MODIFICATION AND PERFORMANCE EVALUATION OF A HOLE MAKER FOR THE TRANSPLANTING OF WINTER SORGHUM (MASAKWA) SEEDLINGS

BY

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BEING A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL ENGINEERING, SCHOOL OF ENGINEERING & ENGINEERING TECHNOLOGY, FEDERAL UNIVERISTY OF TECHNOLOGY, MINNA, IN PARTIAL FULFILMENT OF THE REQUIRMENT FOR THE AWARD OF POSTGRADAUTE DIPLOMA IN AGRICULTURAL ENGINEERING (FARM POWER & MACHINERY)

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DECLARATION

I, ABDU ZANNA, REG. NO. PGD/SEET/AGRIC.ENG./2001/156 hereby declare that roject report was conducted by me under the supervision and guidance of Engr. A. A. Balami, rtment of Agricultural Engineering, Federal University of Technology, Minna, during the /2002 session.

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CERTIFICATION

This Project Report entitled **MODIFICATION AND PERFORMANCE EVALUATION HOLE MAKER FOR THE TRANSPLANTING OF WINTER SORGHUM KWA) SEEDINGS BY** Abdu Zanna meets the regulations governing the award of duate Diploma in Agricultural Engineering (Farm Power & Machinery) of Federal sity of Technology, Minna, and is approved for its contribution to knowledge and literature ation.

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DEDICATION

This project is dedicated to my parents Late Baba sheriff and Ya Mairam, and to my guardian Late Alhaji Zanna Fuguma Barma, and his wife Late Ya Hamsatu. May the souls of all the three deceased rest in perfect peace.

ABSTRACT

Due to the tedious nature of transplanting winter sorghum (*Masakwa*) seedlings using the heavy traditional dibble, a light modified version made of light, hollow strong metals was produced based on analytical calculations and ergonomic consideration of the traditional dibble The tool makes 120 – 150 holes per hour, estimated to be 0.012 to 0.015 hectare per hour. The modified hole maker which has sharp pointed tip, also incorporates water application device, and makes 240 holes per hour or 0.024 hectare per hour. After comparing their performances it was found that the modified hole maker is 40% more efficient than the traditional dibble.

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CHAPTER ONE

1.0 INTRODUCTION

"*Masakwa*" is a unique Winter Sorghum (sorghum bicolour (L.) Moench) cultivar grown during the dry and cool harmattan period, i.e. during the post-rainy season. It is therefore called "harmattan/winter" sorghum. Some call it "Firgi" sorghum in relation to the Firgi soil on which it is grown. It is a short-day, low temperatures (15-30°C) and cold night cultivar. It is also called the miracle crop of Borno State. (BOSADP, 1996)

Masakwa is the major cereal crop grown on the vertisol (productive black cotton soils of 30 – 60% clay) of northeastern Nigeria, western Chad Republic and northern Cameroun, i.e. in the flood plain areas within Lake Chad to the north and Mandara Hills to the south. In northern Cameroun (Maroua), it is called "*Muskwari*" and represents 25 – 30% of the total sorghum production, while in Chad Republic, it is locally known as "Berbere" (Djonnewa and Dangi, 1988). In Nigeria, the major producing areas are the northeastern, eastern and southeastern Borno comprising Kukawa, Monguno, Marte, Nganzai, Dikwa, Ngala, Mafa, Konduga, Bama, Kala-Balge and Gwoza local government areas; and Madagali in Adamawa state. Its suitability to the environment, low production cost, numerous uses and good grain quality made the crop very popular in the producing areas (Anonymous, 1990).

The common types grown across the zones in the various local government areas are: Bulwalana (white), Aja'ama (Cream), Tumbuna (mixed brown) and Buruwu (brown). The ranking of the crop types is based on the type the community like most as their staple food cereal and types that are readily marketable. However, the crop is palatable and nutritious, and is being processed into various forms of food, gruel and local gins. In the various production areas, it contributes 40 – 80% of the cereal to the people. The stalks are used for local building and fencing purposes, while animals feed on the fodder and other crop residues. The producing areas support a large population of livestock as well. (Djonnewa and Dangi, 1988).

The total cultivated land in Borno is estimated (1990) to be 411,915 hectares, while the actual land being cultivated is 41,609 hectares (Anonymous, 1990). See table 1.

Table 1: Masakwa Producing Areas: Under Cultivation

S/No.	L.G.A.	Land area (Sq.km)	Total cultivable (22% of land area)	%	Firgi Land (Ha.)	%	Actual Firgi under cultivation (Ha).
1.	Dikwa	1683	37026	80	29621	20	5924
2.	Ngala	3729	82039	90	73834	15	11075
3.	Monguno	3926	86372	50	43186	10	4319
4.	Kukawa	6710	147620	20	14762	15	2214
5.	Bama	6175	135850	80	108680	15	16302
6.	Gwoza	2689	59158	20	11832	15	1775
	Totals				**411,915**		**41,609**

Source: Borno State Ministry of Agriculture:

Report on Vertisol (Firgi) (Anonymous, 1990).

However, other crops like millet, the conventional rainfed sorghum, maize, cowpea and groundnuts are produced on the lighter soil in most of the areas mentioned. In some places, Masakwa is the second or the third crop in importance. In addition to the cereal crops, vegetables like onions, tomatoes carrots, pepper and garden eggs are massively produced on the vertisol during the harmattan to give (additional) monetary incomes to the communities. Water for the vegetable production is obtained from dug-out ponds or shallow wells made along stream courses. These are irrigated mostly using the shaduf method/system of irrigation. Small irrigation pumps are used in places with developed practices (Anonymous, 1990)

1.1 GENERAL PRODUCTION PROCESS

The cultural practices and management for the production of Masakwa (winter sorghum) are strikingly different from those of "regular" (rainy season) sorghum in many respects. Some of these differences are not un-related to the difficulties bearing the mechanization of some of the necessary cultural operations, mainly due to the nature of the soil. (Ogunlela and Obilana, 1983).

The crop is grown on a moist clay to clay loam soil immediately after the recession of rainy season flood water from the field. The field is cleared in September as the flood water in the fields recedes and grasses began to dry. The grasses are cut (slashed) using local cutlass called "langa-langa" or "bongoro" and then left on the field for about a week to dry and then burned. The (Masakwa) seedlings are grown on small plots on well drained soil near the fields or near the villages between August and September and are then transplanted after five or six weeks in late September and October. Some use fertilizer, manure or pre-emergence pesticide to enhance seedling development. No tillage operation is carried out before or after transplanting the seedlings. It is therefore a conservation or zero tillage system of farming. About 8kg of seeds are require to transplant one hectre of land. (BOSADP, 1989). The yield is 0.6 – 0.8t/ha (Nwaka, 1989). This compares well with the yield of wet season sorghum which is about 0.8 –1.0t/ha (Obilana, 1983).

The peculiar or unique characteristic of this crop is that it is grown when there is no rain at all in the area, and no water is supplied to the field during the entire growing season (except about 100 to 200ml of water poured into the hole at the time of transplanting). The crop survives solely on moisture accumulated in the (versitol) soil during the rainy season (and some precipitation from the atmosphere during the early stage, followed by the cold harmattan breeze for the rest of the growing period). Usually the field is weeded once 3 to 4 weeks after transplanting the seedlings. Weeding (where necessary) is done manually with local hoe (called Fartanya in Hausa). Farmers usually do not apply any manure or fertilizer to the field either before, during or after transplanting the seedlings (Haque and Audu, 1989).

1.2 CONSTRAINTS OF MASAKWA PRODUCTION

Any discussion about Masakwa production in the State is bound to raise more questions than answers about the agronomic characteristics, cultural practices and technological contributions at the moment because very little scientific work has been done with the crop.

However, the principal constraints limiting the production of Masakwa Sorghum in Borno State are highlighted as follows:-

1) Lack of available technologies, e.g. pesticides and improved transplanting materials

2) Limited residual moisture in the post-rainy season, which restricts the crop response to inputs, e.g. the partially dried surface, does not encourage the application of fertilizers.

3) Keeping the land fallow during the rainy season encourages weed growth and clearing for Masakwa transplanting becomes difficult. The land could have been used for other crop, then to be followed by Masakwa – i.e. double cropping.

4) Manual, back-breaking and tedious ridge-making or bunding limits farm size and increase production cost either through hiring labour or spending more hours on holdings. This may discourage farmers from expansion.

5) The strenuous transplanting hole making using human energy to handle the dibble makes the job un-interesting or rather scaring to present-day youths. This makes them to abandon the farms they inherited from their parents to look for easy jobs elsewhere. Improving the transplanting process is the aim of this project.

6) Manual transplanting of Masakwa Sorghum requiring hard labour restrict the area of production, (i.e. low output) and discourages the expansion of farm size.

7) In relation to machine (tractor) use, trafficability and workability of Vertisols are reduced to zero during or immediately after the rainy period, because of the extremely sticky nature of the soil. So the soil can only be worked upon within a narrow range of soil moisture regime.

8) Low plant density resulting in lower grain yield per unit area. This poses challenges to our agronomists/researchers who are supposed to determine the crop density that would give the highest yield.

