DEVELOPMENT OF TWO SIMPLE MECHANICAL WEEDERS AND THE STUDY **OF THEIR** FIELD PERFORMANCES

BY

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DECLARATION

I hereby declare that this Thesis is an original work composed by me and that it is a record of my own research work. It has not been accepted in any previous applications for Higher Degree. All quotations are distinguished by quotation marks and the sources of information are specifically acknowledged by means of references.

ADEREMI O. ADERELE

CERTIFICATION

This Thesis entitled: "Development of two simple mechanical weeders and the study of their Field performances" by A.O. Aderele meets the Regulations governing the award of the degree of Master of Science (Agricultural Engineering) of Ahmadu Bello University and is approved for its contribution to knowledge and Literacy presentation.

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DEDICATION

This thesis is humbly and with special reference dedicated to the SON of God, Righteousness and Truth, JESUS CHRIST who has given me everlasting peace and enabled me to go through all the circumstances of this research work.

Also dedicated with sincere appreciation to my darling wife Adetinuke and my son Adesola who bore the loneliness and even for their patience and support during the study.

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ABREVIATIONS AND SYMBOLS

MW	=	Motorized weeder
WLHH	=	Wheeled Long Handle weeding hoe
MSHH	=	Manual Short handle weeding hoe
F.C.	=	Field Capacity
C.P.	=	Cleanliness percentage
M.C.	=	Moisture content
(R)	=	Right side blade
(L)	=	Left side blade
Z	=	Bite length
h	=	depth of weeding
l	=	blade length
$\phi_{1.1}$-$\phi_{1.4}$	=	blade angle before cutting the soil (rad)
$x_{1.1}$-$x_{1.4}$	=	x coordinates of tip of blades locus (cm)
$y_{1.1}$-$y_{1.4}$	=	y coordinates of tip of blades locus (cm)
$t_{1.1}$-$t_{1.4}$	=	time taken for each blade to rotate (sec) before cutting the soil.
V	=	forward speed of operation (km/h)
R	=	radius of blade from rotor centre. (m)
N	=	blade revolution in rpm.
SF	=	Shearforce (Nm^{-2})
J	=	Second moment of area (m^4)
Y max	=	maximum shear force (Nm^{-2})

Me	=	equivalent bending moment
Ti	=	ideal torque
γ	=	soil density
g	=	acceleration due to gravity
d	=	depth of weeding for wheeled long Handle hoe
N_γ,Nc,Nq, & N	=	Factors from literature?
δ	=	soil/tool friction angle
ϕ	=	coefficient of internal friction
C	=	soil cohesion.
α	=	rake angle
D1,D2,D3	=	depths of weeding for MW.
S1,S2,S3	=	blade speed
DF	=	degree of freedom
SS	=	sum of squares
MS	=	mean sum of squares
F	=	variance ratio
HS	=	Highly significant
n.s	=	not significant
LSD	=	Least significant difference
WH	=	Weed height
WD	=	Weed density

A B S T R A C T

Weed control is a vital and important operation in crop production. The use of mechanical method in controlling these weeds is justified especially during this time in Nigeria when the alternative method (chemical) is getting beyond the reach of our peasant farmers that form the majority. In order to meet the current level of agricultural needs, simple mechanical tools for weeding need to be developed.

The two simple mechanical weeders developed in this study have given satisfactory field performances. The Motorized weeder was found to give an average field capacity of 0.0488 ha/h (88.7% of theoritical field capacity) and could weed to the depth of 40mm and 550mm width for a pass. It also gave an average cleanliness of weeding of 85% It was observed for this weeder that the amount of power required varried with blade rotational speed and depth of weeding, weed density also affected the performance.

The wheeled long handle weeding hoe also gave an average field capacity of 0.00394 ha/h and 88.0% cleanliness of weeding percentage. The amount of

force required at rake angle of 30^{o} to the horizontal and depth of 40mm was about 20N.

When the two weeders were compared the performance of motorized weeder was better than that of wheeled long handle weeding hoe in terms of field capacity but the reverse is the case for cleanliness of weeding.

1. INTRODUCTION

1.1 General

Agriculture which is regarded as farming practice, is a business that sustains life. The beginning of the world is the beginning of agriculture. It is basically the process of food production which involves tillage operations, planting, weeding, fertilizing and finally harvesting. Harvested crops may further go into processing for storage or into another form of food or eaten in raw form.

Agriculture is a source of livelihood for more than half of the world's population. In some countries like Nigeria, more than 70 percent of the inhabitants support themselves by farming, while in the more advanced countries, the proportion ranges much lower, for example in United States and Great Britain (about 5%).

Weed can be regarded as any unwanted plant on a desired field, this may be field for producing human consumable foods or for growing grasses for raising animals. The Oxford Advanced Dictionary defines weed as wild plant growing where it is not wanted.

Nature permits weeds to grow on any cultivated area and man considers it as an undesirable component on the farm. Whatever the method of farming or farming system used, weeds are always

present.

Weed has always been a threat to the farmers' life and its existence on the farm will always demand farmers' attention. In most of the time it is disastrous because of its competition with the crop grown. The early normadic tribes who first attempted to raise crop were also the first to encounter weed (Deutsch, 1972).

Weed control has become a highly specialized activity employing thousands of persons. Schools and Institutions teach courses in weed control and conduct researches in weed control. Industries also provide the necessary technology. Private and public individuals are engaged in the practice of weed control especially during the planting season because the growing of food and fibre crops depends on it for current levels of production.

1.2 Importance of Weeding

Weeds have been a major problem to crop development and growth, which eventually have adverse effect on crop yield and behaviours at storage. Weeds sometimes habour diseases and pests which also reduce the crop yield and call for extra cost in controlling them.

Grist, (1975) stated that, weed adversely affect the micro - climate and that plant habour diseases and pests, increase the cost of production, clog irrigation and drainage canals and lower the quality and quantity of the crop. He then concluded that the competition of one grass plant (Eehinocloa Crusgalli) per square foot reduced yield of rice by 25%.

Lagoke et al (1981), reported a 51% reduction in production yield of groundnut when weed growth was not controlled throughout the growing season.

Weeds not controlled in groundnut and rice were discovered to cause between 34 and 80% loss (Upadhyay and Kabe, 1977).

Ivy and Baker, (1972), reported that the competition of prickly sida with cotton can cause a reduction of cotton yield by up to 41%.

Time of weeding has been found to have a serious effect on the yield of crop especially the post emergence weeding, the earlier and the frequently the weeding is done, the lesser its effect will be on crop yields.

John (1970), concluded that, when weeds are controlled during the first six weeks after crop emergence, it resulted to yield of soyabean to about 85% of when it is cleaned throughout. Delaying weeding until three to six weeks after emergence gave yield to about 89% and 69% respectively.

Webster and Wilson (1966), reported that it is necessary to weed early, while the crop is young. According to them, there was evidence from experiments that many crops, especially maize, cotton and groundnut, are severelly hindered in their early growing stages by even a moderate cover of weeds and that this hinderance reduces final yields. He then concluded that, if weeding is perfectly done in the early stages, quite heavy weed infestation in its later stages does not affect yields.

If weeding was delayed until thinning time instead of being done two or three weeks earlier, there will be a drop in yield, and two subsequent weeding at a later stage in crop growth did little more than one later weeding (Ducker and Hoyle, 1974).

Few people realise the great burden weeds add to our economic existence. The presence of weeds levies a big burden and a heavy tax on farm operation, on food and fibre costs, and consequently on the cost of living of the entire Nigerians. Some of these costs cannot be avoided, as for example, seed cleaning after combine harvesting, to remove weed seeds and dirts etc (Okafor, 1987).

Weeds reduce crop yields by interference. Probably the heaviest loss caused by weeds results from their competition with crops for nutrients, light and moisture (Okafor and De Dalta, 1976).

The plant needs nutrients, moisture and light in definite proportions and when one becomes deficient, the others may not be effectively utilised, even when present in great quantity. For example, non shade-loving plants may be ruined grown under shade though water and mineral nutrients are not limited. In the whole country, water may be a major limiting factor in upland crop production. Poor yields or total crop failures often occur because moisture supply has been exhausted before the crop matures during drought. Weeds contribute greatly to this condition. Naturally, maize and upland rice field infested with Itch grass (Rottboellra Cochinchinensis), Elephant grass (Panicum maximum) or other weeds will have their yields reduced, primarily through the competition for water by weeds and partly through shadding and loss of some mineral nutrients to weeds (Okafor, 1987c).

In irrigated culture, weed-crop competition for nutrients may be greater than for moisture, but competition for water is an important factor even there, especially where irrigation is not continous.

For example, irrigated cotton (Okafor, 1987a), wheat (Okafor 1987b) and rice infested with wild sorghum (Sorghum aethropcum purple nutsedge (Cyperus rotundus), yellow nutsedge (Cypenus esculentus) and wild luffa (Luffa echinata) usually make a slow weak growth until the weeds are removed, when they immediately respond by more rapid growth.

Utulu (1984) recorded 74% dry matter reduction in oil palm seedlings under nursery conditions when the weeds were left uncontrolled. In oil palm plantations, profuse growth of weeds in palm interlines were reported by Ojuederic (1979) to cause about 88% reduction in the number of fruit bearing palms.

Farmers all over Nigeria assume wrongly that removing weeds at any time during the growing season of a crop, solves the problem of weed competition. Because the damage done by weeds to crops before they are removed is irreversible, the time of removal is as important as removal itself. This is because, the longer the weeds compete with the crops after crop emergency the greater their effect may be, and the more the weed-related losses (Okafor, 1987c).

The duration of weed competition often referred to as the "Critical period for weed control", generally defines the time span when weeds present from the beginning of the crops cyle must be removed, or the

point after which weed growth no longer affects crop yield (Nieto et al, 1968).

Kasasian and Seeyave (1969) proposed the working hypothesis that crops require a weed-free respite for one-fourth to one-third of the crop's growing period. Their results confirmed this for beans, tomatoes, sweet potatoes, pigeon peas (Cajanus Cajan), sugarcane, and yams.

Okafor (1982a) reported that full impact of weed competition occurs early in the growing season, and rice tolerated 2-3 weeks of early weed competition with potential yield loss of 5.8 to 9.1%. In irrigated cotton, the critical period was found to be 14 days after cotton emergence, as the crop produced optimum growth and yield when weeds were controlled at that time (Okafor, 1987c),. Irrigated wheat tolerated two to four weeks of early weed competition with minimal yield reduction (Okafor, 1987b).

Enyinnia et al (1986a) reported that 56 days after planting appeared to be critical period of weed interference for yam in a yam/maize/cassava intercrop. Hence in order to obtain good yam tuber yields, weed must be removed from the mixture by 56 days after planting.

Enyinnia et al (1986b) also found that the highest tuber of cassava in an intercrop of yam/maize/cassava was obtained in plots kept weed-free from 56 days after planting to maturity or those kept weed-free for the

first 84 days after planting, hence, for a good tuber yield response, cassava has to be kept weed-free between 56 and 84 days after planting.

1.3 Methods of Weed Control

Weeds are currently being controlled by several methods which include. Manual hoe weeding, chemical, Biological and Mechanical. The choice of method will depend on many factors such as type of weeds, stage of weeding (pre-emergence or post emergence), density of weed, condition of field plot to be weeded etc. These methods will be briefly discussed as follows:

1.3.1 Manual Hoe Weeding:- In Nigeria, hoe-weeding is the most common method of weed control, but the method has more disadvantages than the advantages it offers. The use of these method endangers the life of crops for which weeding is being carried out, it can cause a lot of root injury and stem losses if the hoe is not carefully used. The method is inefficient, time wasting and labour intensive (Chaudhary et al, 1979).

Phillips (1977), showed that it takes a matured man about 120 hours to completely weed one hectare of farm land by hoeing. Since labour is not readily available due to migration of the rural populace to urban centres, a less labour intensive method of weeding is highly needed.

1.3.2 Chemical Weed Control- This method requires the use of chemicals (herbicides). These herbicides are sprayed directly on the weeds or on the ground surface if it is pre-emergence application. Many herbicides are effective against the weeds especially the non-selective types. It is very obvious that chemicals are hazardous but scientists working on the production of such chemicals know the level of hazard involved and this is reflected in the dosage and safety measures recommended (Kaul, 1990).

Herbicides are either in the liquid form or in powdery form and their application is by the use of sprayers or blowers. Chemical method of weed control is widely used by farmers, and it is the most popular method of weed control nowadays, inspite of this, the following disadvantages are against its use extensively:

(i) High cost of purchase of herbicides and sometimes, the correct or recommended types are not readily available.

(ii) Machinery for application, that is sprayers and dusters are also very expensive and require extra cost for maintenance.

(iii) Most of Nigerian farmers are not well exposed to western education. They cannot read and write and this can lead to mishandling the herbicides by not following instruction for use thereby endangering their lives.

(iv) Risk involved in its use, for example, its effect on the crop grown.

Jikihara et al (1981), highlighted the environmental factors that influence herbicidal efficacy as climate (Temperature, Rainfall, Sunlight), Soil (Nature, moisture content) Weed (Composition, germination status and growing status), method of application, formulation of chemical etc; all these could result to inefficient weed control by chemical method.

1.3.3. Biological Weed Control- This is done by introducing a neutral enemy of weed, examples are insects and parasitic plants. Sometimes animals are used to consume weeds but care must be taken to prevent the animal from eating the real crops.

Sheep have been employed to control or weaken many broad-leaved and grassy weeds because of their habit of grazing plants closer to the ground. They have been used to keep weeds along

irrigation banks in check, to weaken weeds like quakgrass or Johnson grass in pastures and to prevent perennial sow thistle and leafy spurge from producing seed. Goats may be used for bush control on range lands or cut-over timber lands reclaiming for pastures. They are also valuable for bramble control in pastures (Helgeson, 1957).

1.3.4 Mechanical Weed Control:- This includes simple cultivation of crop land or by mowing the weeds. The use of plough, harrow or ridger helps to bury the weeds and sometimes cut the weed root system thereby destroying the weeds and preventing further growth of the weed. The mechanical weed control can be subdivided into the following:

(i) Cultivation- This is carried out by the use of hand tools, animal-drawn or tractor-powered equipment. Effectiveness of weed control by cultivation depends on time, thoroughness, persistence, frequency and weed type, for example if cultivation is done at interval of 2 to 3 weeks on annual weeds, this can result to destruction of weed seedlings. But if a land is extensively infested by deep rooted perenial weeds, cultivation alone may not be sufficient, other methods such as the use of mechanical weeder or herbicides should be added.

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(ii) Mowing and Crushing- Mowing is not usually effective for eradicating weeds but it prevents weed from producing seed. It may be used on road-sides, pastures and waste lands without fear of injuring nearby sensitive crops. Where bush is especially tall and resistant to chemical treatments, special crushers equiped with sharp blades are sometimes used. These may be in the form of heavy tanks to which blades are welded and the tanks are filled with water to obtain sufficient weitht for cutting the bush. For thick bush, tractor-pulled rollers with heavy blades or with heavy chisel like points are used to uproot the weeds (Helgenson, 1957).

(iii) Preventive Control- The procedure whereby weed species are prevented from entering a field or achieving an increase in population. It can be achieved by using crop seed and farm machinery which are not contaminated with weed seeds, preventing weeds from producing seeds, prohibiting domestic livestock from transferring weed seeds to clean fields, and such methods.

(iv) Burning- apart from mechanical methods described above, flame cultivation is also used in controlling weeds, for example in destruction of small trees of undesirable hardwoods which are growing on land desired for forest plantation.

Carefully controlled burning kills the undesirable growth and other unwanted grasses or weeds. The most important thing is that the area to be burnt must be such that it can be burnt in a single day for easy control of flame.

Burning is best done during the period of hot dry weather, and also when the bush (weed) has reached its maximum dryness.

1.4. Statement of the problem

It is believed that out of all the operations or processes involved in crop production such as: cultivation, planting, weeding, fertilizing, harvesting and processing, the most difficult and labour intensive one is weeding.

Okafor (1987c), stated that, of the four groups of agricultural production hazards:

(a) animal diseases
(b) plant diseases
(c) insects, rodents and predatory animals,
(d) weeds.

The later, that is weeds has been found to cause the greatest losses.

In Nigeria, hand hoeing of weeds is still the traditional method of weed control in most crops. It is tedious and time consuming thereby

requiring several man-days, and also the few unemployed hands that may be available often demand very high wages.

In fact various methods of weed control are employed on the farm (as discussed above), but much is yet to be achieved in weed control, for example manual hoe weeding is labour demanding, chemical method is very expensive to use and maintain, most of the machines used for weeding in developed countries are either not suitable for our methods of growing crops or very expensive, some other methods can not give total control.

Therefore, to achieve a successful weed control without much problem, simple mechanical weeders should be given a serious consideration. Now that our emphasis is on development of local technologies that are appropriate to our environmental and agricultural conditions, the type of mechanical weeder needed should be simple, easy to operate, less expensive and efficient. For these reasons and others, the following objectives were aimed at in this study.

1.5 Objectives

(i) To design and fabricate 2 different types of mechanical weeders.

(ii) To test these machines and evaluate their field performances individually and comparatively on flat lands.

1.6 Justification

(i) Cost of weeding is very high now, for example, it costs between ₦400 and ₦500 to weed an hectare of farm land by manual hoe weeding.

(ii) Okafor (1987c), gave the losses from weeds for different kinds of agricultural systems: large scale commercial farms - 15% loss; peasant farms - 25% loss. Based on the average yield loss of 20% per year, caused by weeds in field crops, an estimated loss of ₦3.5 billion would be incurred by Nigerian farmers. The estimate does not however take into account the numerous field crop abandoned to weeds yearly by both commercial and peasant farmers.

(iii) These machines are easy to operate on the farm. They can be effectively used for post emergency weeding on flat agricultural lands.

(iv) One of the machines can even be used to cut grass above ground surface level.

1.7 Limit of the Study

This study was limited to design and fabrication of motorised mechanical weeder, and wheeled long handle weeding hoe. Analysis of the results got from the performance of these weeders was also done.

2. LITERATURE REVIEW.

In this chapter, various machines/implements used for weeding are described, the extent of work done on these machines, performances, merits and demerits of each machine are also presented. These machines are divided into manual, the animal drawn weeders and the engine powered or tractor drawn weeders.

2.1 Manually Operated Mechanical Weeders:

"NCAM" Improved weeding Hoe is a very useful tool for weeding and hoeing in the standing crops. It consists of a blade, a connecting socket and a handle. The salient features of this hoe are:

(a) Its blade is made up of high carbon steel and as such it does not require frequent re-sharpening. Indeed, the blade is made out of worn-out discarded materials. Future commercial production will require supply of special materials.

(b) The hoe has a quick attach provision to use a short or long handle for any desirable posture during work.

(c) A rake can also be fitted to the same handle when required for weeding and hoeing.

(d) It eliminates the back-ache experienced during working with the local hoes. The hoe was tested for weeding and hoeing in the maize, groundnut and cassava crops during 1988 planting season. Depending upon the soil and crop conditions, kinds and intensity of weeds, it was found that a person could weed from 0.02 to 0.04 ha/hr. Thus, the labour requirements would vary between 20 and 40 man-hours per hectare depending upon the soil, crop and weed condition. The main advantages experienced during the operation were elimination of the back ache usually encountered with the local hoe with a short - handle operated in bent posture. Besides, less effort was also required to use the improved hoe due to superior grade of steel used for the blade which aids in maintaining a sharp cutting edge of the blade. The disadvantages are the low output and the energy requirement since it is manual.

"NCAM" wheel Hand hoe is a push and pull type of weeder which is used for weeding and hoeing for the crops sown in lines. It consists of a ground wheel with an axle, cup and cone bearing, frame, toolbar, handles and soil working tools. Its salient features include a rim made out of mild steel rods instead of the sleeve bearings. It has the provision to adjust the height of the handle as well as the tool bar with

holes to adjust the distance between the work tools. The principle of working of the wheel hand hoe is simple. This hoe is essentially an inter-row cultivator. It is operated by pushing and pulling action. The stroke length is adjusted by the operator depending upon his arm length and ease of working. The depth of penetration is adjusted by raising or lowering the wheel with the help of the holes provided on the frame. The wheel hand hoe is meant for weeding and hoeing in the inter-row spaces of the crop planted in lines. As such it is not convenient to use it for the crops planted on ridges or mounds. When the inter-row space exceeds the working width of the tool, a strip is chosen and hoed to the full length, thereafter, make a full turn to hoe the remaining strip and work it to the full length again. In some cases it may require even 2 or 3 passes to cultivate the inter - row space. Speed of forward movement to operate the hoe by pulling and pushing action should be adjusted according to the convenience of the workers. Tall workers normally work the hoe with relatively longer strokes as compared to the short - statured workers. Work output is between 0.03 to 0.05 ha/hr. The disadvantages are also the low output and the energy requirement being manually operated machine.

