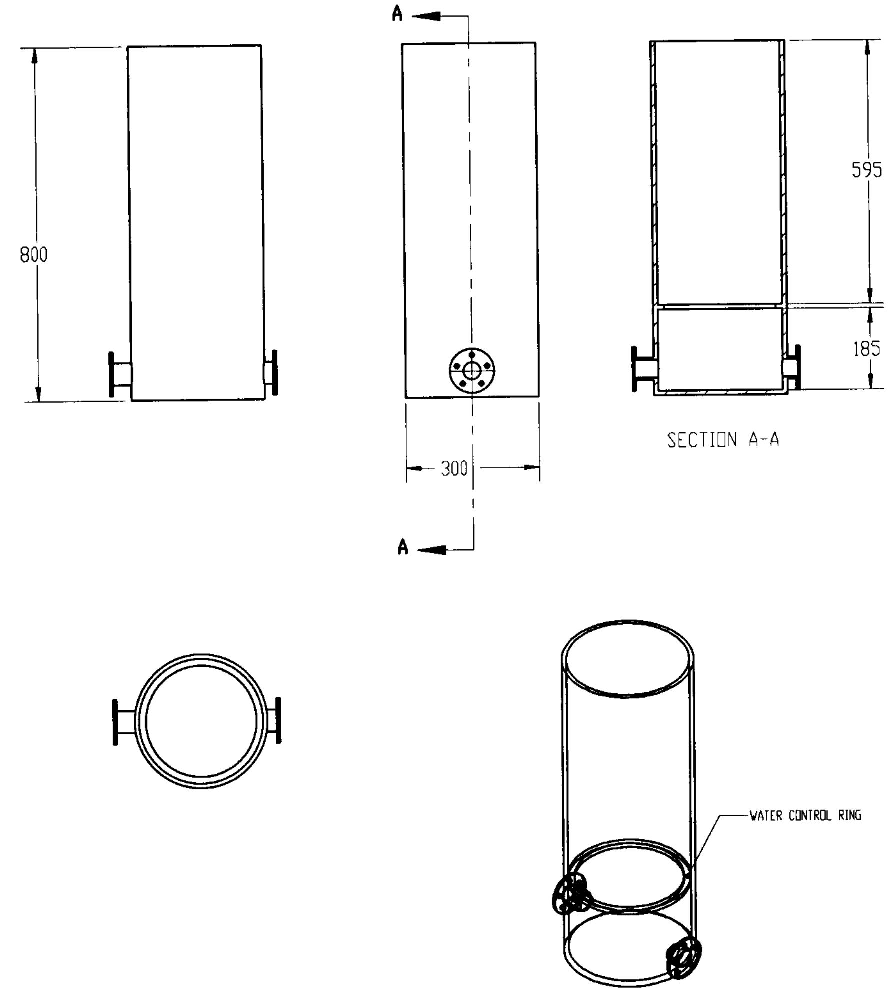
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	frame		1
2	Handle support		1
3	Link bar		1
4	Bed		1
5	Dibble		1
6	Drum		1
7	Cylinder		1
8	Piston		1
9	Handle		1
10	PiPe		1
11	Platform		1
12	outlet pipe		1