9) Non-uniformity of transplanting depth and plant spacings, (i.e. row spacings and individual plant spacings).

10) Limited research work to determine the variety most suitable to particular area or zone. Present production is based on preference.

11) Lack of effective control measures for devastating pests and diseases of Masakwa Sorghum.

12) Holdings are smaller and scattered (from 0.1-1.0ha), so use of machine (tractor), e.g. bunding, may create more problems in reaching individual farms

13) Lack of proximity to source of water in some areas. Therefore, fetching water from a far place unnecessarily stretches the transplanting period.

14) Grazing livestock are attracted to the green, still standing crops or before panicles are gathered from the farms.

Therefore, in a nutshell, the major problems that could be identified in Masakwa production process are: low output due to use of strenuous traditional tool, limited transplanting period, non-uniformity of transplanting depth and plant spacings, and lack of proximity to water source in some areas.

Over the years, no attempt was made to modify the transplanting tool (the dibble) nor diversity or improve any element of the production process despite being the major cereal crop in the Lake Chad Basin flood plains.

This attempt is therefore a pacesetter for the mechanization of Masakwa transplant.

1.3 AIMS AND OBJECTIVES

The aim of the project is to study the principle of construction and operations of the existing tool (Hole Maker – i.e. the Dibble called Gafgal) and make improvements, so that the following objectives could be achieved:-

1) Fatigue should be minimized by using less effort (force or thrust) in making the transplanting holes;
2) There will be reduction in the weight of the tool i.e. the hole maker;
3) There will be reduction in the number of working hours (i.e. man-hours) on the field so that the transplanting exercise will be done within a short period of time.
4) Develop a modern, simple, manually-operated dual purpose (hole making + watering) device that will be used Masakwa producers, and be reliable as well;
5) Form a basis for further improvements (mechanization) of the Masakwa transplanting process, by embarking on the Appropriate Technology best suited to the condition or the ecosystem.

CHAPTER TWO

2.0 LITERATURE REVIEW

Operations requiring mechanization in the production process of Masakwa sorghum are the bunding, making the transplanting hole and water application toe each hole. The bunding using a tractor with well-adjusted ridger can comfortably be done easily or cheaply when there is no other pressing farm work to be done with tractor (i.e. late February to early May). The major problem is mechanizing the transplanting process. Mechanization can be beneficial or detrimental, depending on the circumstances. However ideally we expect mechanization to be quite beneficial, provided is appropriately applied.

"Agricultural mechanization embraces the manufacture, distribution, and operation of all types of tools, implements, machines and equipment, for agricultural land development, farm production and crop harvesting and primary processing. It includes (the use of) three main power sources: human, animal and mechanical." (Holtkamp, 1990).

Mechanization has been a major factor in the development of agriculture in industrialized countries. Indeed, the achieved degree of motorization often serves as a measure of the "modernness" or "progressiveness" of country's agriculture.

One of the main reasons for increasing a farm's degree of mechanization has always been and is still to raise its labour productivity i.e. to achieve a higher output (expanded acreage or higher yield per worker) and/or better income per man-hour of work (ha/h, t/h). In doing so, the farmer substitutes capital in place of scarse/expesivie manual labour (Holthkamp, 1990).

Agricultural machinery and equipment can be referred to as any tool used to execute agricultural operation (from land clearing to harvesting and storage); on arable or dairy farm, etc to reduce drudgery and improve efficiency.

Agricultural progress depends largely on the extent to which mechanical power and machinery can be employed to render labour more productive (Culphin, 1981).

Farm equipment is being increased in size and efficiency so that farmers can produce more with less labour and cost. Fewer farm workers support more people by the use of new developments and improvements in farm machinery (Smith and Wilkes, 1977).

Unfortunately, mechanized methods can also result in some bad effect on soil structure. When (vertisol) soils are wet, tractor wheels can cause paddling of the soil, either by shear compression or by smearing. These bad effects are particularly marked in wet, late seasons when crops have to be carted off waterlogged land. The aim of mechanization must be to equip in such a way that work does not have to be carried out in worst soil conditions (Culphin, 1981). Therefore mechanization may be detrimental in this respect.

However, the most important considerations to be borne in mind at all times are cost effectiveness and appropriate mechanization for a given ecosystem (or level of development). Tools and equipment must be at affordable prices to the greater percentage of farmers. Mechanical power is more economical of medium and large-scale farms where operation/field conditions are suitable for use of wide range of agricultural machinery (Holtkamp, 1990).

2.1 CONDITIONS FAVOURING THE PRODUCTION OF MASAKWA

Three main factors justify, favour or encourage the production of Masakwa, viz:

a) **Climatic factor**, i.e. the dry cool harmattan (winter) temperatures (15-30^{o}c), short-day, long cold night (characteristics of winter period) and annual rainfall of 25-50cm (Olabanji, 1992).

b) **Soil Condition** Vertisols (productive black cotton soils – 30-60% clay) are inherently fertile and have potential to store adequate water for crop growth during the wet and dry seasons to which Masakwa is ideally suited. Bunds are constructed to further enhance the water retention capacity for the Vertisols, which are often built crosswise or across the gradients of the gently sloping land to trap any rain or flood water and allow it to infiltrate into the soil. (Nwaka, 1989).

c) **Economic Factor:** In the various production areas, Masakwa contributes 40-80% of the cereal requirement of the people (BOSADP, 1996).

The crop has low production cost, good grain quality, readily marketable and has numerous uses. (Ogunlela and Obilana, 1983).

2.2 INTRODUCING THE DIBBLE

All Masakwa sorghum farmers, irrespective of the zone, area or locality, use the same type and shape of the traditional transplanting tool – the dibble/dibber. 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 name in some localities. The tool is made from a popular thorny desert plant, Balanite egyptica (called Aduwa in Hausa) (Hague and Audu, 1998). An elderly and experienced farmer asserted that the tree has a quality of being chiseled into different shapes when wet and is very hard and strong when dry. It last longer and is not easily attacked by most wood pests.

2.3 DESCRIPTION OF THE TRADITIONAL DIBBLE

The dibble is usually about 1.2 – 1.6m long depending on height of the farmer-user (Haque and Audu, 1998). It is shaped into three distinct parts: the head, the neck and the long tapering pointed-end body; i.e. the upper unshaped part (the head), the middle slendered cylindrical holding/gripping portion (the neck) and the long (about ¾ of whole length) lower tapering pointed-tip soil insertion part (the body).

The diameter of the dibble at about 20-30cm from the pointed end is approximately 4 - 6.5cm (Haque and Audu, 1998). The middle part (which is shaped to uniform diameter) is used to hold the dibble firmly with both hands for forceful insertion into the soil (Fig. 1).

The upper unshapped part which may or may not be peeled is used as a stopper for the hands as well as to make the dibble heavier for increasing thrust. This portion is about 10-20cm long and has a diameter of about 10-13cm. The dibbles vary in sizes (plate1) and the weights range from 5-7kg. A dibble is carried and handled by one person. It can be made at home by the farmers themselves or purchased from the local markets (at prevailing markets price). If properly kept, it can be used for several seasons (Haque and Audu, 1998).

2.4 TRANSPLANTING PROCEDURE USING THE TRADITIONAL DIBBLE

Two persons usually work together as a team to carryout the job. One person handles the dibble and digs the hole at an interval of about 100-120cm long and between the rows. The second person carries the seedlings 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 (Plate I).

The first person holds the middle part of the dibble with both hands and raises it 50-80cm above the ground and thrusts 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 20-30cm deep and 4-6.5cm. (Haque and Audu, 19908) in diameter at the soil surface (if first attempt fails, possibly due to hard soil condition).

After the hole is made, the second farmer pours a small quantity of water: 100-200ml (Haque and Audu, 1998) 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 tasks sequentially. The roots of seedlings are usually pushed slightly into the bottom of the hole with a short stick of about 40-50cm long and about 2cm in diameter if normal pushing is not satisfactory (Olabanji, 1992) the holes are not covered with soil after transplanting the seedlings (possibly to enhance aeration). Usually, two-thirds of the hole is filled with water.
The farmers make 120-150 holes in an hour and it takes them 60-80 hours to transplant one hectare (Haque and Audu, 1998).