Abom (1989), fabricated a manual inter - row weeder component, that has a weeding mechanism of a single row conical rotor lowland weeder designed by the International Rice Research Institute, Los Bamos, Laguna, Philippines. This manual inter - row weeder consists of a frame conical rotor assemblies, serrated and plain blades, a land wheel, handles, two mounting bracket assembly and a shear. This weeder is a push type, it has two conical shape rotors mounted in tandem with opposite orientation. The plain and serrated blades were alternatively welded on the conical rotors to uproot and bury weeds on the sides of the opposite ridges as the machine is pushed or pulled along. A wheel in front of the rotors provided ease of movement for the machine, coupled with the rotary motions of the rotors too, the shear weeds the furrow. The machine can be set for ridges ranging from 70cm to 90cm by offsetting the two rotors, the depth of cut is determined by the operator but not more than 30mm. When the machine was tested for the best time of cutting, the output was 0.027 ha/hr and this was after 3 weeks of planting. Being manually operated machine, it has a land output and requires a lot of energy to push on the farm. He then recommended that:

- the blades be made longer than 30mm
- it can be converted to animal drawn or mechanical powered machine

- light materials could be used to decrease the weight and thus human effort to push.

Islam and Azharul Hq (1991) developed a low-cost BRRI weeder for lowland paddy that has the following essential components: the wooden core, handle, the frame, the axle and the spokes that were made of iron rod. Three or four spokes were grafted around the wooden core in alternative rows, this arrangement of spokes leaves no spaces unpudded within the rows. The width of weeder is dependent on the length of the wooden core. Three different lengths of wooden core were selected: 15cm, 17cm and 20cm depending on row spacing. The effective puddling depth of spokes was 5cm which is sufficient to destroy most of the weeds. The diameter of the wooden core was 13cm based on the ease of operation and distance covered per rotation. Tests were conducted in clay loam and sandy loam soil in order to evaluate the performance of the weeder. Clay loam soil with a weed density of 500weeds/m^2 and it was also at saturation. In order to compare the BRRI weeder with the Japanese type manual weeder, it was tested in sandy loam soil with a weed density of 375 weeds/m^2 and at saturation. A randomized complete block design was used in the test. The highest and lowest field capacities of BRRI weeder was 0.0462 ha/h

and 0.0261 ha/h with two operators in clay loam soil with a weed density of 500 weeds/m^2, which gave an average field capacity of the BRRI weeder as 0.03405 ha/h. In sandy loam the average field capacity was 0.0351 ha/h with a weed density of 375 weeds/m^2. It has the following advantages.

- materials are easily available
- no sophisticated technique is needed for its manufacture.
- Less costly.
- low power requirement as a result of its weight which was given as 5kg.

But it can be seen that the output (capacity) is low as a result of its size and source of power which is 100% manual. The cleanliness percentage was not given so as to evaluate its capacity with regard to how well it can weed.

2.2 *Animal Drawn Weeders*

Jadhav and Turbatmath (1991) developed Bullock drawn, multipurpose Hoe, which was designed to suit any row spacing between 300mm and 450mm and to perform any of the interculturing operations. It consists of the following components.

1. Main frame with clevis and ferrule:- the mainframe is made of two mild steel flat bar welded 18mm apart with an angle iron piece. The angle piece

is also a component of the clamp that holds the tool bar. The main frame gives attachment to the clevis in the front and to the earthing equipment or weed rake at the rear.

2. Tines with clamps - that can be attached at any desired spacing on the tool bar. Each tine is given a shape at the end such that during operation in the field the soil cutting tool (shovel or sweep) makes an angle of 22^{o} with the horizontal.
3. Shovels - are double ended reversible type, three to five of them can be used depending upon the requirement of crops row spacing.
4. Sweeps - used for weeding and pulverising the top soil to shallow depths for creating mulch.
5. Earthing device attached at the rear of the main frame. It has two trapezoidal wing sheats. The earthing device can be pressed in the soil to scrap the required quantity of soil by applying pressure on the handle. The device can be lifted to reduce the amount of soil being collected.
6. Weed rake - attached behind the main frame to collect weeds removed by the sweeps in the front (in place of earthing equipment).

7. Beam with yoking hook - bamboo beam is used, at one end it is connected to the implement with the ferrule at the other end a yoking hook is fixed on this beam for hitching the implement to the yoke.

8. Handle.

This multipurpose hoe is tested in groundnut, sunflower, and jowar in 1987 and 1988. A bullock pair could operate 2 to 4 hoes at a time. The weight of a hoe is 16kg and the average draft required for a pair of hoes varies from 26 to 32kg. The actual field capacity of a pair of hoes varies from 0.15 to 0.25 ha per hour. The hoe gives 35mm maximum mulching depth, 75mm maximum tilling depth and 50 to 80mm earthing height. The multipurpose hoe is light to handle and operate it is an efficient interculture equipment for weeding, tilling and earthing operations. It involved less cost of operation compared to local implements.

Several types of draft animals are used in Nigeria, the most important being the bull. Work bulls are mostly used in pairs, but sometimes singly, to pull tillage implements. The average draft of the donkey pulled was 450N at an average walking speed of 0.65m/s giving an average power output of about 0.29kw (Musa, 1978) as quoted by

(Gwani, 1990). The Institute for Agricultural Research (IAR) is working towards the improvement of the already developed tool bars to suit the local needs and is developing other animal powered equipment which include:

Straddle row rotary weeder- this weeder uses a set of four gangs of rotary tines which are mounted on a frame which straddles a ridge, digging the soil and removing the weeds. The weeder has a high clearance frame which enables weeding of crops up to one metre high. It is suitable for 76cm and 90cm ridges and is pulled by a pair of work bulls. The best output results are obtained when working on weeds at 2-3 leaf stage and soil moisture within 6 to 12% range (Gwani 1990).

Oni (1990), in the performance analysis of the ridge profile rotary weeders reported that the inclination of the rotary hoe to the ridge profile conforms with the angle of repose of the ridge, its alignment being such that the amount of weeds removed is maximised. The clearance between two adjacant hoes at their closest points at the top of the ridge ensures that the hoe tines do not injure crops above the ridge top. In order for this weeder to perform efficiently he said it is important that weeding

commences about two weeks after planting as delayed weeding is likely to reduce the effectiveness of the tool.

Emcot rotary weeding attachment- it comprises of two gangs of rotary tines which are mounted on a commercially available Emcot toolbar. The Emcot ridging share clears the weeds on the furrow bottom while the gangs rotate on both sides of the furrow digging up the soil and removing the weeds as they rotate. The implement is powered by two work bulls and its output ranges from 0.1 to 0.2 ha per hour on weeds which are at 2-3 leaf stage and with a soil moisture ranging between 6-12% (Gwani, 1990).

The staddle row weeder and the Emcot weeder both conforms reasonably well with ridges constructed with animal drawn and tractor drawn ridges, provided that the field is cleared of stumps and other obstacles likely to hinder operation. They are also good pulverizers of soil when the soil is moist but not too wet (Oni, 1990).

2.3 Tractor Drawn Weeders

The rotary cutters:- This machine shreds, cuts shatters, tears, chops, mows, pulverizes, spreads and mulches. They depend on the very high speed of revolving flails, blades, or hammers for efficient operation. The rotation of a cylinder does the cutting on some machines, in others, the rotating, propeller-like blades attached to a spindle hubs do the cutting. If the flails or blades travel in a 60cm circle, their tips will travel about 180cm per revolution. Many cylinders or spindles travel at 1500 revolutions per minute. Thus the knife, hammer, or flail tip would travel about 2700 metres per minute-more than 160km per hour. One model has a speed at the tips of 8500 metres per minute. With this speed cover must be kept down and the machine must be well balanced. There are two main types; trailing machines and mounted machines. The trailing machines usually have two or more wheels at the rear or sides. The tongue, assisted by skids at the front corners (on some), supports the front of the machine. The mounted machine may have a support wheel at the rear for use when the hydraulic mechanism permits the machine to float. This latter type often has

supporting shoes at the front corners. Two types of cutters are used. About one tenth of the machines have a long horizontal shaft with attached flails, hammers, or knives. When rotated, this cylinder assembly gives a hammer mill effect, about 35 flails or hammers pounding the stalks and trash into thousands of small pieces. The cutter type has short vertical shafts called spindles. A machine may have one, two, or three spindles. The lower end of each spindle has a hub or plate which carries the knives. In this instance the stalks or skins are cut rather than hammered, unless the knives are dull (Stone and Gulvin, 1977).

Rotary Hoes- There are two types of tractor - operated rotary hoes: trailing and mounted. Some of the trailing hoes have wheels for depth adjustment or transport, although most of them do not follow the row ridges in a field. The hoes are made up of gangs-two gangs per section. A hoe may have as many as twelve sections and cover more than 12m. Each section is 105,110, or 115cm in width. The 1.1-m section is popular because it just covers a typical corn row. Infact some hoes are specified by the number of corn rows they can till in one pass. A gang consists of an axle with about seven digger wheels spaced equally on it. Each wheel rotates independently on the axle

when the hoe within bearings attached to the frame. Two axles and their wheels make up a section. They are mounted within a steel frame, with one axle ahead of the other. The teeth on the rear wheels till the soil left untilled between the front wheels, giving complete coverage. The wheels consist of a hub, a bearing, and ten to fourteen teeth. The teeth are set on the hubs so that they dig as they go downward toward the earth and pick up some soil as they rotate upward. The average hoe weighs 7-9kg per wheel. This is usually ample to give sufficient penetration at high speeds. Each seetion weighs a little more than 140kg or about 135kg per metre. The mounted hoes are very convenient, but they are usually narrow which may be a disadvantage when one has considerable ground to cover. Trailing types are the widest. (Stone and Culvin, 1977).

Maiye, (1989), fabricated a low ridge profile inter-row weeder (tractor mounted), that consists of frame, weeding elements or mechanism, weeder support or standard sweeper shears or hoes, mild steel channel, flat metal bar, 25.4mm diameter shaft, 12.7mm diameter steel rod, 6.4mm thick plate and 32mm diameter pipe. The weeding assembly consists of curved mild steel fingers, each welded on to 6.4mm plate of 127mm

diameter which was also welded to sleeve pipes of length 305mm and of 35mm diameter and a rod shaft passed through them: All weeding components of the machine were fixed into channels which were also bolted to adjusting plates of diameter 127mm each. Flat bar of size 25.4mm x 9.5mm were welded to each plate to serve as standard which carries the whole mechanisms on the main beam by an adjustable plate drilled 14.3mm diameter holes round to suit the upper plate carrying the standard for angular adjustment. The weeding elements attached to the gang beam rotates astride the ridge, digging the soil and removing weeds as the tines rotate. A central hoe mounted at the rear gang removed or clear weeds in the furrow bottom between two ridges. The weeder has a high clearance frame which enables weeding even up to 0.9m crop height,. It is suitable for 76 and 90cm ridges spacing. This implement is tractor mounted and be easily drawn for operation. When the machine was tested, it was observed that, the machine could only penetrate to a mean depth of 33.3mm, detail tests were not carried out due to some circumstances beyond control. However the following demerits were found against the machine.

- when the soil is very wet the machine will be inefficient due to absence of scrapper.

- the furrow coverage is not much due to weeding mechanism carrying short spaced tines, and
- additional weights is needed for the machine.

Adelusi (1990), fabricated a three-furrow tractor mounted weeder which consists mainly of a frame, support or standard, weeding elements, sweeper or shears or hoes. The main frame is made up of three equally spaced 50mm hollow rectangular pipe of length 230cm each and carries a three-point linkage. The standard or support attached to the main frame with the end of clamps for depth adjustment. The support was made of 92x40x0.32cm spring of rectangular shape and clamped to the main beam for adjustment. The weeding assembly was cut from mild steel of 6mm plate, 6 small shears were fixed to the standard by means of bolt and nuts. The sweeper shear or hoe was cut from a 6.4mm mild steel plate, all the weeding elements attached to the standard, (Spring material), digging the soil and removing the weeds as the movement continues. A central hoe or sweeper mounted at the rear of two smaller weeder removes or clears weeds in the furrow bottom. The weeder has a high clearance frame which is adjustable enabling weeding even up to 0.9 crop height. It is suitable for 70cm and 90cm ridges.

The machine could not be tested enough to evaluate its general performance, due to lack of time but was tried on the field. From this trial he discovered that the machine could only penetrate to mean depth of 35mm. He then recommended further tests on the machine, additional weight, and change of materials for constructing some of the parts for a better one.

From all the three groups of mechanical weeders discussed above, viz manual, animal powered and tractor drawn, it could be seen that each has one or two disadvantages, although perfection should not be expected from machines, but it will be agreed that the shortcoming of one will lead to the development of another. Manually operated machines are generally of low output and labour intensive. For animal drawn weeder, one can see from figure 2.1 that drought animal areas are limited to the Northern part of Nigeria, hence its use is not universal. The major disadvantage to the use of tractor drawn is the cost of tractors nowadays especially in Nigeria due to devaluation of naira, so tractor now is beyond the reach of low-scale and medium scale farmers, hence another simpler and better alternative should be provided and this led to the development of a simple motorized weeder whose detail description and design is given in the next chapter.

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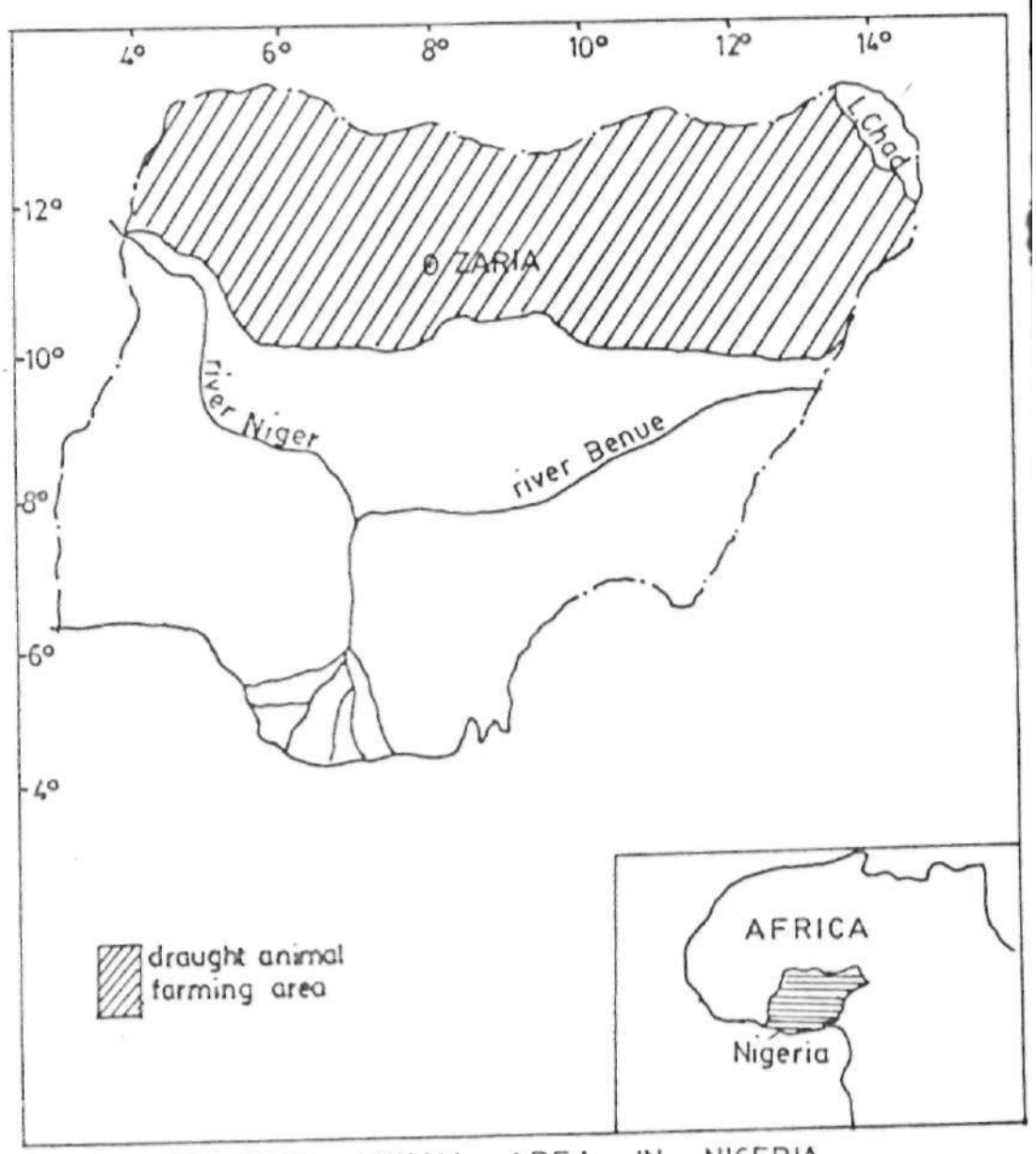


Fig. 2-1 DRAUGHT ANIMAL AREA IN NIGERIA
(source: Oni, 1990)

3. MATERIALS AND METHOD

3.1 Description of The Machine (Motorized Weeder)

This machine is hand push but the weeding component is powered by a small internal combustion petrol engine (5hp rotating at 2500rpm). It is supported by three wheels of 20cm diameter each. It consists mainly of the frame, the handle, three wheels power transmitting pulley, the petrol engine and the weeding components.

The machine is designed to weed within rows of crops planted on flat lands. It has a width of 75cm and length of 105cm so as to be able to weed in between planted crops spaced at not less than 80cm. The length is such that it can accommodate all the component parts of the machine. The maximum width of operation of the machine is 60cm. The engine used to power the weeding components also provides traction aids when the blades cut the soil, hence much effort is not needed to push the machine during operation at any depth of weeding up to 40cm which was the maximum depth used, this serves as additional advantage, that is, using the engine to power the weeder, apart from higher efficiency and capacity achieved.

The maximum depth of operation of the machine is

40cm, this was determined when the weeds found on the field were uprooted at various parts and the average maximum depth of the root was found. The adjustment of the depth of operation is done by adjusting the three wheels of the machine. This weeder can also be used to cut grass above the ground surface at any desired height. Fig 3.1 shows the machine assembly while the side and plan views are shown in fig 3.2.

The details of the construction features of the various parts of the machine are described as follows:

3.1.1 <u>The Frame</u>

This houses the entire machine parts i.e. wheels, handles, engine and weeding component. It forms the overall size of the machine, the length is 105cm and width is 75cm. It is made of 50x50x5mm angle iron, and welded at the four corners. The engine seat is also provided on this frame at the left hand side of the rear end of the machine. This is due to the location of the engine pulley when rotating to the right direction and for easy starting of the engine, that gives power to the weeder. The engine seat is also made of 20x20x2.5mm angle iron.