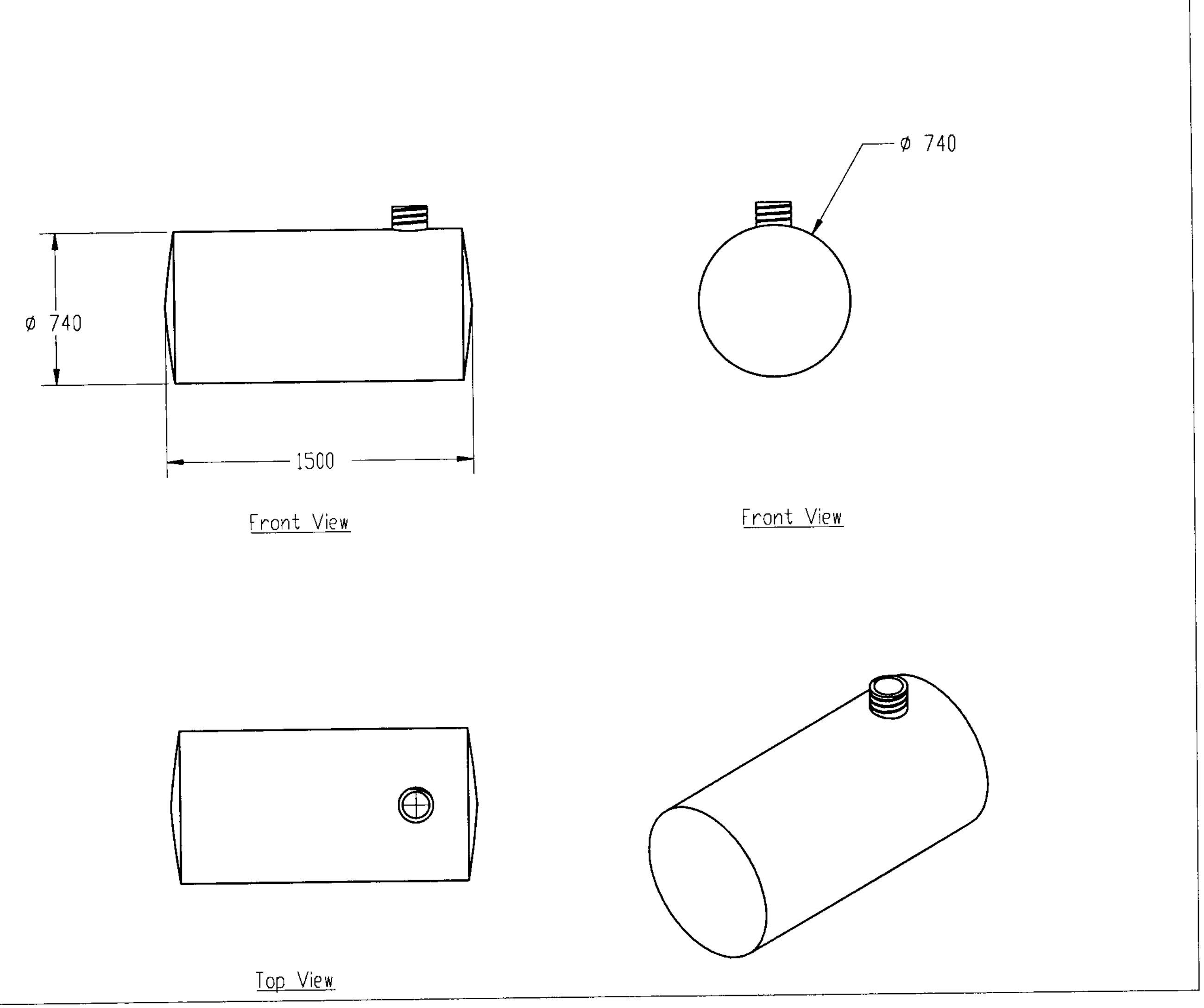
Hanger Support



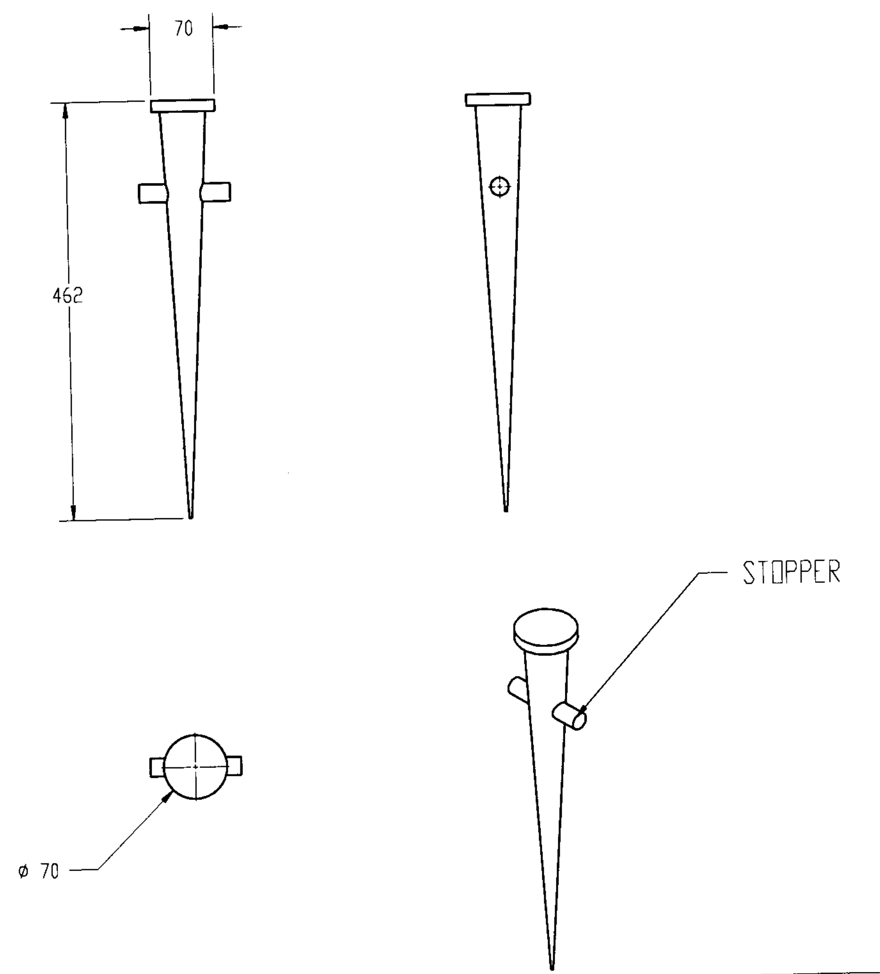