The problems identified with the present transplanting system are:-

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

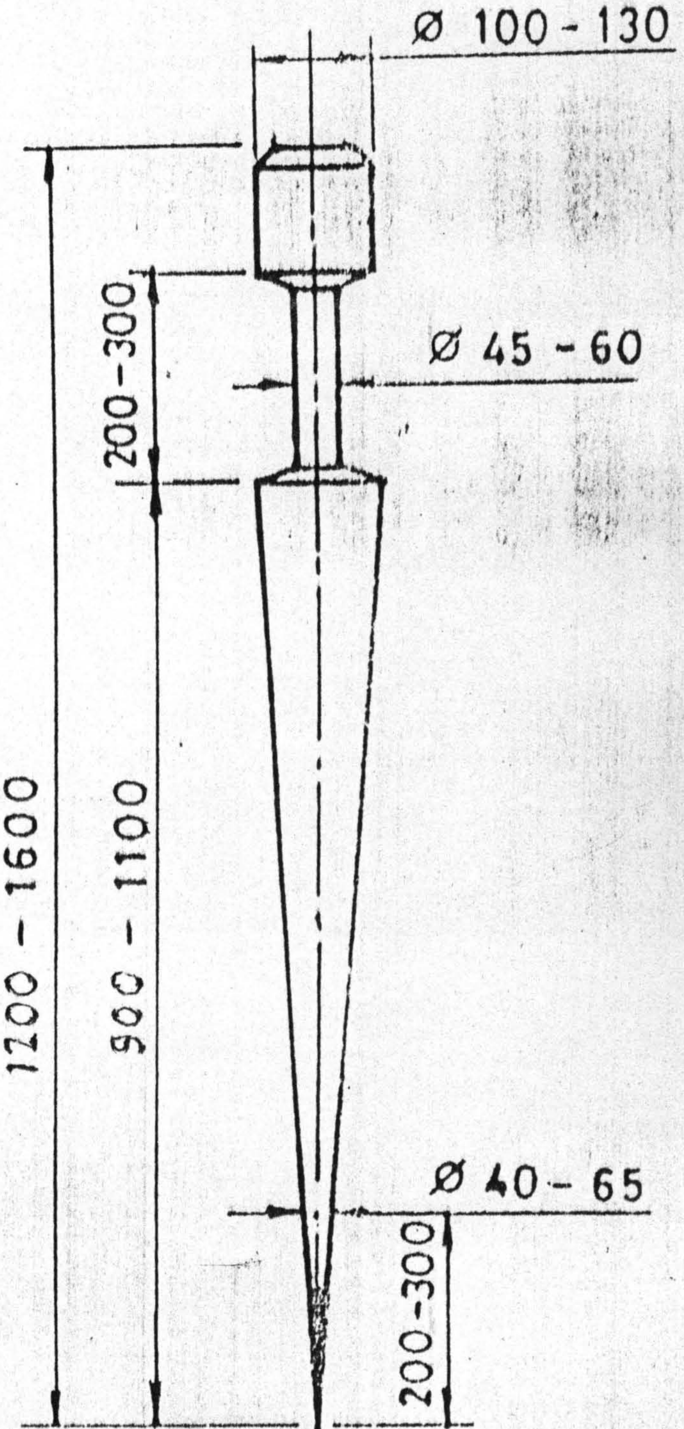


Fig 1: The dibble with approximate dimensions (in mm)