3.1.2 <u>The Handle</u> Two handles are provided to push

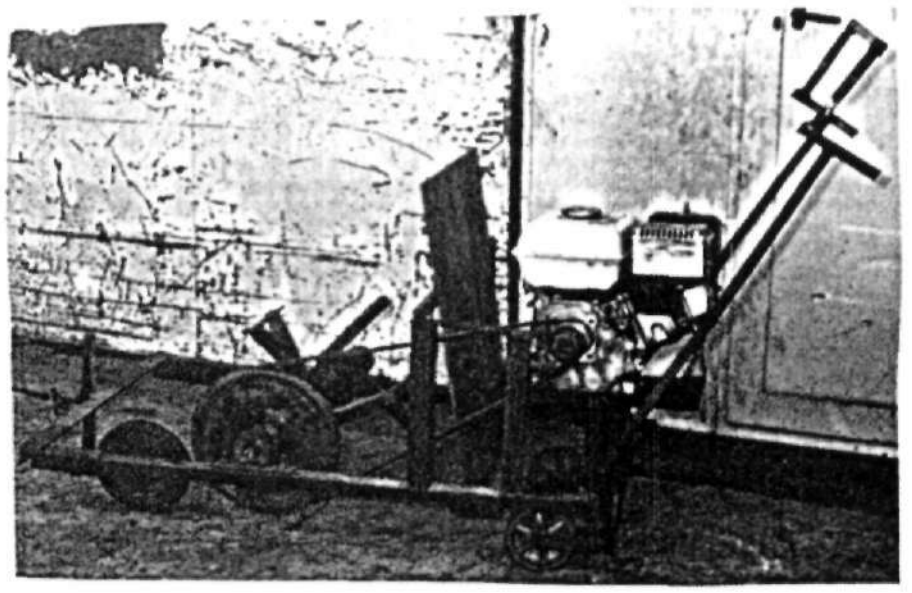


Fig. 3.1(a) Pictorial side view of motorized mechanical weeder

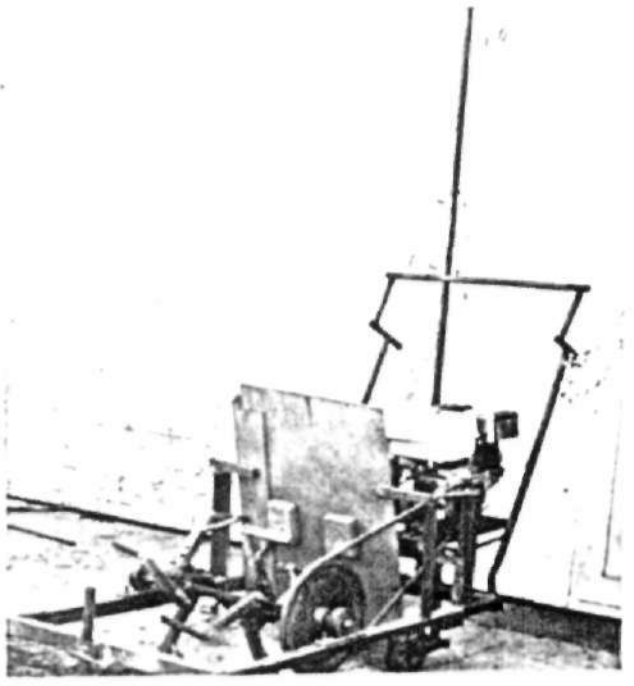


Fig 3.1(b) Pictorial front view of motorized mechanical weeder

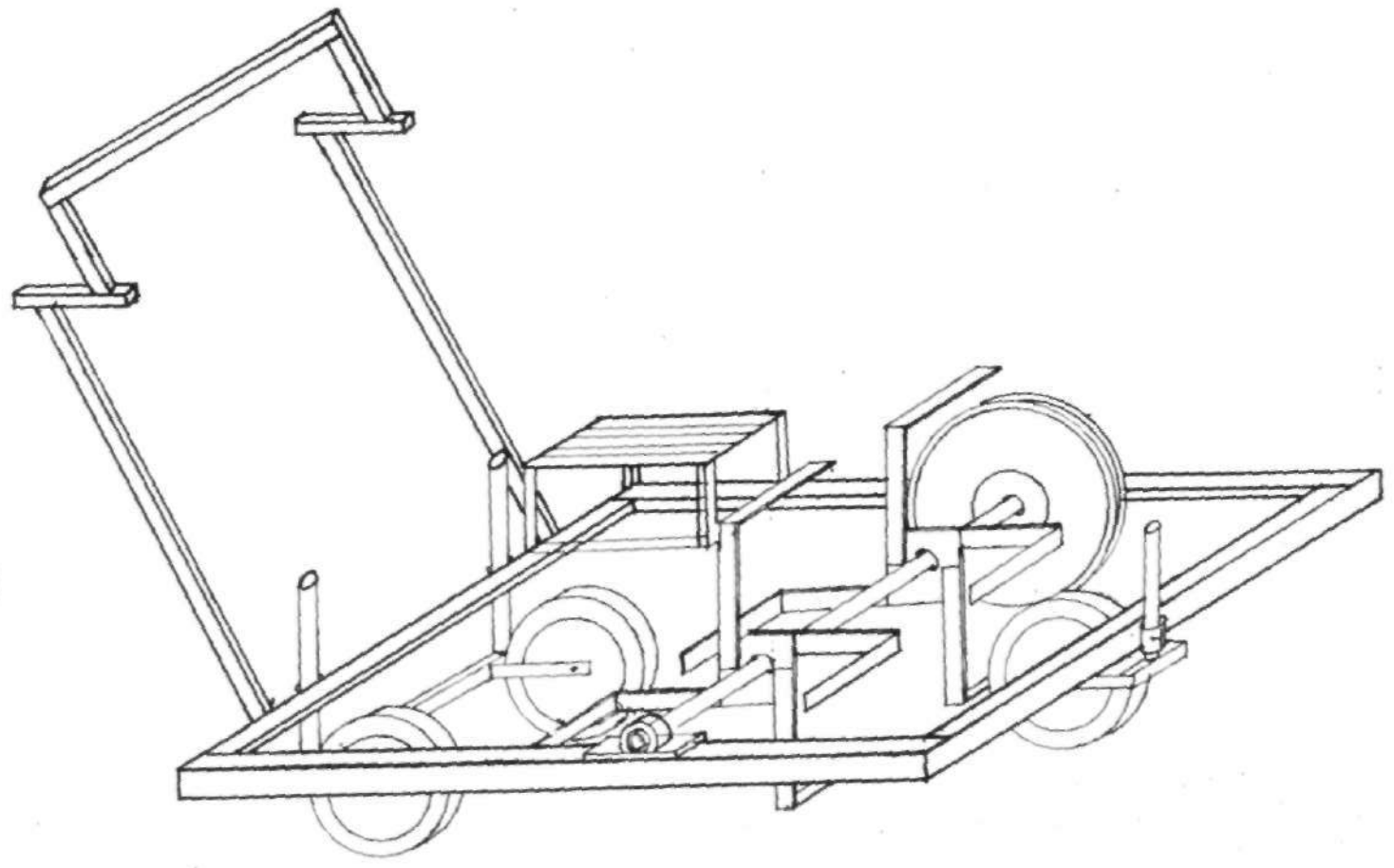
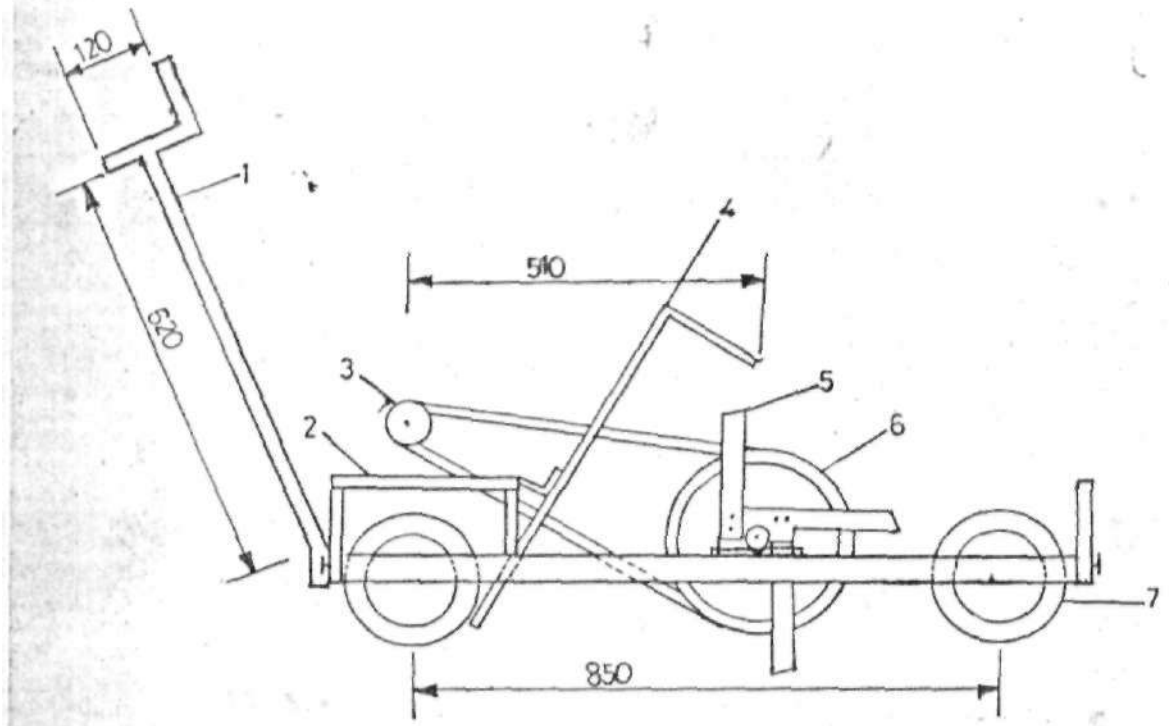
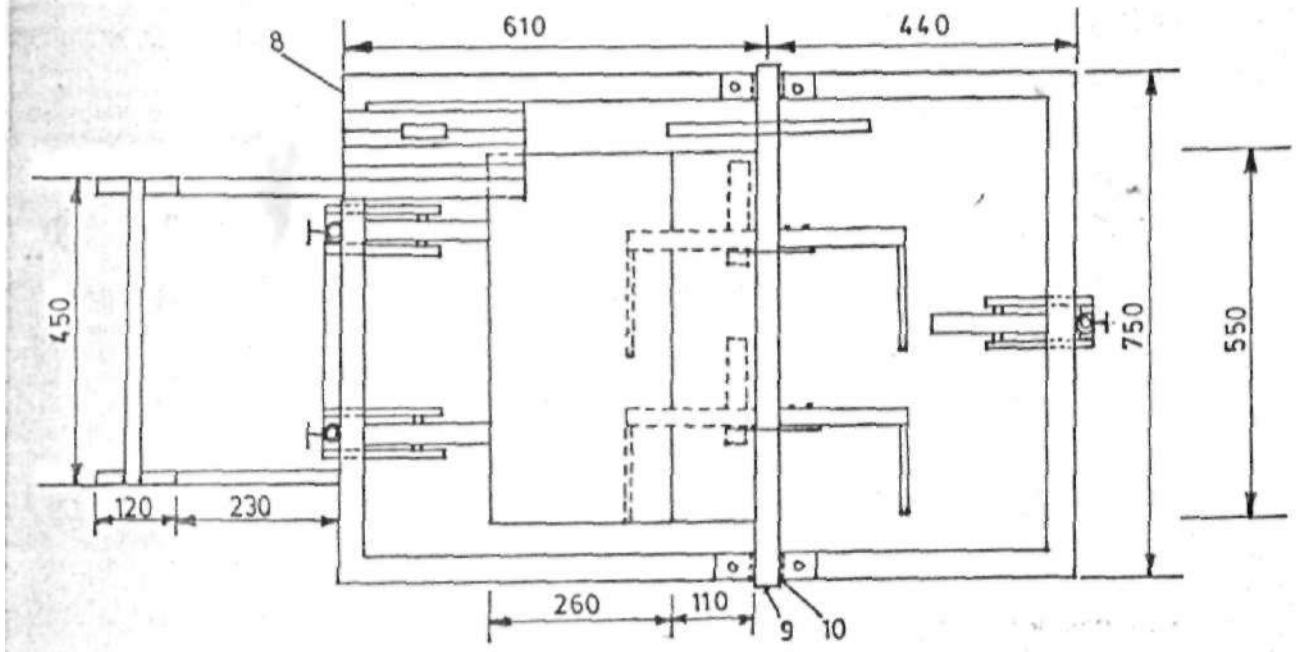


Fig 3.1c ASSEMBLY DRAWING OF MOTORIZED WEEDER
(Detailed demensions are shown figs. 3-2 A & B)



(A) SIDE VIEW



(B) PLAN VIEW

Fig. 3.2 Side and Plan views of motorized mechanical weeder

1.- Handle 2.- Engine Seat 3.- Engine Pulley 4.- Guide 5.- Weeding Blade 6.- Shaft Pulley. 7.- Front Wheel 8.- Frame 9.- Weeding Shaft 10.- Bearing Housing

the machine and they are attached to the rear end of the frame. They are made up of 12.5x12.5mm rectangular hollow pipe and each is about 700mm long.

3.1.3 Weeding Component:- This is made of a solid shaft of 22mm diameter connected to a pulley that receives rotation from the engine. The blades made of 20x20mm rectangular hollow shaft and flat bar for weeding are bolted to two 100x100mm metallic plate of 3mm thickness, that are welded to the bushing, having internal diameter equal to the external diameter of the solid shaft. These plates and the bushings are welded to the shaft and placed 30cm apart. Four cutting blades are then bolted to each plate, arranged in such a way that, there is a small overlap of the area covered. Spring washers are used to prevent loosening of the bolts and nuts. The blades are also supported with brackets for reinforcement. The length of each blade from the shaft centre is 200mm.

The rotation of these blades on the shaft that receives power from the engine through the pulley

creates cutting impact on the weeds roots when cutting below the ground surface. This action also pulverizes the soil and then creates favourable condition for crop growth and development.

When the blades shear the soil, mobility of the machine also is aided. The arrangement of the blades along the shaft is shown in fig. 3.3 & 3.4 and the cutting blades assembly is also shown in fig. 3.5

3.1.4 Transmission (Belt and Pulley): 300mm diameter pulley size is employed to reduce the speed of rotation from the power source. The pulley can be changed to any desired size but consideration must be given to the height of shaft from the ground when the machine is at its lowest height. Therefore since the lowest height of the shaft from the ground is about 170mm, the maximum pulley size diameter should be 320mm.

3.1.5 Wheels: A total of three ground wheels are used to support the machine, they are 200mm in diameter, solid rubber types. Two of the wheels are at the rear end of the machine and spaced 400mm apart, the third wheel is at the

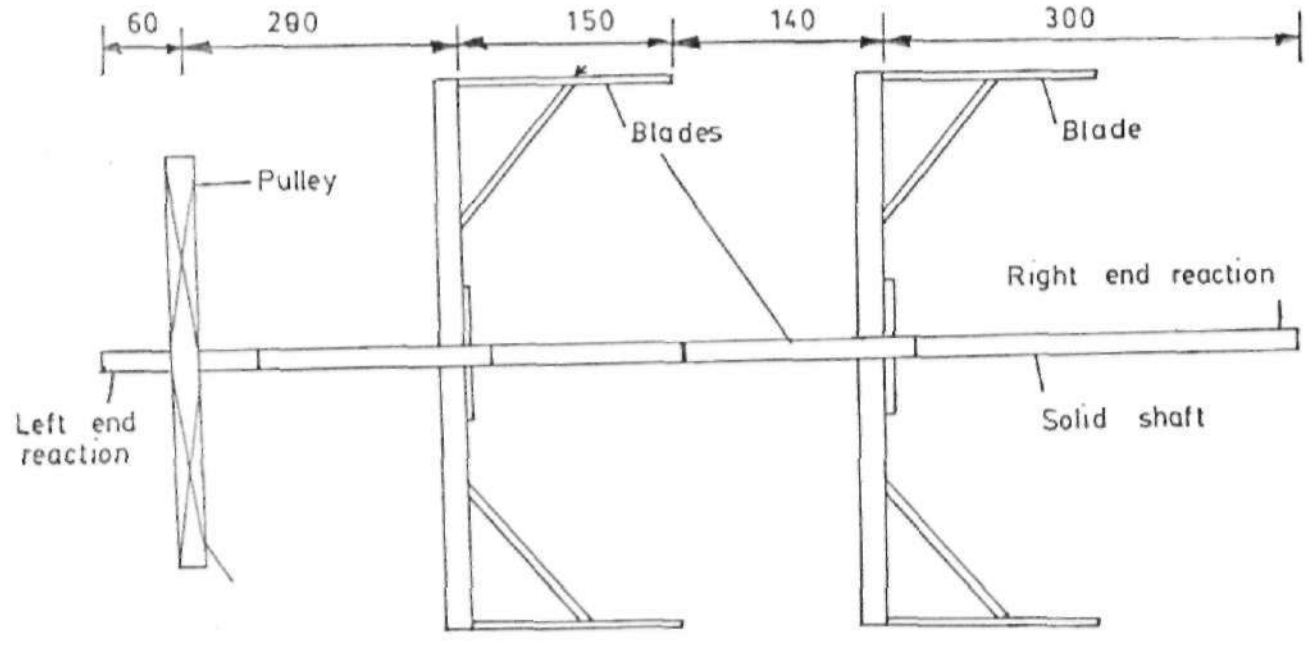


Fig. 3.3 Arrangement of Pulley and Cutting blades on the Shaft

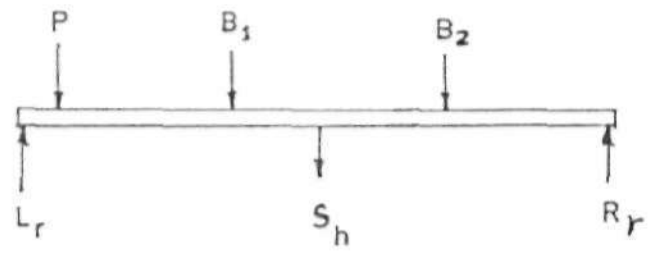


Fig. 3.4 Free body diagram of the arrangement of Pulley and Cutting blades on the Shaft.

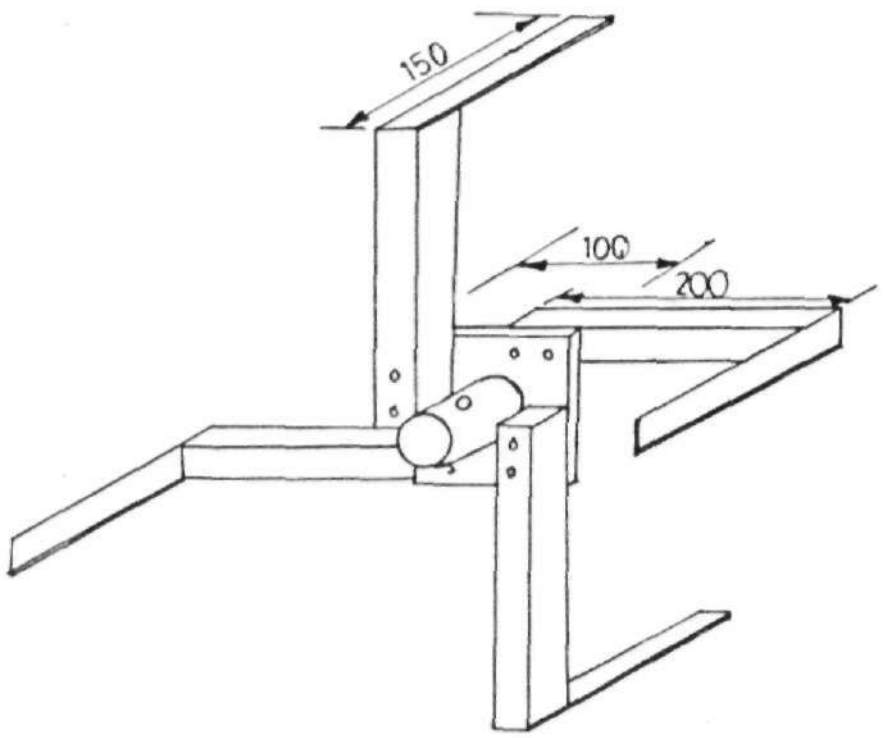


FIG.3.5 CUTTING BLADES ASSEMBLY
(Dimensions in mm)

front of the machine at the centre. These wheels provide mobility and adjustment for increasing or decreasing the height of the machine above the ground surface.

3.1.6 Machine Guard: Guard is used to protect the operator from sand and stones thrown by the weeder when in operation. 5mm thick plywood is used as the guard, which is screwed to two brackets provided on the machine frame.

3.17 Internal Combustion Engine: A (3.75kw) petrol engine was used to power the weeding component. This was selected on the basis of the calculation done on the power requirement shown later. The maximum output rotation of 50mm pulley on the engine is 2500rpm.

3.2 Design Calculations and Analysis

3.2.1 Power Required to Power the Machine.

(a) Blades Arrangement along the shaft:- The two blades assembly 1 and 2 have cutting blades 1.1, 1.2, 1.3, 1.4 and 2.1, 2.2, 2.3, 2.4 respectively. The arrangement is such that when 1.1 makes a cut right side of the plane containing the rotor of blade 1,2 1 makes a cut

on the left plane of the plane containing the rotor of blade 2 etc. Thus the right hand side cut is signified by (R) and left hand side cut by (L) as shown in figure 3.6, in such a way that 2.1 makes angle of 45^{o} with 1.1.

(b) Determination of bite length: the bite length is the distance between two cuts on the same side of a blade. For one revolution of the roter with 1.3 as reference blade, 1.4 makes Z/2 bite length

1.1 makes Z bite length

1.2 makes Z bite length

1.3 makes Z bite length

1.4 makes Z /2 bite length as shown in fig 3.7.

It will be seen that 1.4 bites twice for one revolution and the addition of the two bites

(Z/2+Z /2) = Z bite length

Also blade 2.3 makes Z/4 bite length

blade 2.4 makes 3/4 Z bite length

blade 2.1 makes Z bite length

blade 2.2 makes Z bite length

blade 2.3 makes 3/4 Z bite length and blade 2.4 makes Z/4 bite length. Blades 2.3 and 2.4 bite twice within one revolution and addition of the

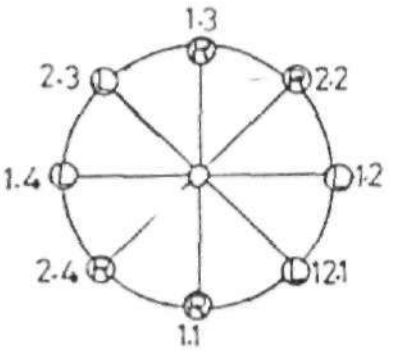


FIG 3.6 BLADES ARRANGEMENT VIEWING FROM THE SIDE

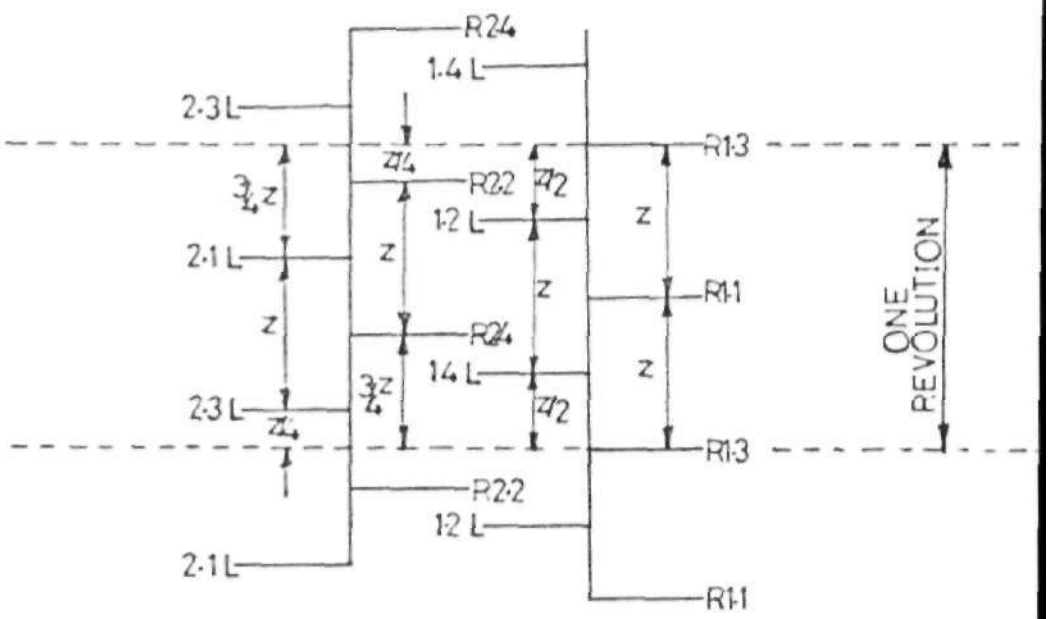


FIG 3.7 SEQUENCE OF CUTTING TO SHOW BITE LENGTH

two also give Z length.