CYLINDER



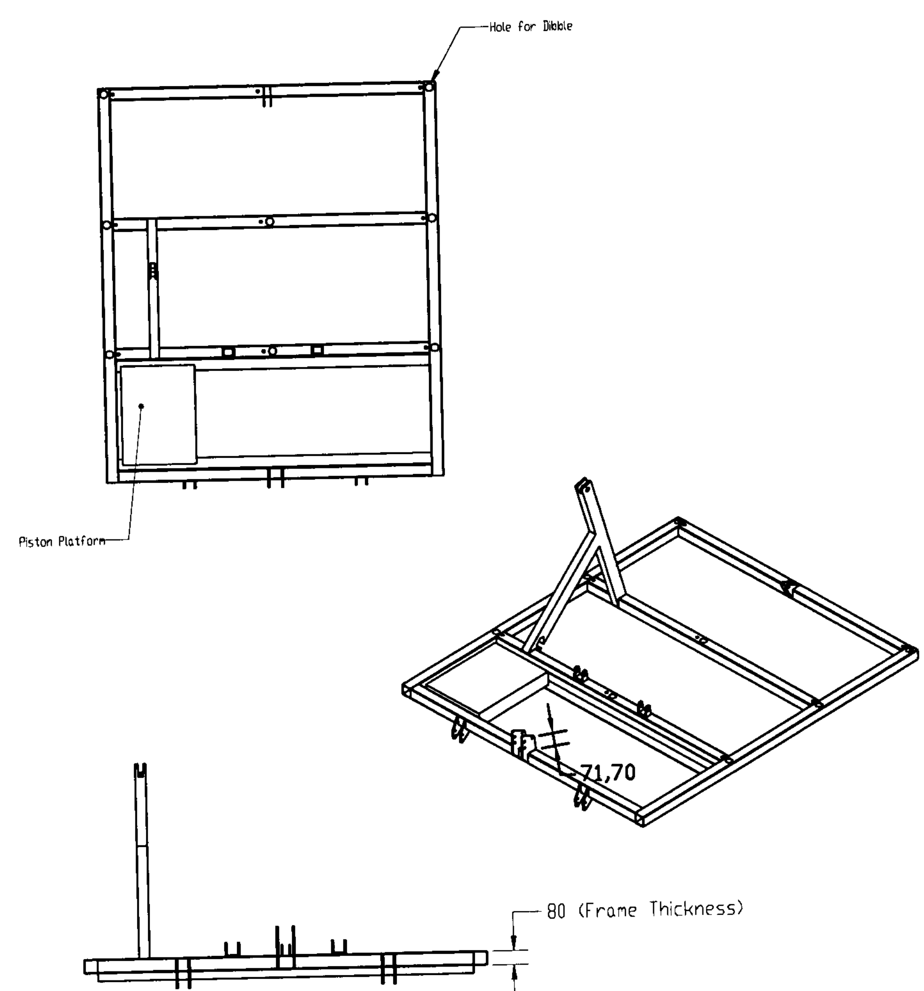
WATER STORAGE TANK



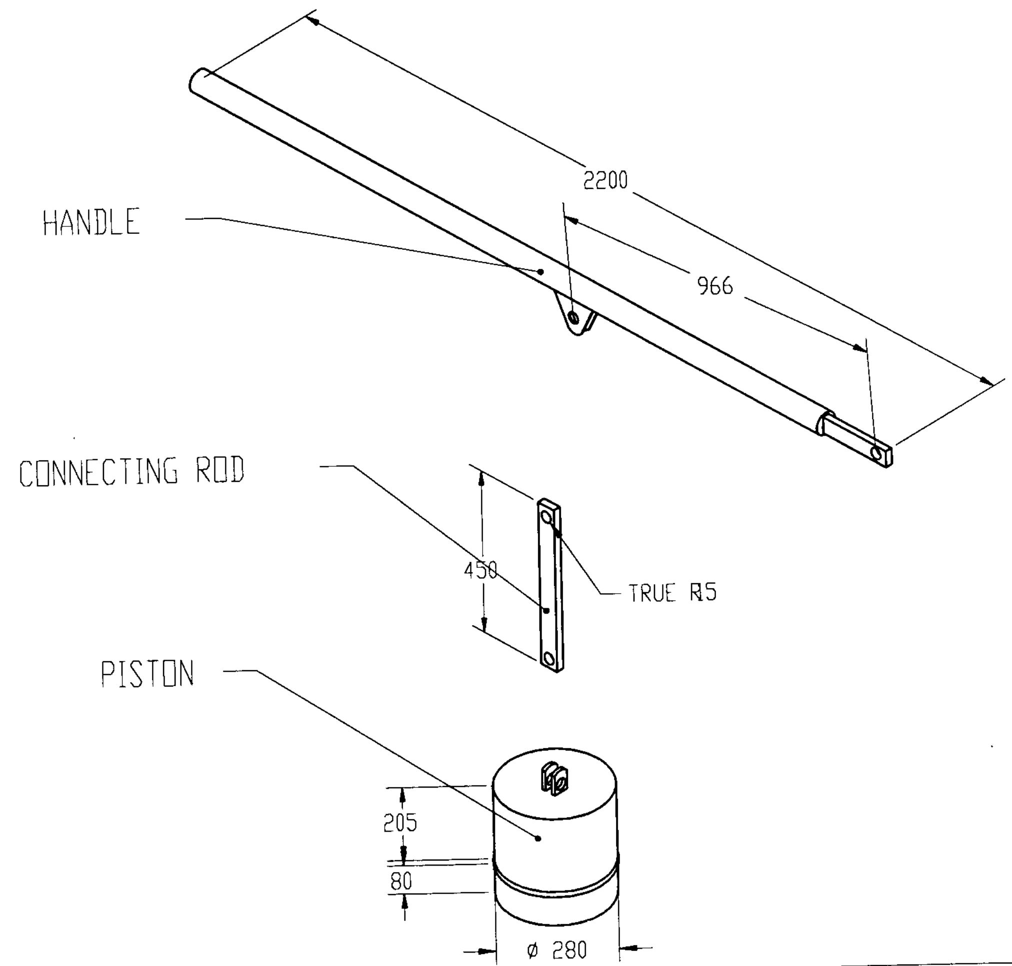
DIBBLE



THE FRAME



PISTON CONNECTING ROD AND HANDLE



PISTON CONNECTING ROD AND HANDLE