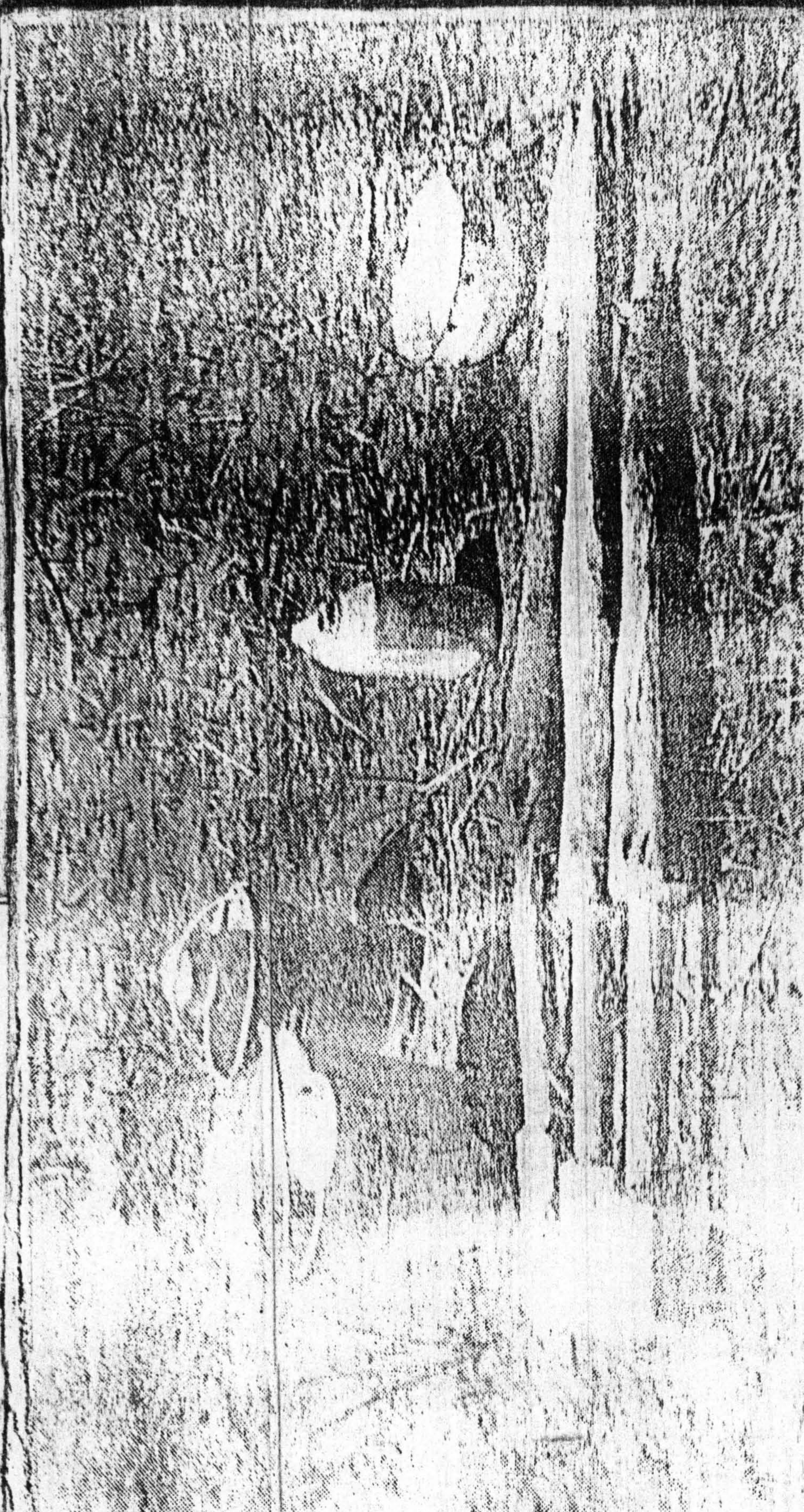


PLATE I. Different sizes of dibbles and different types of water containers

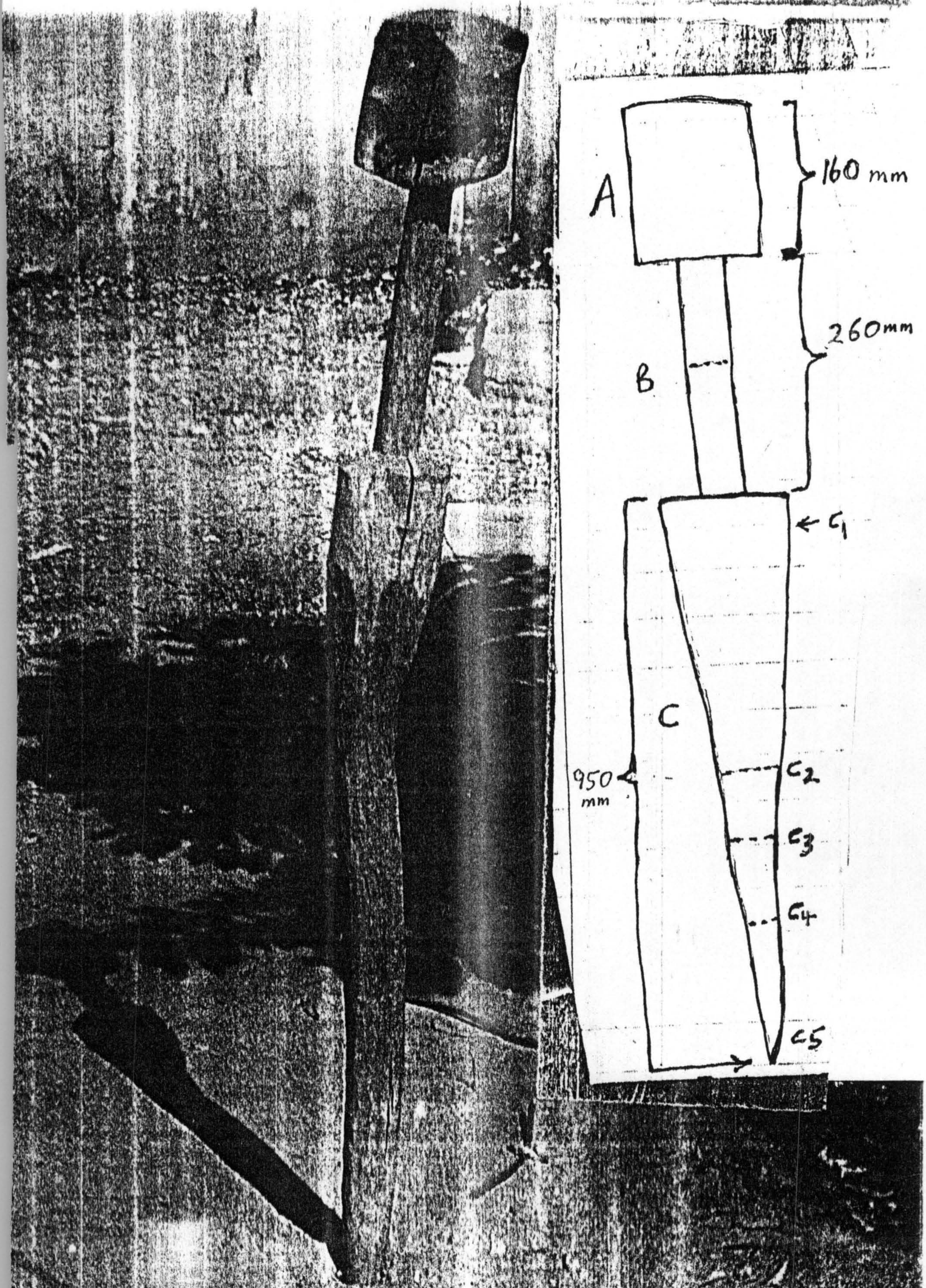


PLATE II: PHOTOGRAPH OF GAFGAL (DIBBLE) TAKEN AT BOSADP, MAIDUGURI

TABLE 2: DEMENSIONS OF GAFGAL TAKEN AT BOSADP, MAIDUGURI

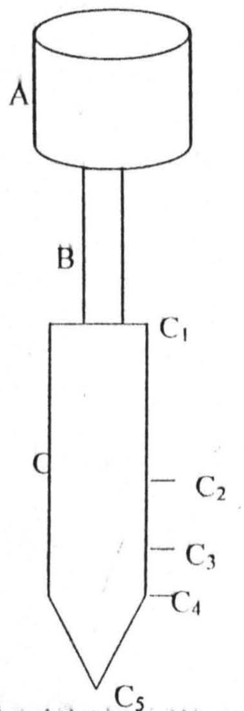


Fig. 2: Analytical Sketch of Dibble (Gafgal) Taken at BOSADP (Plate II)

S/N	Point/Portion	Length (mm)	Circumference	Diameter (mm)
1	A (head)	16	40	127.3mm
2	B (neck)	26	14	44.6mm
3	C (body)	95		
4	Total	137		
5	C1		350	111.40mm
6	C2		210	66.80mm
7	C3		190	60.50
8	C4		170	54.10
9	C5 (tip)		90	28.60
10	C1-C2	680		
11	C2-C3	100		
12	C2-C5	270		
13	C3-C5	170		
14	C3-C4	100		
15	C1-C5	950		
16	C4-C5	70		

NOTE:

1. Circumference is taken with plastic (tailor's) tape, graduated in centimeters
2. Diameter (of tool at various heights/length) is calculated from the formular:

$$C = \pi d, \quad .: \; d = C/\pi, \quad \pi = 3.142$$

2.5 OBSERVATION & POSTULATIONS:

1. Referring to Fig.2, portion A is used as a stopper for the hands and to icnrease4 weight and hence the thrust. This portion is about 10-20cm long and has a diameter of about 10-13cm (Haque and Audu, 1998). The figures given in fig. 2/table 2 safely fall within these ranges (Fig. 1).
2. Convenient holding position for average height person is at the midpoint of the neck (portion B 260cm) which is 108 from the ground level if held upright (Fig.2/Plate II), i.e. 950 + 260/2 = 950+130mm = 1080mm.

3. When working, hands move between 1080±130mm; therefore 1080+130=1210mm, which is average person's breast height. A good thrust/force, using both hands can be exerted at this height. Therefore for convenience, 1200mm could be taken for the overall height of the modified version; which still falls within the local dibble height range earlier given in Fig. 1.
4. At standing posture, the fore-arm is approximately parallel to ground level, dibble is held at neck midpoint (Portion B – Fig. 2), at 1080mm. The elbow is bent approximately 90°, while the fore-arm (relaxed) is parallel to ground level. This enables the user to work for longer hours with less fatigue/stress since muscles are not unnecessarily stretched. When elbow is bent less than 90°, tool holding position is almost at average person's breast height, which is about 120cm. This will give appreciable muscle force/thrust. These are usually what are considered by the local craftsmen when carving the tool, i.e. the ergonomic aspect (proper energy utilization) as explained by an elderly Masakwa farmer, Baba Ali of Ngrurosoye village near Bama. He further said that is why the tools are made in different sizes in relation to heights of users (Plate 1).
5. Hand is only raised up to exert more force/thrust to the tool in order to make a good transplanting hole. This is achieved through experience.
6. Therefore, any modification or Improved version will take note of the thrust, depth and surface width of the transplanting hole, as well as quantity of water to be poured into each hole.

2.6 CULTURAL PRACTICES FOR MASAKWA SORGHUM PRODUCTION

2.6.1 Land Preparation

Masakwa sorghum farm is prepared between harvesting the previous crop around February to the time before next rainy sets in May. Farmers manually construct small dykes/ridges/bunds of about 40-70cm high crosswise on the field. The whole farm is divided into several plots (Olabanji, 1992). This is back-breaking, very laborious, tireless some and time-consuming operation. But where a tractor with a ridger can be obtained, the operation is easily mechanically done. This needs to be intensified in order to impound rain water (which otherwise may flow off) and increase in filtration into the soil profile.

By early September, the field is fairly workable, and weeds on the field are cleared and burnt before transplanting. Insect pests emerging weeds may also be destroyed in the burning process. Some leave the dead grasses to decay, especially where the grasses are less dense and may not obstruct the transplanting process.

2.7 RAISING OF SEEDLINGS:

Seedlings are raised on well drained (lighter) soil after the heavy rains have subsided in August. This is done to prevent over-growing of seedlings.

The plot is tilled with hoe and the soil is sometimes mixed with local manure to enhance proper establishment of seedlings. Some use chemical fertilizers to facilitate growth. Some even dress the seeds with pre-emergence pesticide (Apron plus). The seeds are then broadcasted and covered with soil. Seedlings become ready for transplanting at about 30-40 days (or 4-5 weeks) after sowing (BOSADP, 1993). Seedlings are transplanted early immediately after the rains when the (versitol) soil moisture is high in order to get maximum yield, while delayed transplanting may cause high mortality rate of seedlings, possibly due to drop in the moisture level.

2.8 TRANSPLANTING OF SEEDLINGS

Seedlings are transplanted with bare foot because of the sticky nature of the soil which makes using any footwear very inconvenient. Moreso, using a machine (tractor). However, this is one area that poses a great challenge to technology, especially under Masakwa production (vertisol) soil condition.

The transplanting is done around September/October. Seedlings are uprooted manually from the nursery plots about two days prior to transplanting and tied up in small bundles. The seedlings suffer shock during removal from the soil and transplanting to the farm. The bundles are placed in a up-right position in shallow pool of water for 1-2 days to stimulate the development of new roots (Ogunlela and Obilana, 1983).

Masakwa Sorghum is established by transplanting 4-5 weeks old seedlings in 15-20cm deep, about 6cm wide holes (Olabanji, 1992) made manually with a dibble

Modifying a hole maker (i.e. the dibble/dibber, locally called Gafgal)_ from the traditional to the modified one for transplanting the Masakwa seedlings is a challenge to agricultural engineers. The aim will be to reduce drudgery in the transplanting process and to render labour more productive.

While a tractor-mounted ridger can be used to make the bunds (before rain sets in when the soil is dry and crumbly), to relieve farmers of the back-breaking ridge-making using local tools (holes, etc), improved tools has also to be found/devised to equally relieve them of the strenuous transplanting hole-making and water application processes.

Transplanting is defined as removing established seedlings and replanting or establishing them elsewhere (Hawkins, 1995).

Equipment for placing growing plants or plant parts in the soil is called a transplanter (Smith and Wilkes, 1977).

When large quantities of plants such as cabbage, tobacco, tomatoes, and sweet potatoes are to be transplanted, time and labour can be saved by the use of transplanting machines. With a transplanting machine, it is not necessary to wait for seasonable weather, because the machine automatically pours a small quantity of water around the roots of each plant as it is being set (Smith and Wilkes, 1977).

With some mechanical transplanter a device for watering each plant just before the soil is pressed around it may be fitted for use in dry ground.

It is now a well-established fact that in adverse planting conditions the work done by mechanical transplanter is often appreciably better than that done by good hand workers, even if no watering device is used. Where watering is necessary a device on a transplanter which puts the water exactly where it will do most good – i.e. under the ground and in contact with the plant roots – is a great advantage (Culphin, 1981).

The use of machines forms an important part of present day crop production process and it is dictated by agricultural practices. To determine the level and complexity of mechanization of transplanting Masakwa seedlings, it is important to know the agrotechnical requirements of growing this crop. Also, mechanization of any operation should be economically viable. It should be kept in mind when attempting to develop an improved technology for Masakwa transplant. Examples exist which show the knowledge of parameters of technological procedure of Masakwa transplant predetermine the choice of principles of operation of mechanization facilities (Smekhounov, 1998).

Therefore, the non-availability of machines to perform the transplanting of the Masakwa seedlings prompted the undertaking of this project work.