The specific energy per bite length is given as

$P = 43.9Z^{-0.46} - 0.14Z$ _____ 3.1

(ASAE Yearbook, 1980)

Z = bite length in cm

P = specific energy N/cm^2

Work done per bite length is also:

$W = Zhl(43.9Z^{-0.46} - 0.14Z)$ (Ncm)____3.2

where h = depth of cut (cm)

l = width of blade (cm)

Fig 3.8 shows the angles made by each blade before cutting the soil to the desired depth in polar and cartesian coordinates, mechanism in fig. 3.9

$\theta 1.3 = \Pi/2 + \phi = \Pi/2 + \sin^{-1}((R-h)/R)$

where R is the radius of the rotor and

h the depth of cut

$\theta 1.2 = \phi = \sin^{-1}((R-h)/R)$

$\theta 1.1 = 3\Pi/2 - \sin^{-1}((R-h)/R)$

$\theta 1.4 = \Pi + \sin^{-1}((R-h)/R)$

Time taken = θ/speed of rotation.

$t = \theta/(2\Pi N)/60 = 30\theta/\Pi N$.

where N is the rotation in rpm.

hence $t1.3 = 30\theta\ 1.3/\Pi N$

$$t1.3 = \frac{30}{\Pi N}\left[\Pi/2 + \sin^{-1}\frac{(R-h)}{R}\right]$$

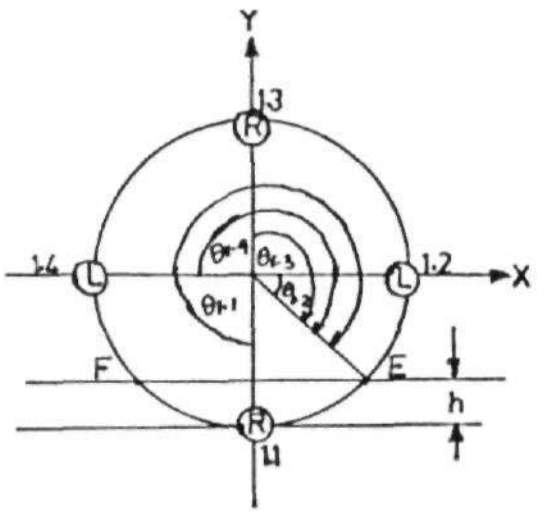


Fig. 3·8 ANGULAR ROTATION OF EACH BLADE BEFORE CUTTING THE SOIL

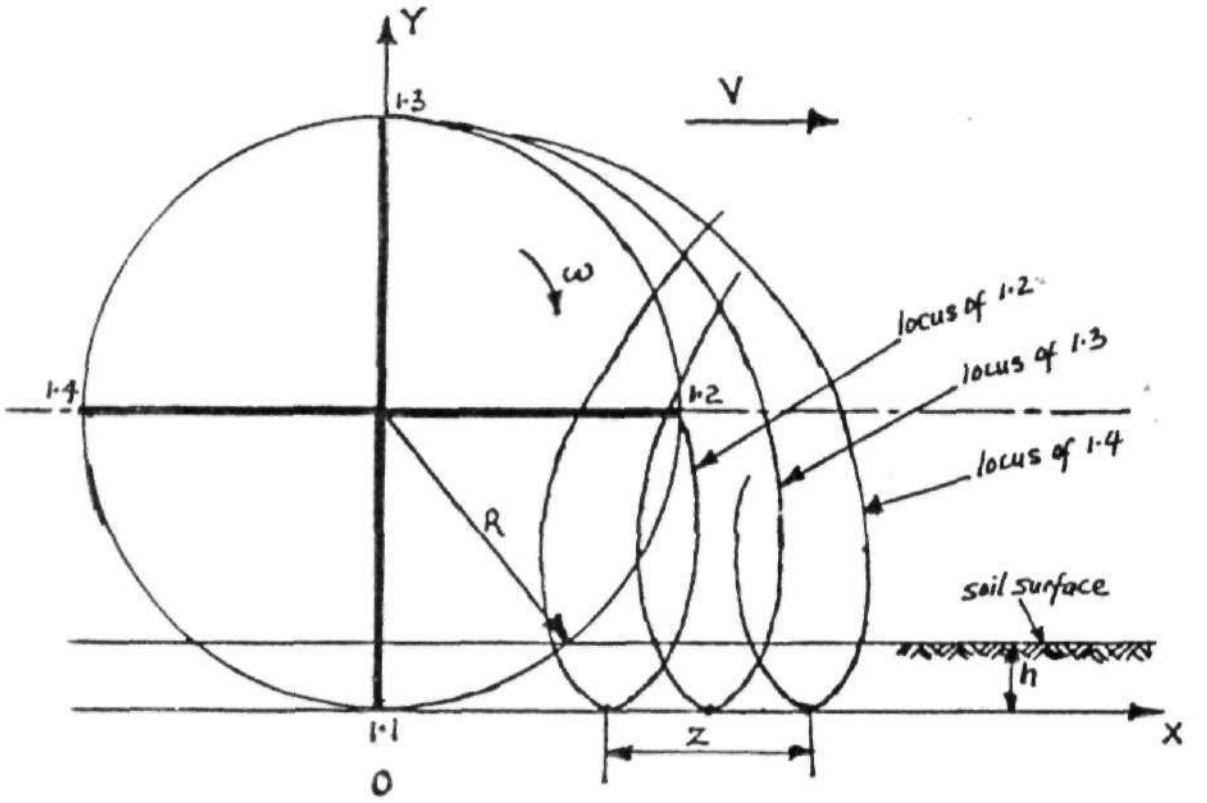


FIG. 3.9 GRADHICAL ILLUSTRATION OF MECHANISM OF OPERATION

$$t1.2 = \frac{30}{\Pi N}\left[\frac{\text{Sin}^{-1}\ (R-h)}{R}\right]$$

$$t1.1 = \frac{30}{\Pi N}\left[\frac{3\Pi}{2} + \text{Sin}^{-1}\ (R-h)/R)\right]$$

$$t1.4 = \frac{30}{\Pi N}\left[\Pi + \text{Sin}^{-1}\ \frac{(R-h)}{R}\right]$$

<u>Locus of Points on tip of Blade</u>

From fig 3.8 and 3.9

$Y1.3 = R\text{Cos}\omega t$

or $Y1.3 = R\text{Cos}\ \Pi\ Nt/30$

$X1.3 = R\text{Sin}\ \Pi Nt/30 + 100vt/3.6$

$Y1.1 = R\text{Cos}\ (\Pi Nt/30 - \Pi)$

$X1.1 = R\ \text{Sin}\ (\Pi\ Nt/30 - \Pi) + 100vt/3.6$

put $t1.3$ for $X1.3$ and $t1.1$ for $X1.1$

$X1.3 = R\text{Sin}\ (\Pi\ Nt\ 1.3/30) + 100vt\ 1.3/3.6$

$X1.1 = R\text{Sin}\ (\Pi\ Nt\ 1.1/30 - \Pi) + 100vt\ 1.1/3.6$

from fig. 3.6, bite length $Z = X1.1 - X1.3$

$= R(\text{Sin}(\Pi\ Nt\ 1.1/30 - II) - \text{Sin}(II\ Nt\ 1.3/30)$

$+ 100v(t1.1 - t1.3)/3.6$

Substituting for $t1.1$ and $t1.3$

$$Z = R\left\{\text{Sin}\left(\frac{\Pi N}{30}\right.\right. \left(30/\Pi N\ (3\Pi/2+\text{Sin}^{-1}\frac{(R-h)}{R} - \Pi\right.$$

$$- \text{Sin}\ \Pi N/30(30/\Pi N\ (\Pi/2+\text{Sin}^{-1}\ \frac{(R-h)}{R}$$

$$+ \quad 100v/3.6\ (30/\Pi N(3\Pi/2 + \mathrm{Sin}^{-1}\frac{(R-h)}{R} - \Pi/2 - \mathrm{Sin}^{-1}\frac{(R-h)}{R}\Big]$$

$$= R\left\{\mathrm{Sin}\left(\Pi/2+\mathrm{Sin}^{-1}\frac{(R-h)}{R}\right) - \mathrm{Sin}\left(\Pi/2+\mathrm{Sin}^{-1}\frac{(R-h)}{R}\right)\right\}$$

$$+ \quad 3000V/3.6N$$

$$Z = 1000V/1.2N \qquad \text{3.3}$$

Fig. 3.10 show the relationship between bite length and blade speed for different forward speed.

Work Per revolution of Rotor

Volume of soil for 1.4 = $\frac{Zhl}{2} = \frac{150vhl}{3.6N}$

Specific energy

$= 43.9\ (150v/3.6N)^{-0.46} - (150V/3.6N)$

$\therefore$ Work = $vhl/N\ (\ 1126.61(v/N)^{-0.46} - 24305.55(v/N)$

For blade 1.1

Volume of soil = $Zhl = 300vhl/3.6N$

Work = $3000vhl/3.6N(43.9(3000V/3.6N)^{-0.46} - 0.14(3000v/3.6N)$

$= vhl/N(1658.467(v/N)^{-0.46} - 97222.22(v/N)$

blade 1.2. is same as 1.1

blade 1.3 is same as 1.1

blade 1.4 second time same as above.

total work done by blades assembly 1.

$= vhl/N(7228.621(v/N)^{-0.46} - 340277.76(v/N)Ncm.$

$= vhl/N(0.072286(v/N)^{-0.46} - 3.4(v/N))kNm$

Work done by blades assembly 2 per revolution;

for blade 2.3

Volume of soil cut = Zhl/4

$= 3000vhl/14.4$

$$Work = 3000vhl/14.4(43.9(3000v/14.4N)^{-0.46}\ 0.14\left\{\frac{3000v}{14.4N}\right\}$$

$= Vhl/N(784.502(v/N)^{-0.46} - 6076.389(V/N))$

for blade 2.4

Volume of soil cut = 3/4 Zhl

$= (9000v/14.4N)hl$

$Work = (9000v/14.4)hl(43.9(9000v/14.4N)^{-0.46} - 0.14(9000v/14.4))$

$= vhl/N(1419.841(V/N)^{-0.46} - 54687.5(V/N))$

For blades 2.1, 2.2

Volume of soil cut each = $Zhl = \frac{3000vhl}{3.6N}$

hence this is the same as 1.1 above, for both

work = $2vhl/N\ (1658.467(V/N)^{-0.46} - 97,222.22(V/N))$

For 2.3 as in above and 2.4, same as above due to the same value of bite length.

Total work done for one revolution by blades assembly 2.

$W = vhl/N\ (7725.62(v/N)^{-0.46} - 315972.2.8(v/N))$ Ncm

$W = vhl/N(0.0772562(v/N)^{-0.46} - 3.159(v/N))KN.m.$ 3.5

Total work done by the two blades assemblies for one revolution.

$Work = vhl/N[0.1495422(v/N)^{-0.46} - 6.562478(v/N)]KN\ m$ 3.6

at Nrpm = 2ΠN radians per 60 seconds

1 revolution = 60/N seconds.

$Power = Vhl/60(0.1495422(v/N)^{-0.46} - 6.562478(v/N))$ 3.7

v = speed of operation in km/h

h = depth of weeding (cm)

l = blade length (cm)

N = blades spped (rpm)

Equation (3.7) implies that power required is proportional to speed, blade length, depth of weeding and blades rotational speed.

Using equation 3.7 above to determine the effects of some variable parameters on the power required by the machine, that is, vary one parameter and keep others constant, results got for speed of operation, speed of rotation of the blades and depth of weeding are given as follows:

(a) For constant N = 400rpm, h = 4cm and l = 15cm.

$P = v(0.1495422(v/400)^{-0.46} - 6.562478(v/400))$

and for different values of V the relationship of

Power required with these forward speed is shown in fig 3.11.

(b) For different values of forward speed and at depth of 4cm, the relationship between power required at different blade speed is shown in fig 3.12.

$$P = v(0.1495422(v/N)^{-0.46} - 6.562478(v/400).$$

(c) For different values of forward speed and at blade speed of 400rpm, the relationship between power required at different depth of weeding is also shown in fig 3.13. These show linear relationship between the power and depth of weeding.

$$P = 0.25vh(0.1495422(v/400)^{-0.46} - 6.562478(v/400)$$

for $v = 1.0$

$$P = 0.25h(2.337078)$$

$$P = 0.584h \quad \text{_____} \quad 3.8$$

Results obtained from above justify the choice of 3.75kw (5-hp) engine to power the machine. Table 3.1 shows the amount of power requirement for different parameters of the weeder.

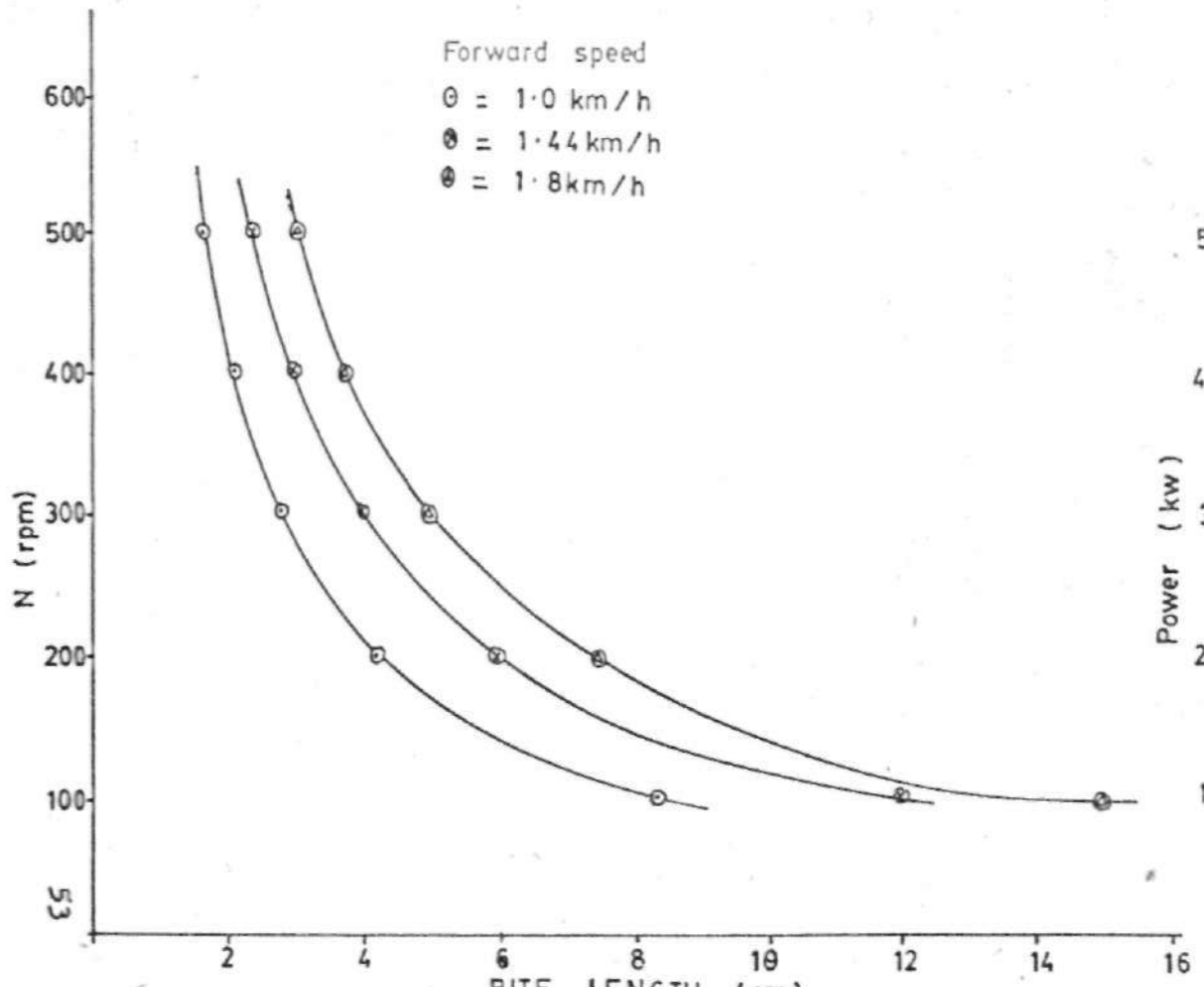


Fig. 3.10 Blades revolution against bite length for three different speed

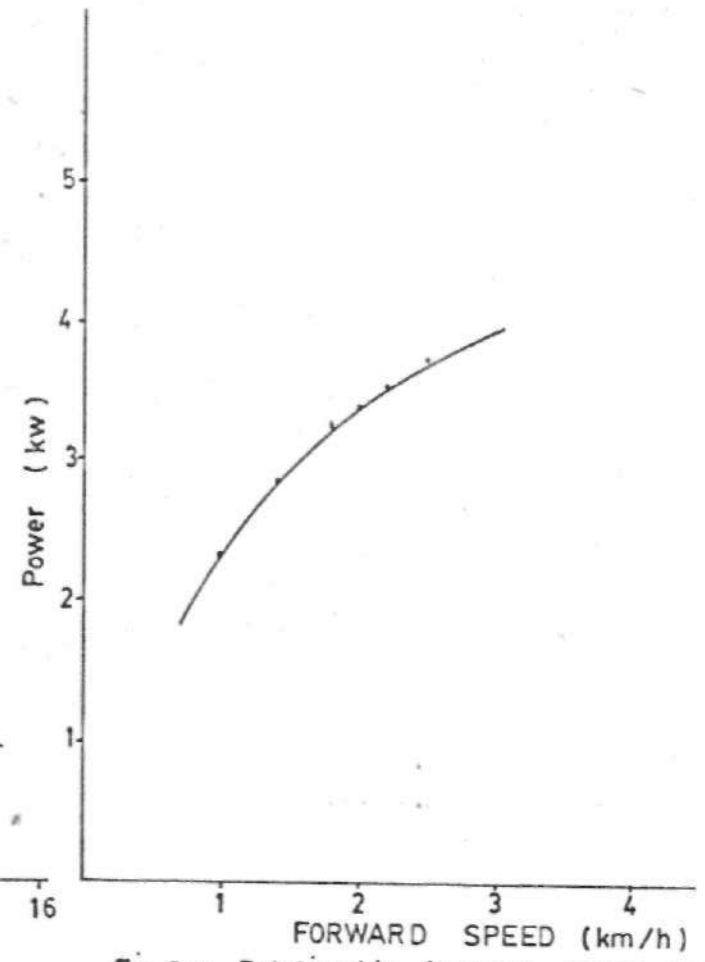


Fig. 3.11 Relationship between power forward speed

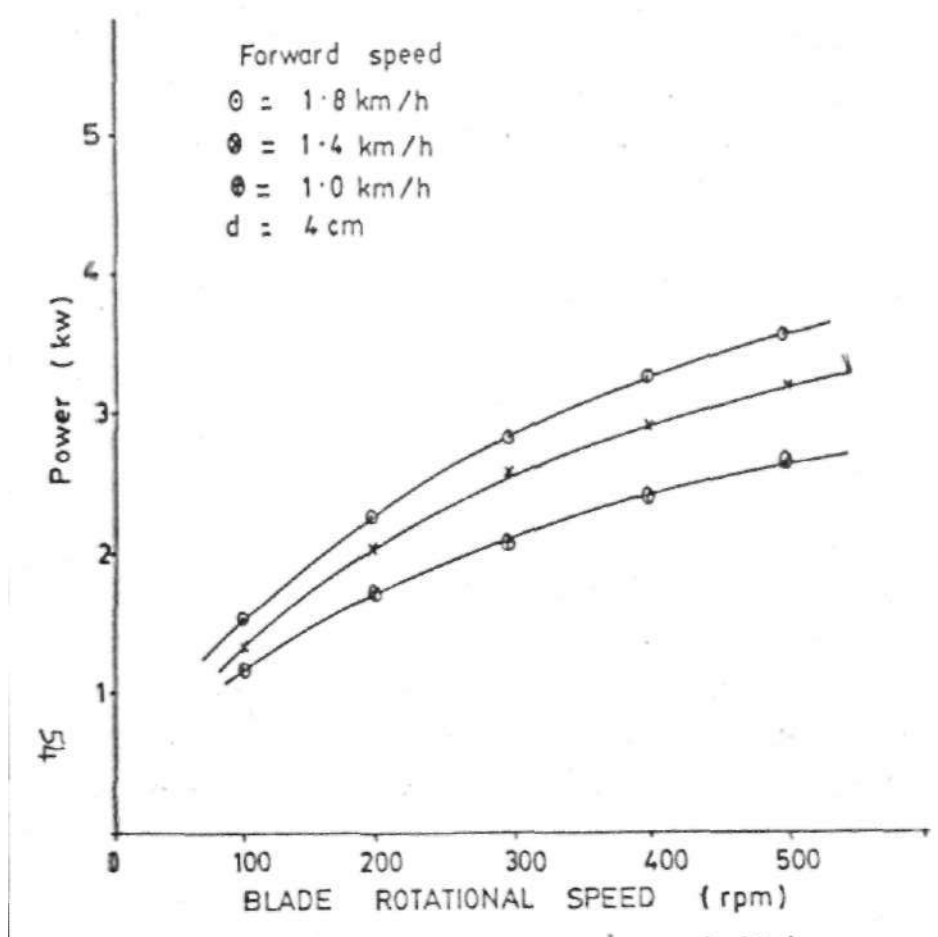


Fig. 3.12 Relationship between power and blade rotational speed.