2.9 SEEDLINGS MANAGEMENT

Most seedlings transplanted need special attention in order to adopt easily into the new environment.

Maintenance after transplanting include:-

a) **Weed Control:** None of the farmers in Masakwa Sorghum producing areas use herbicides for weed control, possibly due to lack of knowledge or uncertainty of the effect. They weed manually, using simple tools, mostly hoes and cutlasses. The frequency of weeding depends on the degree of weed infestation. Generally, there are more weed problems in Bama and Gwoza areas, possibly due to higher precipitation than the drier Dikwa, Ngala, Mafa, Marte, Monguno and Kukawa areas where weed is not a major problem as farmers hardly weed once before harvesting the crop. The partially dried surface does not encourage the growth of weeds, nor the application of fertilizer (Anonymous, 1990).

(b) **Supplying or Replacement of Seedlings:** Should be done 1-2 weeks after transplanting to reduce losses due to plant mortality (Ogunlela and Obilana, 1983).

(c) **Pest and Diseases Control:** Generally, crops grown in fertile soils are naturally healthier and therefore more resistant to insect pests and diseases; some parasites, such as "striga hermonthica" are noticeably less present when soils are fertile (Fuglie, 1998).

(d) **Harvesting:** Depending on the varieties grown, harvesting is done from late December to early February. Harvesting operation is similar to that for the "regular" rainfed sorghum. Stalks are cut at the ground level and laid on the field to allow heads to dry properly. Thereafter, the panicles are cut from the stalk/straws with a sharp knife. It is then threshed, processed and used like any other sorghum variety (Ogunlela and Obilana, 1983).

CHAPTER THREE

3.0 MATERIALS AND METHODS

This design work is based on analytical calculations and practical experience.

Machine Design, is a creation of the right combination of correctly proportioned moving or stationary components constructed and joined to enable the liberation, transformation and utilization of energy. Machine Design helps in selecting the material and best suited shapes, computing the dimensions, strengths, reliability and specifying the manufacturing requirements of the particular components, mechanism or complete machine.

An engineer's objective is always to get maximum efficiency and economy out of men, money and materials to meet the identified needs. A Design should therefore be carried out on the basis of the best technical conditions_ with the least total cost per unit (material cost, manufacturing cost and maintenance cost) consistent with the weight, sign, strength, etc. such a design is called optimum design, which is maximizing the desirable effects and minimizing the undesired effects. The design parameters chosen by the designer are a compromise among several alternatives (Adgidzi, 2003). Therefore, only the feasible design parameters and values would be considered.

3.1 DESIGN CRITERIA OF THE HOLE MAKER

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

(a) Distance between two adjacent rows and successive plant in a row (i.e the row gap and plant distance).
(b) Allowable plant deviation from the axis of the row (agronomic statistical analysis/research)
(c) Transplanting depth
(d) Allowable quantity of lost plant (agronomic research).
(e) Quantity of water required in each hole for plant growth by different soil moisture.

Usually, about two-third of the hole is being filled with water (Haque and Audu, 1998).

Any machine designed for Masakwa seedlings transplant must satisfy the above agronomic requirement – particularly (c) & (e) – if we are to go by the principle of optimum design. In addition, the designer should take into consideration other factors such as simplicity, reliability, ease of operation, maintenance (Smekhounov, 1998).

3.2 ANALYTICAL DESIGN GUIDE FOR THE MODIFIED HOLE MAKER

From the range of values/measurements given in fig.1 (the dibble with approximate dimensions, mm) (Haque and Audu, 1998), specific values are obtained (Plate:II/Fig.2 /Table 2) from a particular dibble and therefore for the purpose of this project the modification will be based on these specific values obtained.

Measurements:-

a) Height of convenient holding position at relaxed standing posture = 1080mm (Fig.2). Therefore, 1080 + 130 = 1210 or 1200mm overall height from the tip is taken for convenience i.e. breast height of average person.

b) Thrust exerting device – pressure/force to be applied by both hands (using the handles) and a foot (through the foot press pedal) – the other foot being used to support oneself.

c) The farmer makes two or three such efforts before he is able to make a hole of about:-

    (i) 20 - 30cm deep, and 4 - 6.5cm in diameter at the soil surface (Haque and Audu, 1998). Mathematically expressed as: $20 \geq Y \leq 30$cm where Y is the chosen depth.

    (ii) 15 – 20cm deep and 6cm wide (Olabanji, 1992)

    (iii) 18 - 20cm deep and 6cm wide (Ogunlela and Obilana, 1983); which are expressed as: $Y \leq 20$cm.

Therefore, from the figures given above, a hole of about 20cm, deep and 6cm surface diameter can confidently be taken (as the optimum/acceptable) since they appeared in all the three sources.

The overall acceptable figures 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 diameters respectively.

Referring to Fig. 2

- Tapering hole depth = points C5 – C3 – C2 = 17 to 27cm
- Hole surface diameter = points C3 – C4 = 6.05 to 5.41cm

This diameter tapers to 2.86cm or lower at the tip (point C5).

Therefore approximate volume of hole (cone-shape) made with dibble

$= 1/3\, \pi\, r^2 h = 1/3\, \pi\, d^2/4 = \pi\, d^2 h/12$

Where d = surface diameter of hole made = 6cm, and h = depth of hole made = 20cm.

Therefore $\pi\, (6^2) \times 20/12 = 188.4955\text{cm}^3 = 188.50\text{cm}^3$

(d) Quantity of water being poured into each hole:-

(i) About two-third of the hole is being filled with water, which is about 100-200ml of water (Haque and Audu, 1998).

Therefore $188.50\text{cm}^3 \times 2/3 = 125.66\text{cm}^3$ = 125.66ml [note 1cm^3 = 1ml]. i.e. 126ml falls within the range (100 - 200ml) given.

(ii) 2 - 3 handfuls (Ogunlela and Obilana, 1983).

3.3 HANDLE DESIGN AND HAND GRIP

A hollow, almost semi-circular steel pipe measuring 30mm across, 40mm down and 1.5mm thickness was used for the handle. It has advantage of being light, strong and convenient to handle. Except for the downward force being applied by both hands to make the transplanting hole, there is no other force or stress acting on it as to cause distortion.

The criteria of the handle design follows Woodson's principles. (Adgidzi and Banseka, 2002) According to Woodson, average length of human palm, Lp = 154.94mm thus, the diameter of the hand grip (D_H) for the handle was given as:

$\pi D_H \leq L_p$ or $D_H \leq 154.94/\pi$ mm ≤ 49.32mm.

The length of the hand grip (L_H), i.e. the handle length was given as:

$L_H \leq 152.4$mm (Adgidzi and Banseka, 2002).

Diameter of the hand grip (D_H), according to Woodson's principle, could be ≤ 49.32mm; but because of the nature of the pipe and the water application device, this diameter got reduced to convenient dimension (which is still within the recommended range) to allow the fingers extend and operate the water release mechanism.

However, for our purpose, length of hand grip (L_H), i.e. the handle length, is taken as 150mm on each side, which is just a little less than Woodson's maximum value of 152.4mm, and in between is 60mm (6cm) which is as well as equal to the given transplanting hole surface diameter. Same length/measurements are used for the Foot Press Pedal in order to maintain uniformity of structure.

3.4 THE FOOT PRESS PEDAL

The Foot Press Pedal is made from a hollow rectangular section steel pipe of 1.5mm thickness 2.5cm width and 5cm breadth. This was cut to 36cm, the same length with the handles i.e 15cm on each side and 6cm in the centre for centrally positioning the tapering hole maker. You can conveniently use either the right or the left foot to simultaneously press down the hole maker with both hands, while the other foot is used for self-support. Moreover the edges of the handles and the pedals were sealed and smoothened to prevent any injury from sharp edges and to give beauty to the configuration. The pedal is also used as a stopper for unnecessarily deeper penetration of the hole maker.

The pointed-tip tapering hole maker, which is supposed to make 6cm hole surface width and 20cm deep is strongly welded at the centre of the Foot Press Pedal.

The top handles and the lower Foot Press Pedals are connected by two equal length parallel square-section hollow steel pipes of 1.5mm thickness and 2.5cm square and lengths of 93.5cm to give the required heights of the modified version. The parallel pipes have a gap of only 1cm between them (i.e. 2.5cm x 2 pipes plus 1cm = 6cm) and are connected to each other at two points by welding metal pieces at intervals of about 31cm in order to add strength to the structure, and the top one is also used to wedge the bolt holding the water release mechanism spring.

All the metals used have almost the same thickness characteristics, and advantage of being very light in weight with respect to their sizes and strong in use and can therefore withstand higher manual pressure/force. They are easily available, less costly and easy to fabricate.

3.4.1 FORCE REQUIRED TO PENETRATE THE SOIL

The force exerted by an average person on the hole maker to penetrate the soil to a depth of 20cm was taken as 340N (i.e. 30kg + 4.04kg) x 9.81.

Where 30kg = the mass of an object that an average person can lift,

4.04kg = the mass of the assembled hole maker

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

3.5 THE HOLE MAKER

The Hole Maker is the principal part of the whole structure. It is cone-shaped and therefore makes a tapering hole of about 6cm surface diameter and centre depth of 20cm when thrust into the moist clay (vertical) soil. The pointer tip is used to penetrate the soil with ease or with less resistance unlike flat-edge object, which compacts the soil only. The smooth surface does not allow soil to stick to the tool.

The hole making portion was constructed using a piece of galvanized pipe of 1.5mm thickness, 6cm external diameter and cut to 20cm length. The first one-third portion maintained the original diameter (6cm), while the lower two-third portion is skillfully shaped to tapering structure in order to give a pointed end for easy soil penetration. This part is centrally strongly welded to the Foot Press Pedal. The 6cm peripheral diameter of the hole maker were bent a little, i.e.5mm from the front and back of the modified tool just to close the small gaps created by the 5cm breath foot pedals and to beautify the structure. This will not however affect the performance or the surface diameter of the transplanting hole because this diameter covers one-third of the hole depth. More-over, shaking to remove the tool from the soil may slightly increase the hole lateral dimensions.

The galvanized steel pipe has the following advantages:-

- the material is easily available
- it is less costly and only a small piece is required
- easy to construct/fabricate and smoothen
- under normal use and care, it can last for several years
- very light in weight and strong

Pressure to penetrate the soil is exerted manually through the hands and a foot simultaneously. It is therefore worth having it as a new innovation in Masakwa (sorghum) transplanting process.

The overall height of the modified hole maker consist of:-

(i)	The handle	- 40mm
(ii)	The parallel connecting pipes	- 935mm
(iii)	The Foot Press Pedal	- 25mm
(iv)	The Tapering Hole maker	- 20mm
	Total height	- 1,200mm

This is average person's breast height where greater downward force can conveniently be exerted. This force replaced portion A in Fig. 3.

3.6 WATER APPLICATION AND REGULATING DEVICE

After successfully constructing the modified Masakwa transplanting tool (Fig.3) based on analytical calculations of the local dibble (Fig. 2), water application Device was also incorporated into the modified version (Fig. 4 and Plate III and IV) in order to facile the transplanting process.

The water Application and Regulating Device consists of:-

1) **Water container (20-litres plastic jerry cane)**

This is chosen because it is easily available, cheap and can be filled according to physical ability of the user. Level of content is also visible to user.

2) 20mm diameter transparent water siphoning hose-pipe for conveying water from container to regulating device (i.e. Open/Close Tap). It is made of plastic, strong, flexible, durable and water flow is visible; and fits well into the system.

3) Water-tight pipe connection, consisting of pipe joints, nipples and hose clips.

4) Spring-operated Open/Close water tap to control downward water flow.

5) 10mm internal diameter transparent water hose pipe connected to reduced-section tap outlet that delivers water to the seedlings transplanting hole made by the hole maker. It has the advantage of fitting well into the system, flexible, durable, strong and water flow is visible.

6) Spring, cable and tap operation lever (attached to handle) to regulate flow of water. The system, works on the principle of small bicycles braking system.

These parts are made from steel metal, and are cheap and easily available. With proper maintenance, they work for long period of time.

3.7 MATERIALS, COSTS, & PURPOSE OF USE:

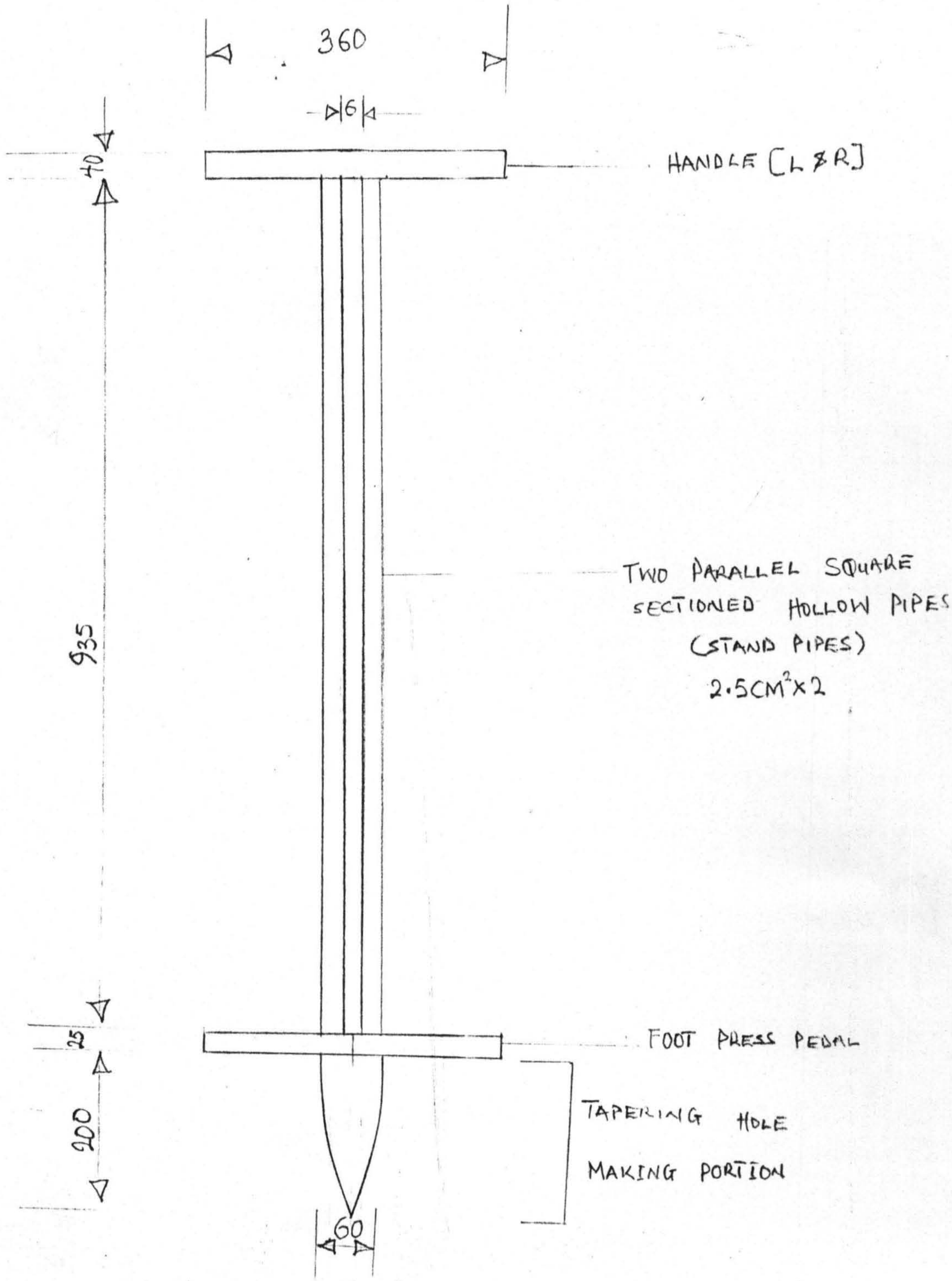
Table 3: Materials Used and Costs

S/N	Material	Quantity	Unit Price ₦	Total Price ₦	Purpose
1.	6cm diameter galvanized water pipe	1	200	200	Hole making portion
2.	2.5cm square-section hollow pipes (300mm long)	1	300	300	Stand gives shape to tool
3.	5cm x 2.5cm rectangular section hollow pipe (500mm long)	1	300	300	Foot Press Pedal
4.	Semi-circular hollow pipe (500mm long)	1	300	300	Handles
5.	Small bicycle brake & cable (set)	1	40	40	Opens water valve
6.	Open/close water tap	1	150	150	Water flow valve
7.	Union/nipple water pipe connections	4	40	40	Water flow regulating
8.	20cm diameter water hose (2m length	1	140	280	Siphoning water from container
9.	10cm diameter water hope (1m length)	1	100	100	Delivers water to hole
10.	Hose clips	9	40	360	Tightens connections
11.	Bicycle jack spring	1	30	30	Closes water valve
12.	Water valve connection/extension	1	50	50	Holds spring and cable
13.	Bolts, nuts & washer		50	50	Holds spring to stand pipes
14.	Plastic jerricane	1	150	150	Contains water
15.	Spray painting			400	Beautifying
16.	Labour			450	Assistance in cutting/welding
17.	Strap (10m length	1	25	250	Holding water container
18.	Misc item/charges 10% of total cost			357	
19.	Total			**N3,927.00**	

3.8 MAINTENANCE AND CARE OF THE MODIFIED HOLE MAKER

1) Avoid rough or careless handling of the tool
2) Since the parts are made from less costly and locally available materials, it is recommended that any part or item found to be defective should be replaced
3) Use rubber wrapping under the hose clips to prevent scratching of the metals. Rusting may develop from scratched surfaces
4) Use simple water filter or strainer, which can be a piece of cloth, on the end of the water siphoning pipe to prevent particles (soil, etc) entering the water release valve. This may accumulate and eventually block the passage and enhance affect the water supply system, since the water may be from ponds.
5) At the end of every use, clean thoroughly and keep in a safe place
6) At the end of season, clean thoroughly, apply rust-preventive and store in a safe place.

It can be put in a polythene bag prior to proper storage. The delicate parts may be stored separately.