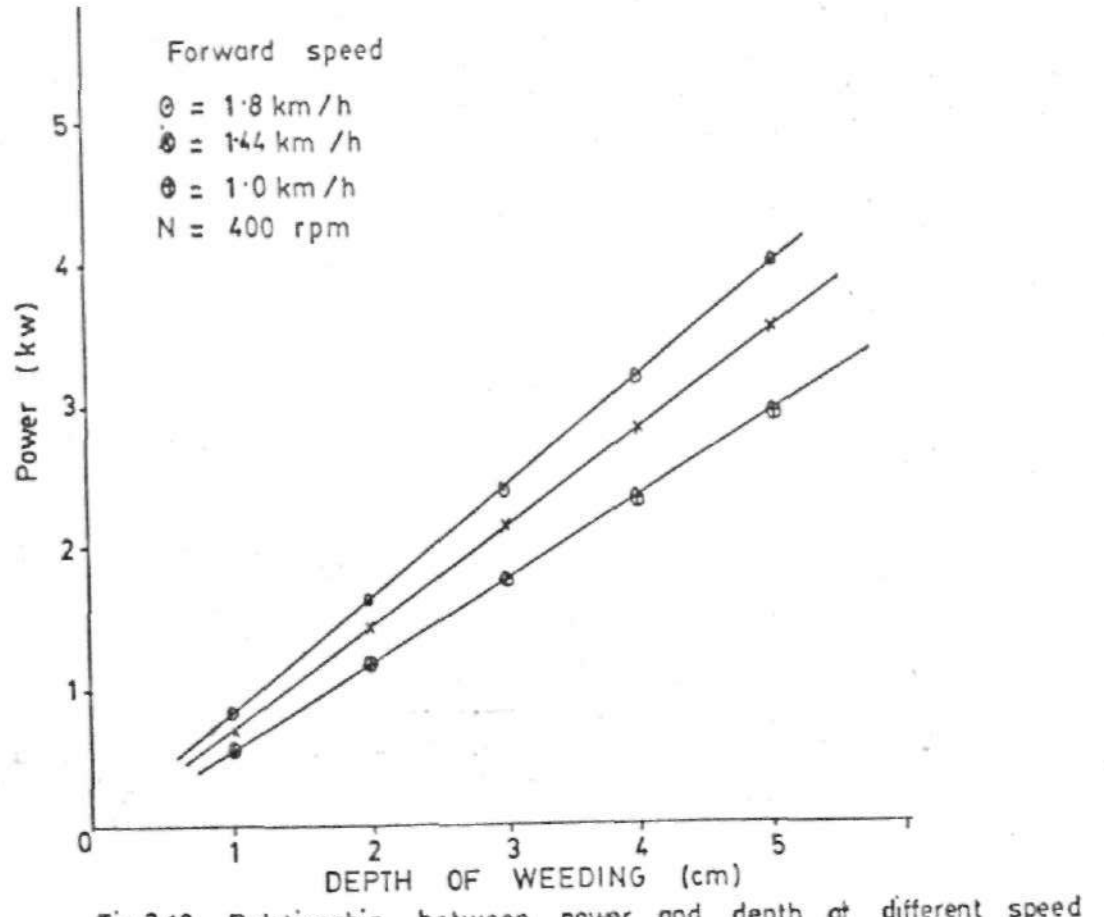


Fig. 3.13 Relationship between power and depth at different speed

Table:3.1 Power requirement at different blade speeds, depths of weeding and forward speeds.

V(Km/h)	Depth	Power (Kw) required at different blade speed (rpm)				
	h(cm)	P100	P200	P300	P400	P500
1.0	1	0.295	0.42	0.51	0.58	0.65
	2	0.059	0.84	1.02	1.17	1.30
	3	0.88	1.26	1.53	1.75	1.95
	4	1.18	1.68	2.04	2.34	2.59
	5	1.47	2.10	2,55	2.92	3.24
1.44	1	0.35	0.504	0.62	0.71	0.79
	2	0.69	1.01	1.24	1.42	1.58
	3	1.04	1.51	1.86	2.12	2.38
	4	1.37	2.02	2.48	2.83	3.17
	5	1.73	2.52	3.10	3.54	3.96
1.8	1	0.38	0.56	0.68	0.79	0.88
	2	0.76	1.12	1.37	1.58	1.76
	3	1.13	1.67	3.05	2.39	2.65
	4	1.51	2.23	2.74	3.18	3.53
	5	1.89	2.79	3.42	3.97	4.41

The above shows that the power requirement increases with the forward speed of operation, depth of weeding and rotational speed of the blades.

2.4 Shear Force (SF) acting on the Shaft

End Reactions. Fig 3.4 shows the free body diagram of the arrangement of pulley and the two blades assemblies on the shaft. LR and RR represent left reaction and right reaction respectively.

P = pulley (44.15)

B1= blades assembly 1 (29.43N)

Sh= shaft (30.41N)

B2= blades assembly 2(29,43N)

Total length of the shaft = 0.85m

Taking moment about LR

$$RR \times 0.85 = (44.15 \times 0.04 + 29.43 \times 0.28 + 30.41 \times 0.428 + 29.43 \times 0.57)\text{N-m}$$

$$= 29.706\text{N-m}$$

$$RR = 29.706/0.85$$

$$= \underline{46.71\text{N}}$$

To find LR, sum of the upward forces = sum of the downward forces

$$= LR+RR = (44,15+29.43+30.41+29.43)\text{N}$$

$$LR = (133.42 - 46\text{-}71)\text{N}$$

$$= \underline{86.71\text{N}}$$

Vertical Shear Force

Since weight of the shaft = 30.41N and the total length = 0.85m.

Hence weight/length = 30.41/0.85

$$= \underline{35.8\text{N/m}}$$

SF at LR = 86.71N

SF between LR and P = SF at LR - (35.8x0.04)

= 85.28N

SF at P = (85.28 - 44.15)N

= 41.13N

SF between P and B1 = SF at P -(35.8x0.28)

= 31.11N

SF at B1 = (31.11 - 29.43)N

= 1.68N

SF between B1 and B2 = SF at B1 - (35.8x0.25)

= -7.26N

SF at B2 = (-7.26 - 29.43)N

= 36.69N

SF between B2 and RR = SF at B2 -(35.8x0.028)

= - 46.71N

SF at RR = (-46.71+46.71)N

= NIL or 0.0N
Zero Newton.

Shear force diagram is shown in fig. 3.9

Maximum Bending Moment

From the shear force diagram. The diagram shows that zero occurs at a point 0.38m from the left-hand reaction.

Hence the maximum bending moment Mm on the shaft is:

$$Mm = (86.71(0.38)-44.15(0.34)-29.43(0.06) -35.8 \times(0.16)\ (0.38)\ N-m$$
$$=(32.95-15.01-1.77-2.18)N-m$$
$$= 13.999N-m$$
$$14.0N-m$$

3.2.5 Shaft Diameter

Maximum torque has been determined as 101.46N-m(3.2.2)

For a circular solid shaft the following expression holds:

$$J/r = T/Ymax. \quad \text{_____} \quad 3.9$$

Where J is the second moment of area (M^4)

r = radius of shaft (m)

T = maximum torque developed

Y_{max} = maximum shear stress of the shaft

Mild steel shaft is chosen because of its availability and durability and

Ymax for mild steel = $40x10^6 N/m^2$

$J = 1/2\Pi r^4$ and from equation 3.3

$$1/2\Pi r^3 = T/Ymax \quad \text{_____} \quad 3.10$$

$$r = \sqrt[3]{2T/Ymax}$$

r = 0.0117m

r = 11.7mm

hence diameter = 23.4mm

25.4mm diameter was chosen.

3.2.6 Equivalent Bending Moment, Stress in the Shaft and Ideal Torque for the Shaft

(a) Equivalent Bending Moment: Me 1b-in as expressed by Hicks(1985) for a solid shaft is:

$$Me = 0.5(M + (M^2+MT^2)^{0.5} \quad \text{3.11}$$

Where M= maximum bending moment acting on the shaft 14.0N-m (124 1b-in)

T = maximum torque acting on the shaft 1b-in

= 898.65 1b-in.

hence,

$$Me = 0.5(124+(124^2+898.65)^{0.5})$$
$$= 515.58 \text{ 1b-in}$$
$$= 58.74\text{N-m}$$

(b) Stress in the Shaft (s)

Using the flexure relation: (Hicks, 1985)

$$s = Mc/I$$

M = Me = 515.58

c = d/2 where d is the shaft diameter (in)=0.5 in

I = section moment of inertial of the shaft about neutral axis (in^4)

$$I = d^4/64$$
$$= 0.049in^4$$

hence

$$S = \frac{515.58 \times 0.5}{0.049}$$

$$= 5261.02 \text{ lb/in}^2$$

$$= 36.29 \text{KN/m}^2$$

Since this is less than maximum allow able stress in shaft, the shaft is safe.

(c) Ideal torque for shaft Ti

$$Ti = M + (M^2+T^2)^{0.5} \text{ lb-in} \quad 3.12$$
$$= 124+(124^2+898.65^2)^{0.5}$$
$$= 1031.16 \text{ lb-in}$$

$$= 116.42 \text{N-m}$$

3.3 Selection of Manufactured Parts

3.3.1 Vee-Belt

Only one Vee-belt is used to transmit power from the engine to the weeding component.

Considering the pulley size of the engine used and that on the rotor shaft and also that widths and depth. Also bearing in mind the centre distance between the two pulleys.

The vee-belt chosen has:

width of 15mm

depth or thickness of 12mm.

3.3.2 Bearings

Two ball bearings are used for the shaft holding the blade assembles. The bearings have a bore of 22mm.

3.3.3 Pulley

Diameter of the pulley used is 300mm.

hence angular velocity (maximum)

$$= \frac{400 \times 2\pi \times 0.15}{60} = 6.28 \text{m/s}$$

$$= 20 \text{ft/sec}$$

Intensity of tensile strength of pulleys in lb/in is given by $St = v^2/10$

hence $St = \frac{20^2}{10} = 40 \text{lb/m}^2$

$$= 275.8 \text{ KN/m}^2$$

3.3.4 Maximum Power Required to Push the Weeder

For manually operated machine velocity of operation is rated between 0.8 to 1.2m/s, hence using an average velocity of 1.0m/s.

The total weight of the machine = 55.7kg

= 546.8N.

Power = Force x Velocity

= 546.8 x 1.0 watts

This is the minimum power required to push the machine, to account for:

(i) frictional resistance of wheel bearings

(ii) reistance at the wheels soil interface as they move over rough terrain.

(iii) shear resistance of the cutting blades against the soil.

(iv) other resistances.

A factor of about 15% is added

Hence actual maximum power

= (0.547 + 0.15 (0.547))Kw.

Pmax = 0.628 Kw

3.4 Cost Estimation (MW)

S/No	Material	Quantity Used	Value(₦)
1	Length 50x50mmx6m A/Iron	6m	300.00
2	Length of 25x25mmx6m A/Iron	6m	250.00
3	Length of 50x5mmx6m Flat Bar	6m	270.00
4	Length of 150x150x3mm Flat Bar	4m	150.40
5	Length of 25mm diameter mild steel rod	2m	150.00

6	Length of 25mm G.I. pipe	3m	50.00
7	Length of 15x15mmx6mm hollow shaft	4m	125.00
8	300mm diameter pulley (single V)	1	850.00
9	120mm diameter pulley (single V)	1	600.00
10	20mm bore ball bearings	4	900.00
11	Vee-Belt	1	150.00
12	20mm diameter wheels	3	105.00
13	M10x35 Bolt/Nat	32	192.00
14	M12x50 Bolt/Nat	8	56.00
15	M15x50 Bolt/Nat	10	50.00
16	M17 x 100 Bolt/Nat	8	64.00
17	Plywood 10mm thick	1/2 full size	120.00
	TOTAL COST OF MATERIAL		4,382.90
	COST OF LABOUR UTILISED FOR FABRICATION		750.00
	CONTINGENCES		500.00
	SUB TOTAL		₦5632.90

+

5.HP Petrol Engine ₦8,500.00

From the above estimate, the total cost of producing the weeder is ₦5,632.90. When the cost of the 5hP internal combustion engine is added it gives a total cost of ₦14,132.90

3.5 Wheeled Long Handle Weeding Hoe (WLHH)

3.5.1 Description This hoe is simply made up of

aluminium pipe as the handle, ground wheel and the hoe blade. The aluminium pipe is 19mm diameter and 1560mm long. The wheel and the scraper is attached to the handle at 500mm point from the bottom end of the handle. The hoe blade was bent at an angle of 65° based on the results obtained from ten weeding hoes, measuring their angles with horizontal. This blade is welded to a 12.5mm diameter short piece of galvanized iron pipe, which is then bolted to the handle for easy removal when another blade of different bent angle is to be fixed. The assembly drawing of this is shown in fig. 3.14.

3.5.2 Design Analysis:- The main objectives of the design are to reduce the amount of force applied by the farmer on the hoe and to reduce the load in transporting the weeding hoe during non-weeding strokes.

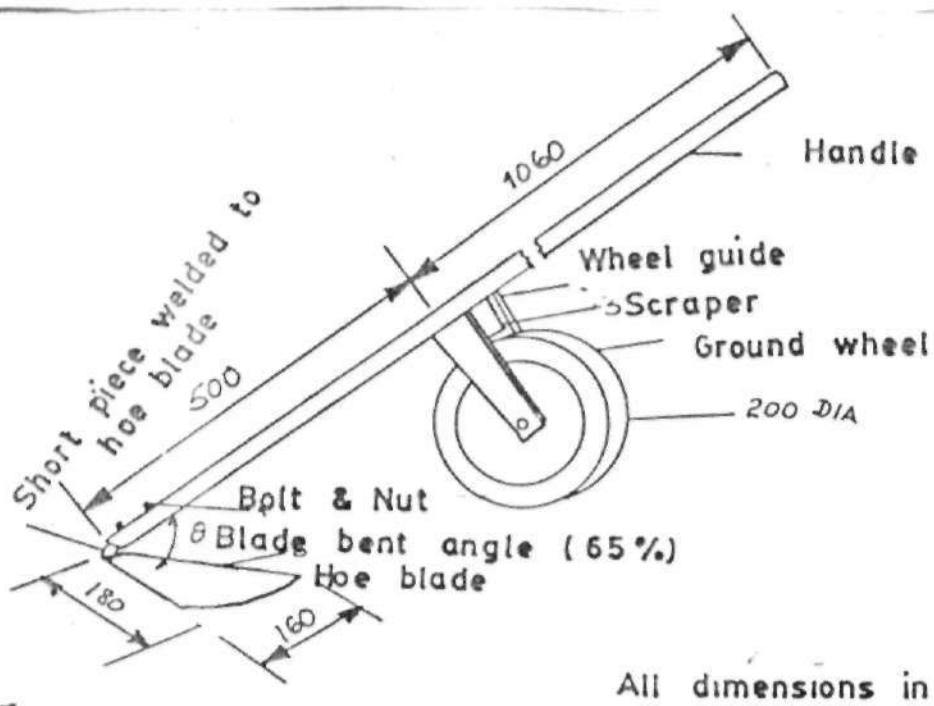
Considering the tillage tool/soil interface, this tool is raked at an angle α and the cutting force (P) is as shown in fig. 3.15.

Keithiarachi and Reece (1974) have shown that for a simple cutting tool, the cutting force is given by the equation.

$$P = (\gamma g d^2 N\gamma + cd Nc + qdNq)\ w \qquad \text{3.13}$$

where r = soil density kg/m^3

g = gravitational acceleration m/s^2



All dimensions in mm.

FIG. 3.14 WHEELED LONG HANDLE WEEDING HOE (WLHH)

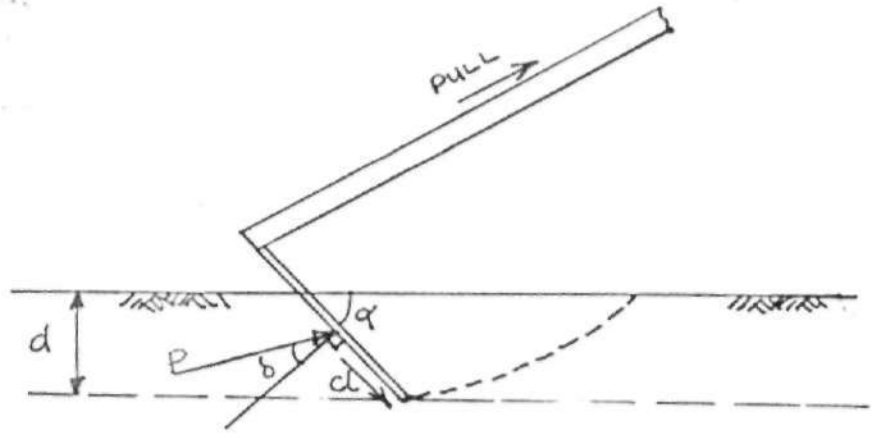


Fig. 3.15 Direction of cutting force P for a tool raked at angle α (Hettiarachi and Reece, 1974).

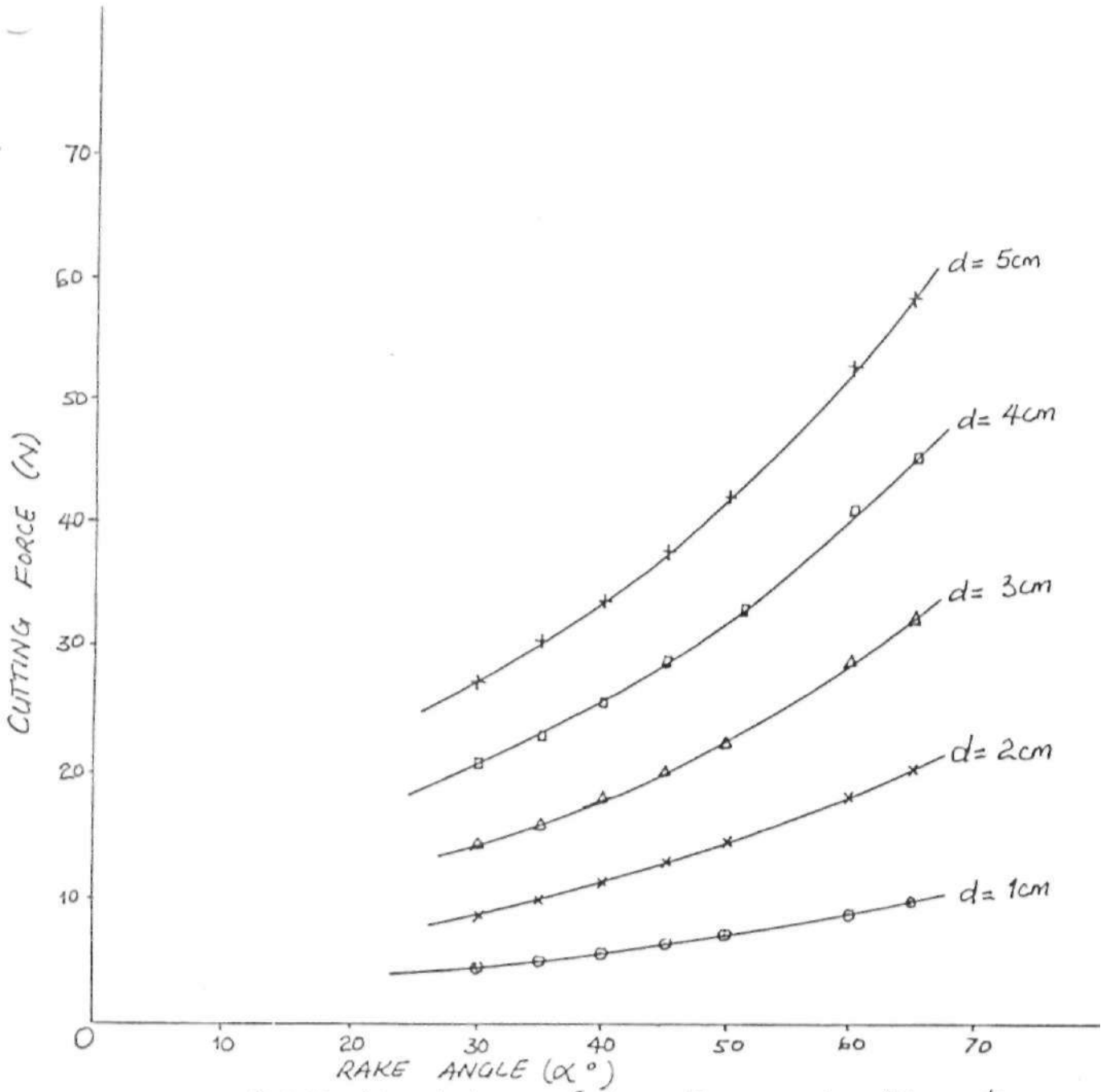


FIG. 3.16 Relationship between Cutting Force and rake angle at different depths of weeding.

d = depth of cut (m)

c = soil cohesion kN/m^2

q = soil surcharge pressure, KN/m^2

w = width of tool m.