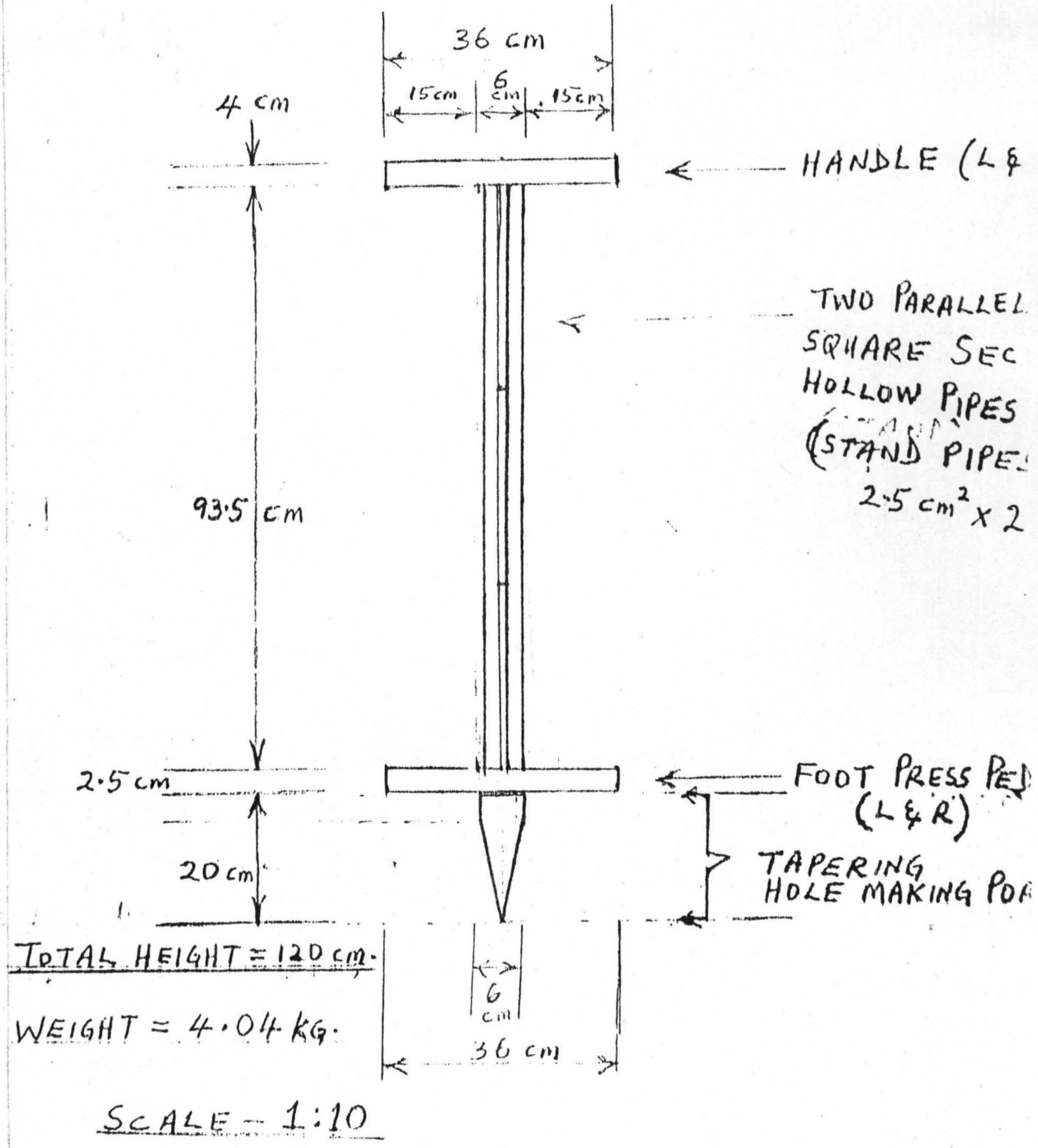


WEIGHT : 4.04Kg

SCALE : 1:10

DIMENSIONS: ALL DIMENSIONS IN mm.

Fig. 3. Modified Masakwa Sorghum Seedlings Transplanting Hole Maker -


36 cm
15cm
6 cm
15cm
4 cm
HANDLE (L&
TWO PARALLEL
SQUARE SEC
HOLLOW PIPES
(STAND PIPE
2.5 cm² x 2
93.5 cm
2.5 cm
FOOT PRESS PE
(L&R)
20 cm
TAPERING
HOLE MAKING POI
TOTAL HEIGHT = 120 cm.
6 cm
WEIGHT = 4.04 KG.
36 cm
SCALE - 1:10