N_γ, Nc, Nq are N factors representing density, cohesion and surcharge pressure. These factors can be evaluated or selected appropriately from charts.

The following values are used for the soil (sandy loam) based on literature.

ϕ = coefficient of Internal soil friction $=35^o$

δ = soil/tool friction angle = 25^o

C = 20kPa

γ = 1400 kg/m^3

In this analysis we shall assume the surcharge to be zero since this is mainly the mass of weeds and are considered neglible. We are going to consider different rake angles α = 30^o, 35^o, 40^o, 45^o, 50^o, 55^o, 65^o

From charts of Hettiaratchi and Reece (1974) N factors for these rake angles are given as in Table 3.2.

Table 3.2 N factors for different rake angles.

α°	$N_{\gamma}, \delta=0$	$N_{\gamma}, \delta=\phi$	Nc, $\delta=0$	Nc, $\delta=\phi$
30	1.2	2.02	0.52	2.4
35	1.1	2.00	0.64	2.7
40	1.02	2.02	0.26	3.10
45	1.00	2.15	0.90	3.50
50	1.00	2.25	1.05	4.00
55	1.02	2.40	1.20	4.40
60	1.1	2.60	1.45	5.00
65	1.15	2.90	1.70	5.40

To calculate the actual N factor at $\delta = 25^{\circ}$ we employ the formula.

$$N = N\delta=0 \ (N\delta=\phi/N\delta=0)^{\delta/\phi} \quad \text{_____} 3.14$$

and this gives:

α^{o}	N_{γ}	Nc
30	1.741	1.550
35	1.686	1.789
40	1.662	2.075
45	1.728	2.374
50	1.705	2.730
55	1.879	3.036
60	2.033	3.511
65	2.227	3.881

For sandy loam soil $\gamma = 1400 kg/m^3$

$c = 1.63 kN/m^3$ $\quad \phi = 35^{o}$

$P = (1.4 \times 9.81\ d^2 N_{\gamma} + 1.63 dNc)W$

For w of 15cm.

$P = 0.15(13.734 d^2 N_{\gamma} + 1.63 dNc) \times 1000N$

$P = 150(13.734 d^2 N_{\gamma} + 1.63 dNc)$ N.

The cutting force at different depths and value angles were calculated and are given in table 3.3.

Table 3.3 Cutting force at different depths of weeding (N)

α°	P1cm	P2cm	P3cm	P4cm	P5cm
30	4.15	9.01	14.6	20.90	27.92
35	4.72	10.14	16.25	23.05	30.55
40	5.42	11.52	18.3	25.77	33.93
45	6.16	13.03	20.62	28.91	37.92
60	9.00	18.84	29.53	41.04	53.39
65	9.95	20.81	32.60	45.30	58.91

This is also illustrated in fig 3.16

From fig. 3.15 the total horizontal component of focus on the cutting blade is:

$$H = P \sin(\alpha + \delta) + Cadw \cot\alpha$$

and the vertical component.

$$V = P\cos(\alpha + \delta) - Cadw$$

But $Ca = c\cot\phi \tan\delta$

$= 1.6\cot 35^{\circ} \tan 25^{\circ} = 1.065$

hence; $H = P\sin(\alpha + 25) + 0.00700125\cot\alpha$ _____3.15

and $V = P\cos(\alpha + 25) - 0.00799125$ _____3.16

Using the values of P for h = 0.04m

Table 3.4 Horizontal and vertical components of the cutting force.

α°	P(N)	H(N)	V(N)	$\sqrt{H^2+V^2}$	$\tan^{-1}(v/H)$
30	20.90	17.13	11.98	20.90	34.97°
40	25.77	23.37	10.88	25.78	24.96°
45	28.91	27.17	9.88	28.91	19.98°
60	41.04	40.89	3.57	41.05	4.99°
65	45.30	45.30	- 0.008	45.30	-0.01°

From the above the least force occured at = 30^{o}
and = 20.90N.

and angle makes with the horizontal = 35^{o}.

For optimum design, the resultant force must go along or be parallel to the handle. Thus the inclination of blade to handle should be very close to $(30+34.97)^{\bullet} = 64.970^{\bullet} \approx 65^{o}$

and this justifies the inclination angle used.

To determine the height of hand above the ground.

let l. be the length of handle

h = height above the ground.

From fig. 3.15

$l \sin 35^{o} = h$

$h = 1.56 \sin 35^{o}$

$= 0.89m$

approximately 1.0m above the ground.

3.5.3 Principle of Operation- The blade is fixed to the handle through the provided holes at the bottom end of the handle, it must be bolted tightly to prevent loosening and thereby disturb the operation. This hoe is essentially an inter-row cultivator and it is convenient to use especially on flat lands. It should be noted that when weeding the wheel should not be made to touch the ground except when the hoe is to be moved away from the operator. After weeding



FIG. 3.17 Wheeled Long Handle Weeding Hoe in Operation.

the hoe blade can be replaced with a rake, to gather the weeds to a desired place for later burning.

3.6 Experimental Design

Three designs are used to test the mechanical weeders. The first design is completely randomized block design. This is used to test for the performance of the motorized weeder, to study the effects of depth of weeding and rotational speed of the blades on the performance of the machine, in terms of cleanliness percentage of the covered area and field capacity of the machine in hectarage covered over an hour.

The three depths used are 20mm, 30mm and 40mm (maximum depth of operation), while the three speeds are 300, 350 and 400 rpm. For these reasons a total of three rows were used, each row is for a speed and these stand for the treatments. Three blocks were used also for the three depths of operation.

Each row is spaced 90cm (0.9m) and has a length of 15m, for a block there are three rows and have an area of about $40.5m^2$ per block, giving a total area of about $121.5m^2$ for the design plot. This was replicated twice and the average found, it was also done at three different stages of weeding.

The second design used is paired plot to compare the performance of motorized weeder with that of long handle wheeled hoe, motorized weeder with manual hand hoe and also long handle wheeled hoe with manual hand hoe. These plots are made up of two rows of 15m long each, replicated three times.

The three weeders were compared collectively by using another randomized block design.

The type of soil found on the experimental plot was mainly sandy loam soil, and the type of weed that occupied the entire area was grass, about 90% of which was carpet grass (Eehinocloa Crusgalli).

The moisture content of the soil during the test was between 11.6% and 14.3% dry basis with an average value of 12.8%.

4. RESULTS AND DISCUSSION

4.1 Introduction

The results obtained in this study are presented and discussed in this chapter. The discussion of these results are divided into four groups such as:
motorized weeder, wheeled long handle hoe, with manual short handle weeding hoe and the discussion of the effect of some conditions or factors on the performance of the motorized weeder.

4.2. Motorized Weeder (MW)

4.2.1 Field Capacity of the Weeder

Table 4.1 presents the field capacities of MW at 14.3% moisture content at different speeds and depths of cut. These capacities varied from minimum value of 0.0395 ha/h at depth of 30mm and blade speed of 300rpm to a maximum value of 0.0505ha/h at depth of 30mm depth of cut and 400rpm blade speed. The average field capacity of all these capacities was found to be 0.0459 ha/h.

Also at 11.6% moisture content the field capacities varied from miminum value of 0.0403 ha/h at depth of 40mm and blade speed of 350rpm to a maximum value of 0.0532 ha/h at depth of 40mm and blade speed of 300rpm. And the average

value was 0.0465ha/h. These are shown in Table 4.2 below.

The lowest value for the field capacity was obtained at 12.5% moisture content (Table 4.3) and also it was at this moisture that the highest value of field capacity was obtained, these are 0.036 ha/h and 0.0576 ha/h respectively. Average value of these capacities was also 0.0447 ha/h. Capacity of 0.036 ha/h was at depth of 40mm and blade speed of 350rpm while 0.0576ha/h was at 30mm depth and 350 rpm blade speed.

Table 4.1 Field Capacity of Motorized Weeder in Sandy loam Soil at 14.3% Moisture Content dry Basis

	Field Capacity (Ha/h) by speeds		
Depth	S1	S2	S3
D1	0.0480	0.0422	0.0482
D2	0.0395	0.0504	0.0505
D3	0.0478	0.0441	0.0427

Average value = 0.0459 ha/h.

D1 = 20mm depth S1 = 300rpm blade speed

D2 = 30mm depth S2 = 350rpm blade speed

D3 = 40mm depth S3 = 400rpm blade speed

Table 4.2 Field Capacity of Motorized Weeder in Sandy loam soil at 11.6% moisture content dry basis

	Field Capacity (ha/h) by speeds		
Depth	S1	S2	S3
D1	0.0480	0.0443	0.0514
D2	0.0432	0.0520	0.0420
D3	0.0532	0.0403	0.0445

Average value = 0.0465 ha/h

Table 4.3 Field Capacity of motorized Weeder in Sandy Loam Spil at 12.5% M.C Dry Basis

	Field Capacity by Speeds		
Depth	S1	S2	S3
D1	0.0395	0.0458	0.0415
D2	0.0499	0.0576	0.0466
D3	0.0429	0.0360	0.0427

Average value = 0.0447 ha/h.

Table 4.4 gives the average value of these capacities at the three moisture conditions given above for the three depths of weeding and three blade ratational speeds. The minimum average value was 0.0401 ha/h at 40mm depth of cut and 350 rpm blade speed and the maximum average value was also 0.0533 ha/h at 30mm depth of weeding and 350rpm blade speed. The average values at each depth of weeding were also calculated

and those for each blade ratational speed. The overall average field capacity was then found to be 0.057 ha/h. This is the average field capacity of the motorized weeder.

Table 4.4. Average Field Capacity of Motorized Weeder in sandy loam Soil at the Three moisture conditions of 14.3%, 11.6% and 12.5%

	Field Capacity (ha/h) by Speeds			
Depth	S1	S2	S3	Average
D1	0.0452	0.0441	0.0470	0.0454
D2	0.0442	0.0533	0.0464	0.0480
D3	0.0480	0.0401	0.0433	0.0438
Average	0.0458	0.0458	0.0456	0.0457

In the analysis of variance of the average field capacities of the motorized weeder presented in Table 4.5. The calculated variance ratio (F) value (0.86) for the speed was less than the table F value at 2 and 4 degree of freedom (6.94) at 5% level it means the difference among the means of the speeds was statistically insignificant. Likewise for the depth, as the calculated F value (1.87) for the depth was less than the table F value at 2 and 4 degree of freedom (6.94) at 5% level, of significance the difference among the means of the depths was statistically insignificant.

Table 4.5. Analysis of Variance of the Average Field Capacities of the motorized weeder in Sandy loam Soil at the Three Moisture Conditions at Differant Speeds and Depths (Completely randomized design).

Sources of Variation	DF	SS	MS	F
Speed	2	0.000024	0.000012	0.86 (n.s)
Depth	2	0.0000503	0.00002515	1.81 (n.s)
Error	4	0.0000557	0.0000139	- -
Total	8	0.0013	-	- -

n.s. = not significant

The first three tables show the capacities of the motorized weeder at three different stages. Stage one was ten days after planting, stage two was eight days later and stage three at 10 days after stage two. The analysis of variance at these three stages is shown in Table 4.6 below.

Table 4.6 Analysis of Variance of the Field Capacities of the motorized weeder in Sandy loam at Different speeds and depths for the three stages of weeding.

Source of Variation	DF	SS	MS	F	
Treatment (Depth	2	1.70×10^{-5}	0.85×10^{-5}	0.236	(n.s)
Error (a)	6	2.17×10^{-4}	0.36×10^{-4}	-	
Stages	2	1.92×10^{-6}	0.96×10^{-6}	0.686	(n.s)
Interaction(Depth and Stages)	4	3.85×10^{-4}	0.96×10^{-4}	68.57	(H.S
Error (b)	12	1.708×10^{-5}	0.14×10^{-5}	-	-
Total	26	6.38×10^{-4}	-	-	-

H.S - Highly Significant

From this table, the calculated F value (0.236) for treatment was less than the table F value at 2 and 6 degree of freedom (5.14) at 5% level of significance, it means, the difference among the means of the treatments (depths) was statistically insignificant. Likewise for stages, as the calculated F value (0.686) was less than the table F value at 2 and 12 degree of freedom (3.88) at 5% level of significance, the difference was insignificant. But for the interaction between treatment and stages the calculated F value (68.57 was greater than the table F value at 4 and 12

degree of freedom at 5 and 1% level of significance, (3,26 and 5,41 respectively). There was no interaction between the treatment and the stages of weeding because F value was highly significant

The least significant difference (LSD) for the treatment, stages and interaction are calculated thus:

$$\text{LSD (treatment} = \text{table t value at 0.05 and x 6 DF} \sqrt{\frac{2\times\text{Error (a) MS}}{9}}$$

$$= 2.447 \times \sqrt{\frac{2\times 0.38\times10^{-4}}{9}} = 6.92\times10^{-3}$$

$$\text{LSD (stages)} = \text{table t value at 0.05 and X 12 DF} \sqrt{\frac{2\times\text{Error(b)MS}}{9}} = 1.22\times10^{-3}$$

$$\text{LSD (interaction)} = = 2.179 \times \sqrt{\frac{2\times 0.14\times10^{-5}}{3}} = 2.11\times10^{-3}$$

When the treatment means were compared using the calculated LSD = 6.92×10^{-3}; it was observed that the difference between means of treatment D2 and D1 was statistically, insignificant with that of treatment D2 higher than treatment D1. So also as that of treatment D1 and D3 but treatment D1 is superior to treatment D3.

When the stages means were also compared using the calculated LSD = 1.22×10^{-3}, it was observed that the difference between stage II and stage I was

Statistically insignificant with that of SII greater than SI. Likewise is that of stage SI and SIII but SI is superior to SIII.

For interaction, the analysis is as follows:

Mean at stages I, II and III

	I	II	III
D1	0.0461	0.0479	0.0423
D2	0.0468	0.0457	0.0514
D3	0.0449	0.0460	0.0405

LSD = 2.11×10^{-3}

Ranking:

D2SIII	D1SII	D2SI	D1SI	D3SII	D2SII	D3SI	D1SIII	D3SIII
0.051	0.048	0.047	0.046	0.046	0.046	0.045	0.042	0.041

a b
c d

Treatment	SI	SII	SIII
D1	0.0461(bc)	0.0479(b)	0.0423(d)
D2	0.0468(bc)	0.0457(c)	0.0574(a)
D3	0.0449(c)	0.0460(bc)	0.0405(d)

Means that are followed by the same letter of ranking (a,b,c---) are not statistically significant when within stage.

At the same level of treatment, it was observed that the stages are different for the three treatments, with stage III superior to all other stages at treatment D2.

At the same stage when the treatment means were

considered it was observed that at stage I, treatments D1, D2 and D3 are statistically at par, but D2 is superior to all other treaments. It was also observed at stage II that treatment D1 was insignificant with that of D3 with D1 superior to D3. Followed by the treatment D2 which was statistically at par with D3 but D3 is superior to D2. At stage III it was observed that treatment D2 was higher than all other treatments but the difference between that of treatment D1 and D3 was statistically insignificant.

4.2.2 Cleanliness of weeding (Weeding Efficiency)

This cleanliness percentage was determined by finding the difference in weed density for each plot before and after weeding and express this as a ratio of the weed density before weeding. The weed density was determined by using 100cm^2 10cmx10cm(0.01m^2) metal frame and counting the weeds within the frame, multiplication of this by 100 gives the density per square metre. The density varied from minimum of 1520 weeds/m^2 to maximum of 2460 weeds/m^2 in the whole experimental plot.

In Table 4.7 the cleanliness percentage of the motorized weeder at 14.3% M.C. is presented which shows a minimum value of 75% at 30mm depth and 400rpm

blade speed and a maximum value of 93% at 30mm depth and 300 rpm blade speed. This gave an average value of 84.5% cleanliness at this moisture content.

Actually, one expected the cleanliness of weeding to increase with depth and speed from theoritical prediction, but because a lot of factors were responsible for the results obtained from the field like variation in weed density, soil surface condition, weed height and so on these made the actual to be different from predicted results.

Table 4.7 Cleanliness % of Motorized Weeder in Sandy loam Soil at 14.3% M.C. dry basis.

	Cleanliness % by Speeds		
Depth	S1	S2	S3
D1	75	78	88
D2	93	83	75
D3	89	95	85

Average value = 84.5%

Table 4.8 below also shows the cleanliness at 11.6% moisture content. The values varied from minimum of 56% at 40mm depth and 350rpm blade speed to a maximum value of 93% at depth of 30mm and blade speed of 350 rpm. The average value for all these was 77%.

Table 4.8 Cleanliness % of Motorized Weeder in Sandy Loam Soil at 11.6% moisture Content dry Basis.

	Cleanliness % by Speeds		
Depth	S1	S2	S3
D1	75	81	83
D2	82	93	88
D3	66	56	75

Average value = 77.0%

At 12.5% moisture conditions, the minimum value of cleanliness percentage occurred at the same depth of operation of 30mm but at different blade speeds. The minimum value of 70% was at 350 rpm while the maximum value was at 400 rpm, and the average value was found to be 81.1%. (Table 4.9).

Table 4.9 Cleanliness % of Motorized Weeder in Sandy Loam Soil at 12.5% M.C Dry Basis.

	Cleanliness % by Speeds		
Depth	S1	S2	S3
D1	73	72	79
D2	85	70	88
D3	79	75	83

Average = 81.1%

Table 4.10 Average Cleanliness % of Motorized Weeder in Sandy Loam Soil at the three Moisture Conditions of 14.3%, 11.6% and 12.5%

	Cleanliness % by Speeds			
Depth	S1	S2	S3	Average
D1	74.3	77.0	83.3	78.2
D2	86.7	82.0	83.7	84.1
D3	76.0	75.3	81.0	77.4
Average	79	78.1	82.7	79.7

When the values obtained from the above moisture conditions were combined to find their averages, the result is presented in Table 4.10. In this table the minimum and maximum value occured at the same speed of 300 rpm but at different depths. The minimum was at depth of 20mm (74.3%) while the maximum value of 86.7% was at depth of 30mm. The average for each depth of operation are also presented and those at each speed of blade. Hence the overall average which is the average cleanliness percentage of the motorized weeder was 79.7%.

Table 4.11 Analysis of Variance of the Average Cleanliness percentage of the Motorized Weeder in Sandy Loam Soil at the three moisture conditions at different Speeds and Depths (Completely randomized design.)

Source of Variation	DF	SS	MS	F	
Speed	2	35.11	17.555	1.838	n.s
Depth	2	80.69	40.345	4.22	n.s
Error	4	38.2	9.55	-	-
Total	8	154.0	-	-	-

In the analysis of variance presented in Table 4.11 above, the calculated F value for speed (1.838) is less than the table F value at 2 and 4 degree of freedom at 5% level of significance (6.94), it means that the different among the means of the speeds is statistically insignificant. Likewise for the depth, as the calculated F value (4.22) is less than the table F value at 2 and 4 degree of freedom for 5% level of significance (6.94), the difference among the means of the depth was statistically insignificant.

Combining these three results which were obtained at three different stages of weeding and at the stated moisture conditions, the analysis of variance of these three stages of weeding is presented in table 4.12, below.

Table 4.12. Analysis of Variance of Cleanliness Percentage of the Motorized Weeder in Sandy Loam Soil at Different Speeds and Depths for the Three Stages of weeding.

Source of Variation	DF	SS	MS	F	
Treatment (depth)	2	372.67	186.33	37.8	H.S
Error (a)	6	29.6	4.93	-	
Stages	2	257.56	128.78	37.8	H.S
Interaction (Stages and Depth)	4	1412.0	353.0	103.7	H.S
Error (b)	12	40.84	3.40	-	
Total	26	2112.67	-	-	

H.S = Highly Significant.

The above table shows that, the calculated F value for depth is 37.8 which is greater than the table F value at 2 and 6 degree of freedom at 5% level of significance (5.14) and even at 1% level of significant (10.92) it means that the difference among the means of the depths was statistically highly significant. The same condition holds for the means of stages and interaction between depth and stages, it means there was no interaction between the stages and the depth of weeding for the cleanliness percentage.

When the least significant different (LSD) was

calculated by using the formula stated in section 4.21 above for treatment, stages and interaction, the following results were obtained:

LSD (treatment = 2.56

LSD (stages) = 1.89

LSD (interaction) = 3.28

Comparing the treatment means using the calculated LSD (2.56), it was observed that treatment D2 was significantly higher than all other treatments, this was followed by treatment D1, which is also superior to treatment D3.

When the stages means were also compared using the calculated LSD value of 1.89, it was observed that stage I was statistically higher than other two stages of weeding, this was followed by stage III which was also higher than the mean at stage II.

For the interaction between the depth of operation the mean at the three stages presented thus:

	I	II	III
D1	80.3d	79.7d	80.3d
D2	83.7c	87.7ab	86.0bc
D3	89.7a	63.7f	77.0e

These three stages are ranked with LSD value of 3.28 as follows:

D2SI	D2SII	D2SIII	D2SI	D1SI	D1SIII	D1SII	D3SIII	D3SII
89.7	87.7	86.0	83.7	80.3	80.3	79.7	77.0	63.7

a_____

b_____

c_____d_____e_____f_____

At the same level of treatment, it was observed that the stages were not different in the case of treatment D1, but stages I and III are superior to stage II. For treatment D2, stages II and III were not different but the mean of stage II was superior to that of stage III. Likewise, the different between stages I and III was not statistically significant with that of stage III superior to stage I. For treatment D3, the difference among the means of the stages was statistically significant with that of stage I superior to all other stages, followed by stage III which was also superior to stage II.

At the same stage, it was observed that there was significant difference between the means at stage I with that of D3 higher than other treatments, followed by treatment D2 which was also superior to D1. At stage II also, there was signigicant difference between the means of the treatment with treatment D2 significantly higher that the other two treatments, this was followed by treatment D1 which was also greater than treatment D3. At stage III, the difference between the means of the

treatments was statistically significant, with that of treatment D2 higher than others, followed by treatment D1.

4.2.3 Effect of Some Environmental Factors and Conditions on the Performance of Motorized Weeder

From tables 4.1, 4.2 and 4.3, the maximum value of average field capacity of 0.0465ha/h occured at 11.6% moisture content, followed by 0.0459ha/h at 14.3% moisture, and the minimum value of the average field capacity of 0.0447 ha/h occured at 12.5% moisture content. From these, one can say that the optimum moisture content to achieve the highest value of field capacity will be at 11.6%, although some other factors may be responsible which will be discussed later. But for cleanliness percentage, the highest value of 84.5% was at 14.3% moisture content, followed by 81.1% at 12.5% moisture content, and the minimum value at 11.6% (77.0%), these are shown in tables 4.7 to 4.9. It can be seen that the highest value of field capacity and the lowest value of cleanliness of weeding percentage occured at the same moisture content of 11.6% but the lowest value of field capacity and the highest value of cleanliness of weeding percentage occured at different moisture conditions of 12.4% and 14.3% respectively.

Considering the values of the average field capacities presented in table 4.4 and the corresponding values for the cleanliness percentage in table 4.10. When these values are plotted against their corresponding values to determine the relationship between the two as shown in fig 4.1, choosing the best line offit which was calculated thus by (least square method):

Table 4.13: Average field capacities and corresponding cleanliness percentages.

Average F.C ha/h	Cleanliness %
0.0452	73
0.0442	85
0.0480	79
0.0441	72
0.0533	70
0.0401	75
0.0470	79
0.0464	88
0.0433	83

$$y = a + bx \quad \text{4.1}$$

$$b = \frac{\sum(x-\bar{x})\,(y-\bar{y})}{\sum(x-\bar{x})^2} \quad \text{4.2}$$

$$a = \bar{y} - bx \quad \text{4.3}$$

$\bar{y} = 79.7\%$, $\bar{x} = 0.0457$ ha/h

$b = -412.53$

$a = 98.55$

hence $y = 98.55 - 412.53x$

Implies $CP = 98.55 - 412.53FC$ 4.4

or $FC = (98.55-CP)/412.53$

where CP = cleanliness percentage

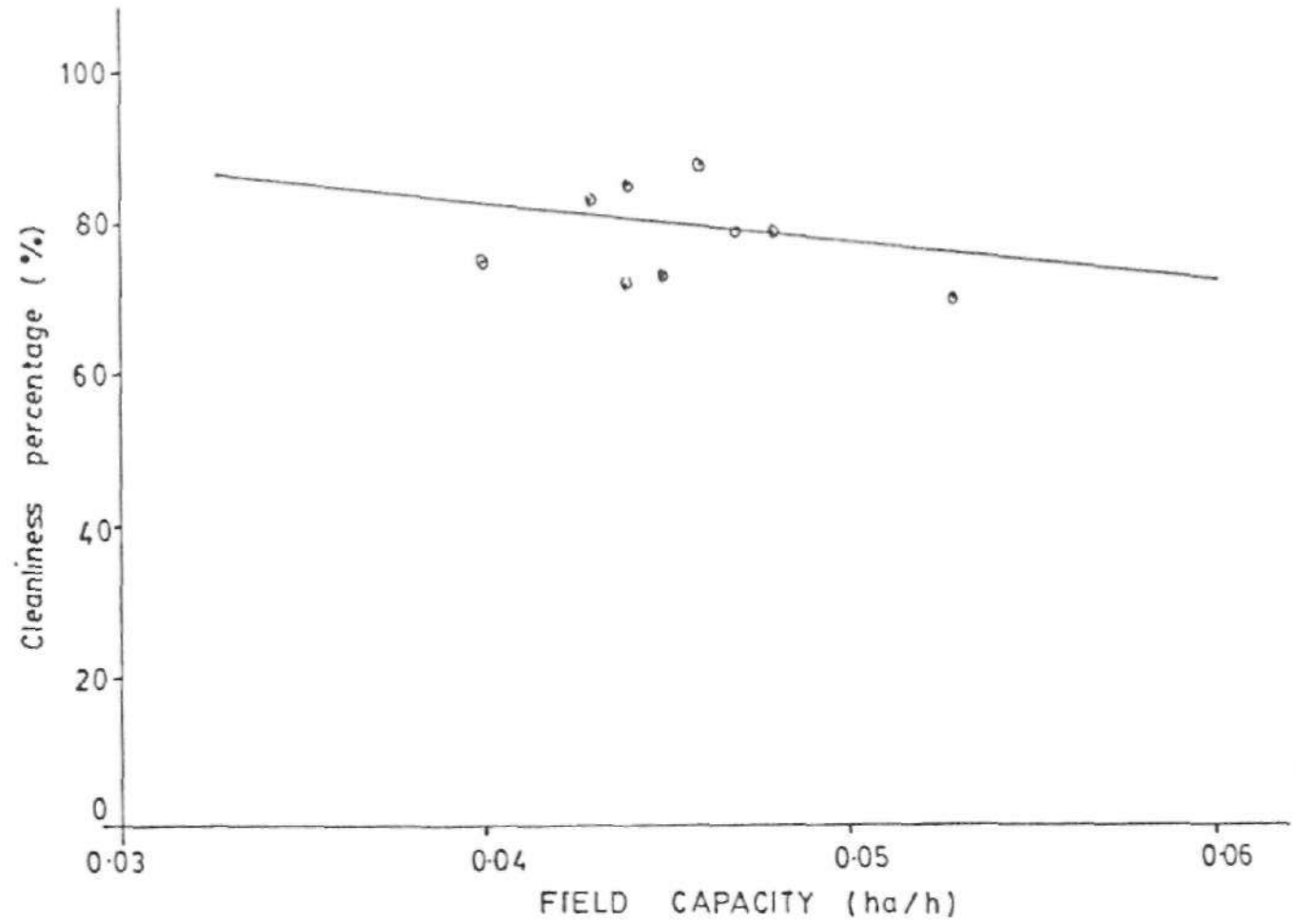


Fig 4.1 Relationship between cleanliness of weeding and field capacity of M.W.

and FC = field capacity (ha/h)

Equation (4.4) expresses the mathematical linear relationship between the cleanliness percentage of weeding and the field capacity of the motorized weeder, this is represented graphically in fig. 4.1.

From Table 4.13, and fig 4.1, it can be deduced that there is an inverse linear relationship between the cleanliness percentage and field capacity: which means as the cleanliness percentage decreases, the field capacity increases for the motorized weeder. This condition holds for the highest value of field capacity of 0.0533ha/h and the lowest value of cleanliness percentage of 70% in table 4.13.

The performance of this weeder is also expected to be affected by the weed height and density, so it will be necessary to discuss the effect of these two conditions on the field capacity and cleanliness percentage of the weeder. The average values of the weed height, densities, field capacities and cleanliness percentage for each plot are presented together in Table 4.14.

Table 4.14 Average field capacities and cleanliness percentage for each plot with their corresponding weed heights and densities at the moisture conditions of 14.3%, 11.6% and 12.5% for each plot.

Weed Height (cm)	Weed density /100cm^2	Field capacity (ha/h)	Cleanliness %
11	16	0.0452	73
8	12	0.0442	85
8	18	0.0480	79
7	20	0.0441	72
10	17	0.0533	70
9	22	0.0401	75
9	24	0.0470	79
10	19	0.0464	88
10	21	0.0433	83
Average 9.11	18.8	0.0457	79.7

(a) Weed Height and Field Capacity

When the values of the weed height are plotted against the field capacity the result obtained is shown in fig 4.2. It will be observed that the points are scattered, this is as a result of the closeness of the values of the weed height to the average value, the variation in between them is not much.

In trying to get the best line using the least square method shown in equations (4.1) to (4.3) above.

Calculation shows that:

$b = 437.66$

and $a = -10.89$

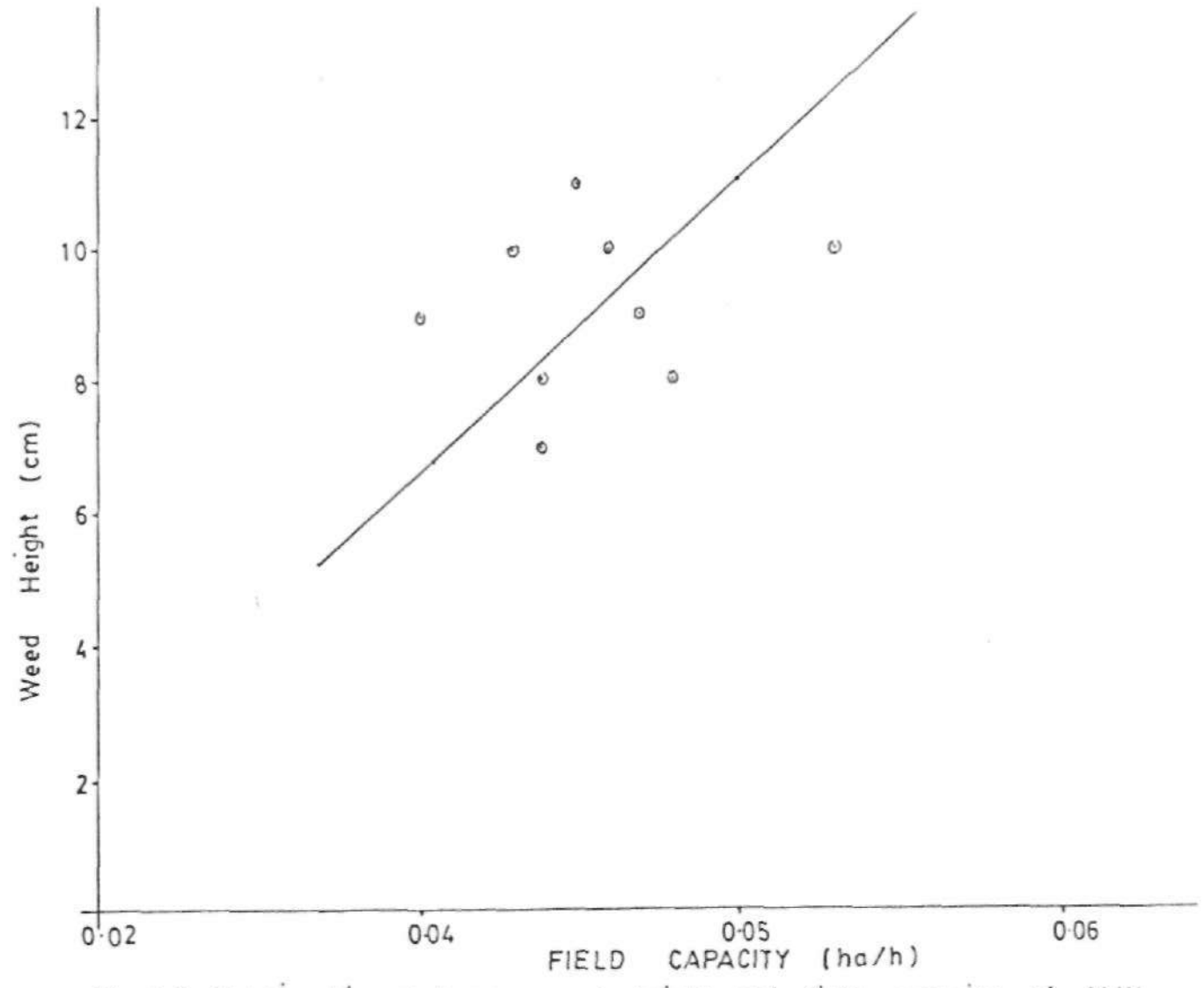


Fig. 4·2 Relationship between weed height and field capacity of M.W.

putting this value in equation 4.1

$$y = 437.66x - 10.89 \quad \text{4.5}$$

but y = weed height (WH)

and X = field capacity (FC)

$$\text{hence FC} = (WH + 10.89)/437.66 \quad \text{4.6}$$

Equation (4.6) shows that the weed height has positive effect on the field capacity of the weeder which may not be true under normal condition, hence this condition may not be general because weed heights of 3cm or 15 to 20cm were not available in the data collected, only the maximum height on each plot were taken. Also the values considered varied between 7cm to 11cm with just a difference of 4cm between the minimum and maximum.

From Table 4.14, the corresponding value of field capacity of 0.0452 ha/h at the maximum weed height of 11cm was not the highest value, also 0.0441 ha/h field capacity value corresponding to minimum value of weed height of 7cm was not the lowest. It can be seen that the maximum field capacity occured at 10cm weed height and the minimum value at 9cm weed height.

(b) Weed Height and Cleanliness Percentage

The plot of weed height against cleanliness percentage is shown in figure 4.3. As in the

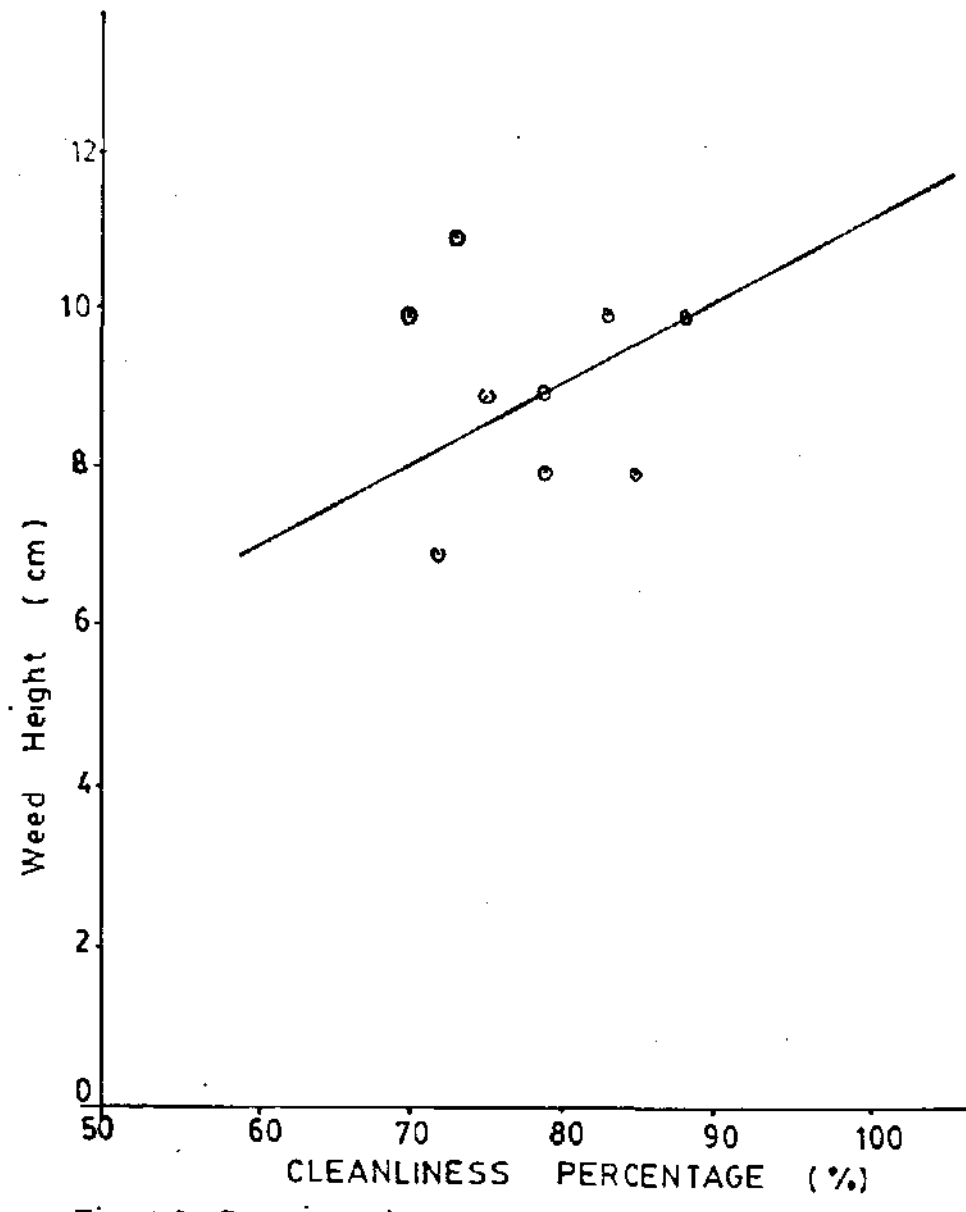


Fig. 4·3 Relationship between weed height and cleanliness percentage of M.W.

case of (a) above, the points are also scattered, because of the values of the weed height considered which are between 7cm and 11cm, they are very close to the average value of 9.11cm.

The best line obtained from least square method from these scattered point also shows that as the weed height increases the cleanliness percentage increases.

With these data.

$b = 0.104$

and $a = 0.85$

hence from $y = a+bx$

$$CP = (WH-0.85)/0.104 \qquad 4.7$$

where CP = cleanliness percentage.

From table 4.14, as stated above, this condition may not be general because the maximum value of cleanliness percentage and the minimum value 88% and 70% respectively occured with the same weed height of 10cm. Other reasons for this are same as those stated in (a) above.

(c) Weed density and field capacity

From fig 4.4 it can be seen that these points that are plotted against each other are scattered. The graph shows that weed density has negative effect on the field capacity of the weeder. From

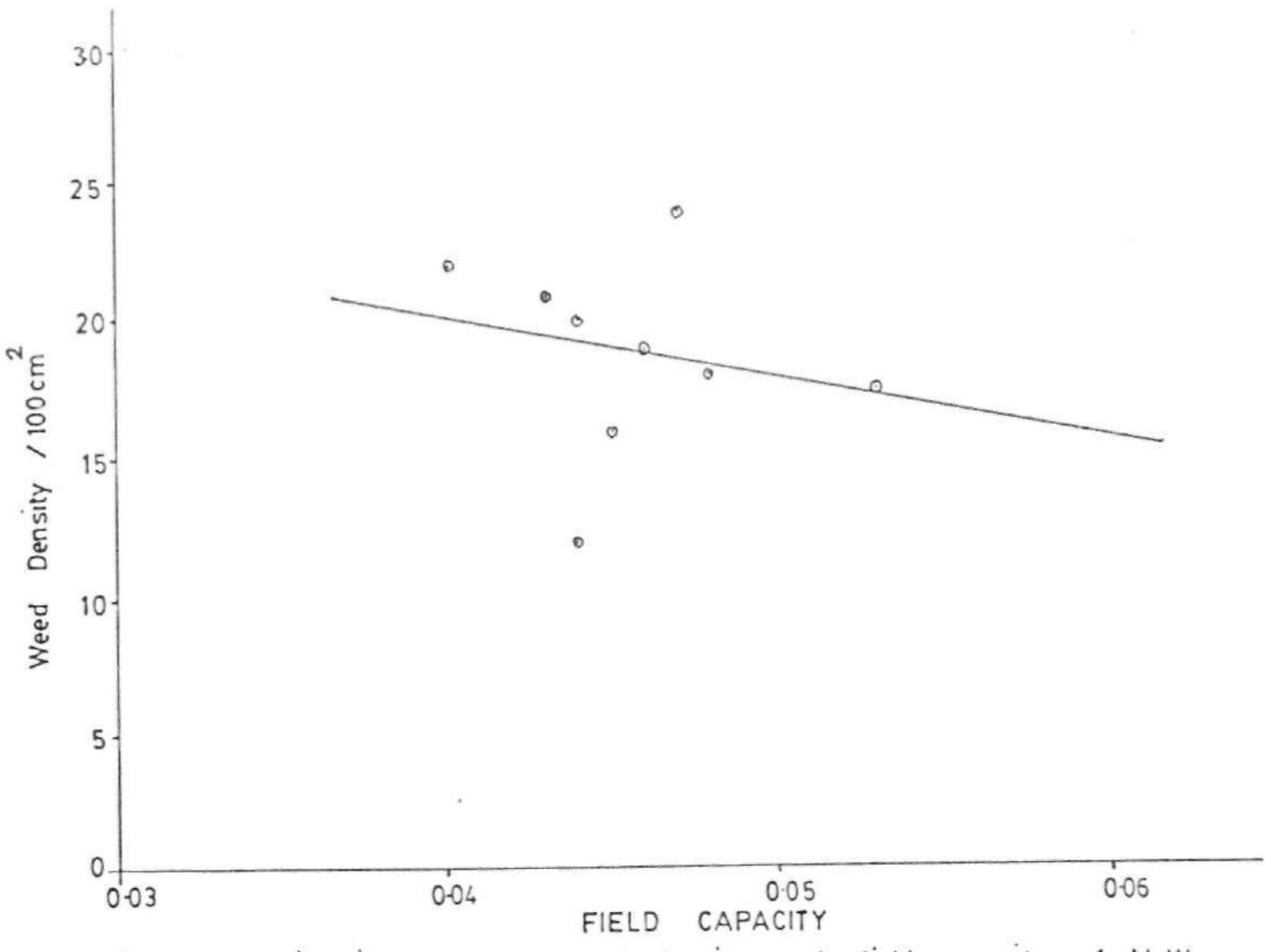


Fig. 4·4 Relationship between weed density and field capacity of M. W.

the best line (using the least square method)

$$b = 206.13$$

and

$$a = 28.22$$

$$FC = (28.22-WD)/206.13$$

$$WD = 28.22 - 206.13FC \quad \text{_____} 4.8$$

where WD = weed density.