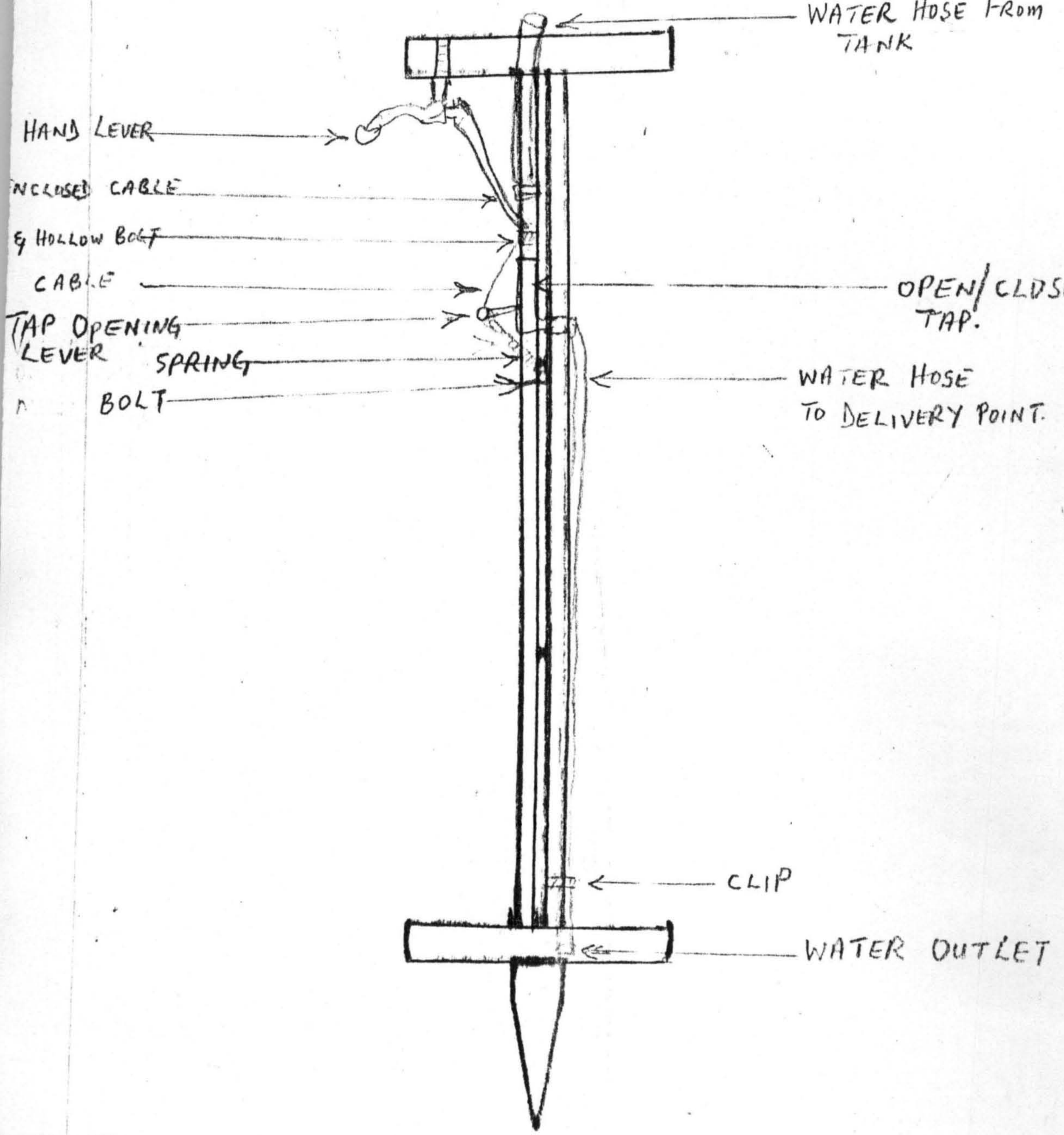


Fig. 4. Modified Hole Maker With Water Application Device

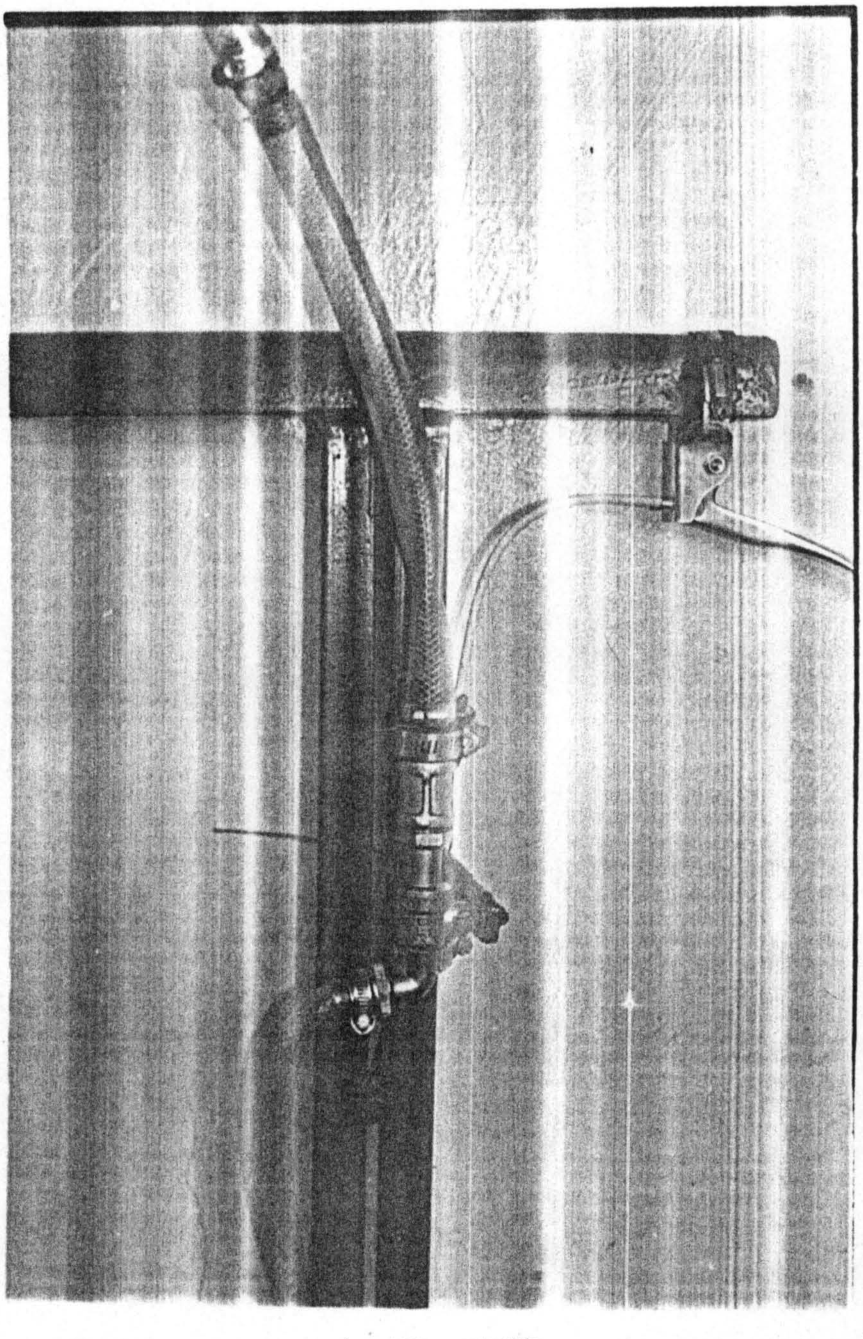


PLATE III Water Application Device On Modified Hole Maker

IV(a) Viewing From Front

IV(b) Viewing From Side

PLATE IV: Working Procedure Of Modified Hole Maker

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 RESULTS

After the assembly of the various manufactured parts into one complete tool, i.e the modified hole maker, it was tested at the Experimental Vegetable Farm of Yobe State College of Agriculture, Gujba along Biu Road. This area has a similar soil condition with the Masakwa producing areas.

The modified tool weights only 4.04kg as against 5 to 7kg of the local dibble (Hague and Audu, 1998). One notable achievement is that the weight is substantially reduced by the use of strong hollow-metals, while the hole making efficiency is increased by the use of more pointed tip. This improved the penetrability.

Evaluating the performance of the modified tool on the Experimental Farm, one acre (0.405 hectare) of land is taken for the testing, then projected to 1.5 acres (0.607 hectare) and 1 hectare (2.47 acres), and the result recorded in Table 4 below:-

Table 4: Modified Hole Maker Test Result

S/N	Plot of Land	No. of Holes	Time (hours)	Quantity of water (Litres)	No. of 20-litre Jerri cane
1	1 acre (0.405 ha)	4,050	16.88 (17)	510.30	25.52 (26)
2	1.5 acre (0.607 ha)	6,070	25.29 (25)	764.82 (765)	38.24 (38)
3	1 ha (2.47 acres)	10,000	41.67 (42)	1,260	63

Making the hole and releasing about 126ml of water takes about 15 seconds on the average.

Therefore, in one hour, 3600/15 = 240 holes can be made.

In 1 hectare, there 10,000 holes of 1m apart (equidistant), at low plant density to reduce risk of water stress and give bigger panicle (Olabanji, 1992).

Therefore, $\frac{\text{10,000 holes}}{\text{240 holes/hour}} = 41.666 = 42$ hours

One hectare can be completed in 42 hours with the modified hole maker, while with the traditional dibble, it takes 60 to 80 hours to transplant one hectare, and farmers make 120 to 150 holes in an hour (Haque and Audu, 1998).

4.2 DISCUSSION

Table 4 shows the Test Result of the experiment. The plots of 1 acre, 1.5 acres and 1 hectare could be holed, watered and transplanted with 510, 765 and 1,260 litres of water respectively at a time of 17, 25 and 42 hours respectively, when two persons are working together, i.e. one person making the holes and putting water and the other follows putting only the seedlings into the hole.

Therefore, one hectare of land could be transplanted within 42 hours (or 5 to 6 days at 8 hours/day) as compared with the traditional dibble which does one hectare of land within 60 to 80 hours, i.e. farmers make 120 to 150 holes in an hour (Haque and Audu, 1998).

Since the area covered with respect to time with the modified hole maker (42 hours per hectare or 0.024 hectare per hour) is higher than the traditional dibble (60 to 80 hours per hectare or 0.0125 to 0.0167 hectare per hour) we can confidently say that the modified hole maker is 40% efficient than the traditional dibble.

The efficiency could be found as follows:

$$\epsilon_d = \frac{70 - 42}{70} \times 100 = 40\%$$

where 70 and 42 are the average hours per hectares for the local and modified hole makers respectively.

With the successful fabrication of this simple, dual purpose tool, all of our earlier stated aims and objectives have been achieved. Safety of user was also fully considered. The local dibble is strenuous in use while the modified one has reduced the stresses and strains to the minimum.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

Masakwa is a unique harmattan Sorghum produced massively in the Lake Chad flood plains through (vertisol) soil water conservation and transplanting process. A local dibble is used in making the transplanting hole while a second person follows and pours some quantity of water, then inserts two to three seedlings into the hole. To ease the operation a modified tool was successfully designed and fabricated based on the ergonomic aspect of the traditional dibble using locally available light, strong and hollow metals. This contributed to reduction in weight. Force to make the transplanting hole is applied using both hands and a foot simultaneously. Water application device was incorporated into the modified version. The cost of producing the modified tool is relatively low and it is hoped the local producers will be able to buy. With this development our aims and objectives are achieved.

5.2 CONCLUSION

1. From the design, construction/fabrication, and testing, it was observed that the modified hole maker is less costly, portable, aesthetically attractive and easy to use and maintain.

2. The design analysis is very simple, likewise the fabrication. It is therefore easily adoptable.

3. There is flexibility in the choice or use of materials to meet the identified needs, e.g. small bicycle parts are used because they serve our purpose very well and are relatively cheaper than, say motor cycle parts

4. The power/thrust requirement for using the tool is quite low, thus it imposes very little fatigue/stress on the user. Where the force applied by the hands is not sufficient to penetrate the soil, the foot press pedal is simultaneously used.

5. Making a good hole and applying a good quantity of water at an appreciable speed determines the efficiency of transplanting.

6. Conservation/Environmentalists will no doubt welcome this innovation because our plants (Balanite egyptica) will be saved.

7. Safety in use was considered in the design and fabrication of the modified version, likewise energy saving.

8. This effort serves as a spring-board for further engineering research/improvement in the design/production of transplanting tool or device for Masakwa seedlings

9. Despite the low cost of production, subsequent productions will be far much cheaper.

10. The modified hole maker is 40% more efficient than the traditional one.

5.3 RECOMMENDATIONS:

1. Further research or field test may be carried out to further evaluate the performance of the key parameters like the extent of force required to penetrate the soil, the quantity of water to be released per dose or per hole, average time taken to transplant an area per unit time (e.g. ha/h), general efficiency of the tool, etc.

2. After the necessary tests, evaluations and possibly improvement, the tool be introduced to Masakwa Sorghum producing areas.

3. Since locally available materials are used, our artisans or local craftsmen can be encouraged to fabricate the tools

4. Because of the simplicity in design, fabrication, use and maintenance, it is recommended that this tool be introduced to our local Masakwa sorghum farmers, and then only acknowledge the effort of designer or the initiator. It is a tool worth having it.

This will make our local producers to taste additional little bit of modernity after the tractor field bunding/ridge-making which replaced the back-breaking ridge-building (to impound water) in some areas. Reduction in drudging will further boost production in agriculture.

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