Showing that as the weed density decreases, the capacity increases, that is equation (4.8) shows an inverse linear relationship between the weed density and the field capacity of the motorized weeder. Table 4.14 also shows that at high density of 20 weeds/100cm^2 (2000/m^2) and above lower values of field capacities were obtained especially at 2200 weeds/m^2, the lowest value of 0.0401 ha/h of field capacity was obtained.

At lower weed density values of 1200 to 1700 weed s/m^2, higher values of field capacities were obtained also, it was within these values of weed density that the maximum field capacity was obtained.

(d) Weed density and cleanliness percentage

Like in other analysed results above, scattered values were obtained when the weed density was plotted against cleanliness percentage (fig 4.5). The best line of it from these points gave rise to the following equation.

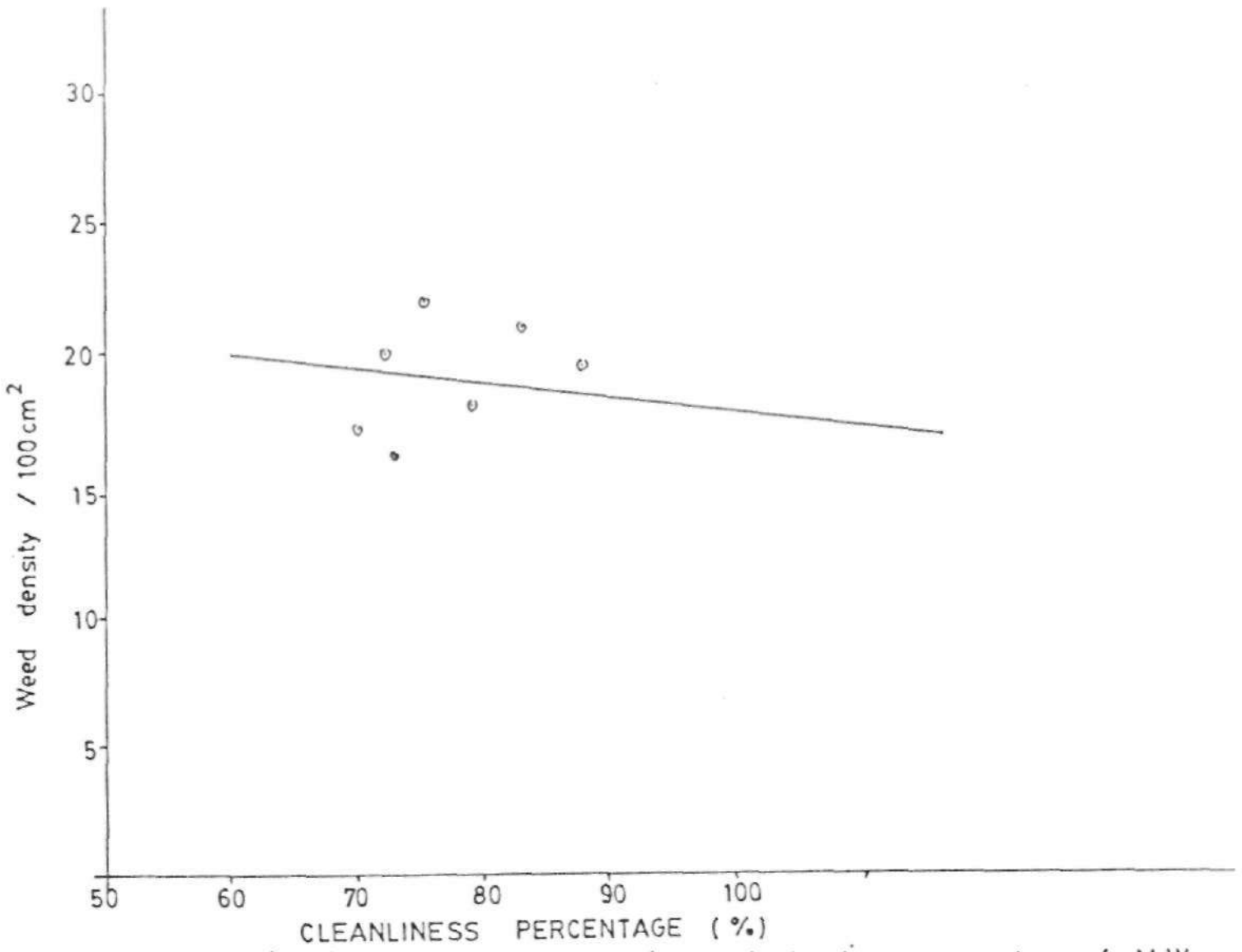


Fig. 4·5 Relationship between weed density and cleanliness percentage of M.W.

$$b = -0.057$$

$$a = 23.36$$

hence $$CP = (23.36-WD)/0.057 \quad \text{4.9.}$$

This equation (4.9) also shows an inverse linear relationship between the weed density and the cleanliness percentage, which means as the density increases, the cleanliness percentage decreases. The result shown in table 4.14 also confirms this, when the density are less than 2000 weed s/m^2 higher value of 85% and aboves were obtained. Also with high density value of above 2200 weeds/m^2, lower values of cleanliness percentage were obtained, as low as 75%.

From the above, it can be seen that the performance of this motorized weeder is not limited to the effect of speed of the blades and depth of operation alone. Other factors are the moisture condition, weed density, weed height and weed type, soil surface condition, that is eveness of the soil surface. This greatly affected the performance especially during the first time of weeding. There were only two major types of weeds on the experimental plot and both of them are grass. It is expected that if the weeder is tested on another type of weed that is not grassy, there is tendency for a better performance to be achieved.

In conslusion, the average field capacity of the motorized weeder was 0.0457ha/h and average cleanliness percentage was also 79.7%. Results also showed that the operation forward speed of the weeder varied from minimum of 0.22m/s to a maximum of 0.26m/s. The rotational speed of the blades and the depth of cut were found to have effect on the performance of this weeder. Other factors include weed density, soil surface conditions and so on. There was a significant difference between the interaction of stages and depth of operation. Average field capacity was 81.4% of the calculated theoritical field capacity, hence the efficiency of operation was 81.4%.

4.3 Wheeled Long Handle weeding Hoe (WLHH)

For this weeding hoe, three blocks were used and two operators, this was done for three stages of weeding as in the motorized weeder discussed above.

4.3.1 Field Capacity of the Hoe- The results obtained for the three stages of weeding, at 14.3%, 11.6%, and 12.5% moisture for the three blocks and two operators are presented in table 4.15 to 4.17.

Table 4.15 Field capacity of WLHH in sandy loam soil at 14.3% moisture content.

Block	Field Capacity (ha/h) by operators OP1	OP2
I	0.0043	0.00389
II	0.0040	0.00378
III	0.0041	0.00902

OP1 = Operator 1

OP2 = Operator 2

Table 4.16 Field Capacity of WLHH in Sandy Loam Soil at 11.6% moisture content.

Block	Field Capacity (ha/h) by Operators OP1	Op2
I	0.0036	0.0039
II	0.0042	0.0036
III	0.0040	0.0043

Table 4.17 Field Capacity of WLHH in Sandy Loam Soil at 12.5% moisture content

Block	Field Capacity (ha/h) by Operators Op1	Op2
I	0.0041	0.0036
II	0.00371	0.0041
III	0.00385	0.0039

At 14.3% moisture content (Table 4.15), the highest value of 0.0043ha/h was achieved by operator 1 at block 1 and the lowest value of 0.00378ha/h was at block 2 and by operator 2. For the second stage of weeding at 11.6% moisture content the highest value of capacity of 0.0042 ha/h was by operator 2 and at block 2 while the minimum field capacity of 0.0036 ha/h was by both operators, the first operator at block 1 while the second operator was at block 2 (Table 4.16). The reverse of this is the case for the third stage of weeding at 12.5% moisture content, (Table 4.17). At this stage the maximum capacity of 0.0041 ha/h was achieved by the two operators but at different blocks. The first operator was at block 1 while the second was at block 2, the minimum value of 0.0036 ha/h was by operator 2, and at block 1 of the field.

From the above it could be seen that maximum capacity was 0.0043ha/h and it occured with operator 1 and at block 1 and during the first stage of weeding at 14.3% moisture content. The minimum value of 0.0036ha/h occured with the two operators at different blocks, for the remaining two stages of weeding.

When these values from the three stages of weeding were combined and the average found the various values

of field capacities obtained are presented in Table 4.18 below.

Table 4.18 The average field capacity of WLHH on sandy loam soil at the three moisture conditions of 14.3%,11.6% and 12.5%.

	Field capacity ha/h by operator	
Block	Op1	OP2
I	0.0040	0.00379
II	0.00397	0.00383
III	0.00398	0.00407
Average	0.00398	0.00390

The average value for the two operators

= 0.00394 ha/h

From Table 4.18 above, the maximum average field capacity value occured at block 3 (0.00407 ha/ha) with operator 2 and the minimum average field capacity value but at block 1. The average field capacities of operators 1 and 2 were 0.00398 ha/h and 0.00390ha/h respectively, giving an overall average field capacity of 0.00394 ha/h for this WLHH.

In the analysis of variance for the average field capacity (Table 4.19), the calculated F value for the block (1.01) was less than the table F value at 2 and 2 degree of freedom at 5% level of significance (19.00) it means the difference among the means of the block was statistically insignificant. Likewise for the

operators as the calculated F value (1.12) was less that the table F value at 1 and 2 degree of freedom at 5% level of significance (19.51), the difference between the means of the field capacity of the operators was statistically insignificant.

Table 4.19 Analysis of Variance of the Average field capacities of WLHH in sandy loam soil at the three moisture conditions at different blocks and with 2 operators.

Source of Variation	DF	SS	MS	F
Block	2	2.33×10^{-8}	1.165×10^{-8}	1.01 n.s
Operator	1	1.287×10^{-8}	1.287×10^{-8}	1.12 n.s
Error	2	2.303×10^{-8}	1.15×10^{-8}	- -
Total	5	2.92×10^{-8}	-	- -

4.3.2 Cleanliness Percentage of WLHH- For the three stages at three moisture conditions considered, the cleanliness percentages for this weeding hoe are presented in Tables 4.20, 4.21 and 4.22, below.

Table 4.20 Cleanliness percentage of WLHH at 14.3% moisture content in sandy loam soil.

Block	Cleanliness % by Operators OP1	OP2
I	88.0	87.0
II	87.5	83.3
III	90.0	92.8

Table 4.21 Cleanliness percentage of the WLHH in Sandy Loam Soil at 11.6% Moisture content

Block	Cleanliness % by Operator Op1	OP2
I	90	84.5
II	88	87.8
III	93	87.0

Table 4.22 Cleanliness Percentage of the WLHH in Sandy Loam Soil at 12.5% Moisture Content

Block	Cleanliness % by Operator OP1	OP2
I	83	90
II	82	85
III	89	86

From Table 4.20, both maximum value and minimum value of cleanliness percentage were achieved by the second operator, the maximum value of 92.8% was at

Block III while minimum value of 87% was at Block I.

From the second stage of weeding at 11.6% moisture content (Table 4.21), the maximum cleanliness percentage value of 93% was by the first operator and at block 3 while operator 2 achieved the minimum value of 84% at block 1 of the field. 90% was the maximum moisture content by operator 2 at block 1 and operator 1 at block 2 respectively (Table 4.22).

Table 4.23 also presents the average values of the cleanliness percentage for the three stages.

Table 4.23 Average cleanliness Percentage of WLHH in Sandy Loam Soil at the three moisture conditions of 14.3%, 11.6% and 12.5%

Cleanliness % by Operators

Block	OP1	OP2
I	87.0	87.0
II	89.5	85.4
III	90.7	88.6
Average	89.1	87.0

Overall average for both operators = 88.05%

From the above table, the minimum value was 85.4% and the maximum was 90.7% which occured at Block 2 and with operator 2 and Block 3 with operator 1

respectively, giving an average value of 88.05%.

Table 4.24 Analysis of variance of the cleanliness percentage of the WLHH in sandy loam soil at the three soil moisture conditions of 14.3%, 11.6% and 12.5%.

Source of Variation	DF	SS	MS	F	
Block	2	8.05	4.025	1.92	n.s
Operator	1	6.41	6.41	3.05	n.s
Error	2	4.197	2.099	-	-
Total	5	18.66	-	-	-

In the analysis of variance shown in Table 4.24 above, the calculated F value for the block (1.92) is less than the table F value at 2 and 2 degree of freedom at 5% level of significance (19.00), it shows that the difference among the cleanliness means of the blocks was statistically insignificant. Also for the operators as the calculated F value (3.05) is less than the table F value at 1 and 2 degree of freedom at 5% level of significance (18.51), the difference between the cleanliness means of the operators was statistically insignificant.

In conclusion, the average field capacity of the wheeled long handle how (WLHH) was 0.00394ha/h and the average cleanliness percentage of weeding was also 88.05%. There was insignificant difference

between the blocks used and operators for both the field capacity and cleanliness percentage.

4.4 Comparison of the Performances

When comparison was to be made between the two developed weeders (MW and WLHH), three blocks were laid out, one for MW, one for WLHH and the last block was for manual short handle hoe (MSHH) as control. Depth used for MW was 40mm and the blade speed was 400rpm. Two operators were used for each weeder and the results obtained are presented in Tables 4.25 to 4.30 below, weeding was done at three different stages.

Table 4.25 Average Field capacity of MW at three stages in sandy loam soil.

	Field Capacity (ha/h) by operators	
Stages	OP1	OP2
I	0.0504	0.0505
II	0.0520	0.0480
III	0.0576	0.0511
Average	0.0534	0.0499

Table 4.26 Average cleanliness percentage of MW in sandy loam soil at three stages.

Stages	Cleanliness percentage (%) by operators OP1	OP2
I	83	85
II	88	81
III	85	89
Average	85.3	85.0

Table 4.27 Average of WLHH in sandy loam soil at three stages

Stages	Field capacity (ha/h) by Operators OP1	OP2
I	0.0042	0.0039
II	0.0041	0.00393
III	0.00388	0.00390
Average	0.00406	0.00391

Table 4.28 Average cleanliness percentage of WLHH in sandy loam soil at three stages.

Stages	Cleanliness percentage (%) by operators OP1	OP2
I	88.5	87.7
II	90.3	86.3
III	84.7	87.0
Average	87.8	87.0

Table 4.29 Average capacity of MSHH in sandy loam soil at three stages.

Stages	Field capacity (ha/h) by Operators OP1	OP2
I	0.0038	0.0039
II	0.00375	0.0041
III	0.0036	0.0038
Average	0.00372	0.00393

Table 4.30 Average cleanliness percentage of MSHH in sandy loam soil at three stages

Stages	Cleanliness percentage (%) by Operators OP1	OP2
I	92.0	95.0
II	98.0	93.0
III	93.0	97.0
Average	94.3	95.0

From the above tables, the average field capacities for the three weeders, MW, WLHH and MSHH were found to be 0.0517 ha/h 0.00399 ha/h and 0.00383 ha/h respectively. Likewise the cleanliness percentage were 85.2%, 87.4% and 94.7% respectively for MW, WLHH and MSHH. From these results, the average capacity of the MW was about 13 times grater than that of WLHH, but the cleanliness percentages of the WLHH was better than that of MW (2.6% higher).

These average values for the two weeders and MSHH collectively presented in tables 4.31 and 4.32 below.

Table 4.31 Average field capacity (ha/h) values for the three weeders at the three stages.

	Stages		
Weeder	I	II	II
MW	0.05045	0.050	0.0544
WLHH	0.00405	0.00402	0.00389
MSHH	0.00385	0.00393	0.0037

Table 4.32 Average cleanliness percentage (%) values for the three weeders at the three stages

	Stages		
Weeder	I	II	II
MW	84.0	84.5	87.0
WLHH	88.1	88.3	85.85
MSHH	93.5	93.5	95.0

When the analysis of variance of the field capacity for the weeders was calculated the variance ratio value for the weeder was 842.59 and this shows that the difference among the field capacities of the weeders was highly significant with that of MW superior to other weeding tools.

Also for the cleanliness percentage the difference among the weeders, cleanliness percentage was significant but not as high as that in field capacity

with the cleanliness of MSHH superior to the other mechanical weeders. These are presented in tables 4.33 and 4.34 below.

Table 4.33 Analysis of Variance of the field Capacity of the three weeders at three different stages.

Source of Variance	DF	SS	MS	F	
Weeder	2	0.00455	0.002275	842.59	H.S.
Stages	2	0.000052	0.0000026	0.96	n.s
Error	4	0.0000108	0.0000027	-	-
Total	8	0.004566	-	-	-

Table 4.34 Analysis of variance of the cleanliness percentage of the three weeders at three different stages.

Source	DF	SS	MS	F	
Weeder	2	147.88	73.94	30.71	H.S
Stages	2	1.398	0.699	0.29	H.S
Error	4	9.6325	2.408	-	
Total	8	158.91	-	-	

The comparison of the developed weeders was limited to capacity and cleanliness alone because those were the two areas of interest in this research work and also they were the two common factors to the developed mechanical weeders. Other results obtained from the study have already been discussed in chapter 3 because they were based on the analysis of designs.

The above results analysed in this chapter were based only on the data collected on the field during the testing of the machines.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Mechanical method of weed control in Nigeria is yet to receive a higher priority, millions of Nigeria farmers still use the conventional method of hoe weeding, because chemical method which has been an alternative has now gone beyond the reach of peasant farmers which form the majority in food production. Hence simple mechanical weeding tools need to be developed and improved upon for higher efficiency and better weed control.

The development of these two simple mechanical weeders forms a partial contribution in the solution to the weeding problems faced by our farmers.

The motorized weeder which was designed to work to a maximum width of 550mm, on flat agricultural land and to utilized 3.75kw petrol engine as source of power for weeding could weed to a maximum depth of 40mm has been found to be very efficient with an average capacity of 0.0459 ha/h when tested alone under different speeds and depths of weeding and 0.0517 ha/h for another test in comparing its performance with the WLHH when weeding to depth of 4cm and blade of 400rpm. The cleanliness percentage average for weeding

was about 85% during the tests.

The wheeled long handle weeding hoe which was designed to reduce the amount of force needed for weeding and eliminate bending was also found to give an average capacity of 0.00394ha/h and average cleanliness percentage of about 88.0%. The amount of effort rquired at rake angle of 30^{0} and depth of 40mm was about 20N. This WLHH can be used both on flat land and on ridges but care must be taken when working on ridges. Some reasons beyond control could not make it possible for it to be tested on ridges.

The choice of the weeder to use among these two weeders will depend on individual, the type of crop, land condition, availability of power required and so on. Much work is still expected to be done as given below.

5.2 Recommendations

The following recommendations are however suggested for further studies.

Further tests to be carried out within different arable crops and different types of weed.

Change some parts of the machine like the guide, wheels or replace them with a more durable components.

Modify the motorized weeder to weeding within ridges.

Provide effective total coverage for the blades of MW, so that they will not be cutting the leaves of growing crops when weeding.

The wheeled long handle weeding hoe can be improved by increasing the wheel to two and make the position along the handle variable.

The blade of the WLHH can be replaced with some other weeding attachments.

Further test should also be carried out to determine its energy requirements, effect on spinal cord muscle and so on.

To enhance efficient and through tests of further developed or improved machines of these types, construction work should be carried out and should be completed before the beginning of planting season (between October and April of the following year). Small and well prepared field should be provided for trial tests which should be very close to the workshop. Field for experimental tests should be prepared on time and planting done accordingly. And most importantly, a standby petrol engine for the machine should be made available that can be used anytime without problem in collection.

REFERENCES

Abom, T. B. (1989) "Fabrication of manual Inter-row weeder". Unpublished Higher Diploma project report, A.B.U. Zaria.

Adelusi M. (1990) "Fabrication of Three furrow Tractor mounted weeder" Unpublished HND project report, A.B.U. Zaria.

Adejonwo, K.O. Ahmed, M.K Lagoke, S.T.O and S.K. Karidari (1986) "Chemical weed control in irrigated okra (Abelmos - chus esculentus (L) Monench)". Paper presented at the 16th Annual Conference, Nigerian Society for plant protection, A.B.U., Zaria March, 1986.

Adigun, J.A and S.T.O Lagoke (1986) "An evaluation of herbicides for weed control in irrigated sweet papper (Capsium annum L.)". Paper presented at the Ann. Conf. Nigerian Society for plant protection, A.B.U., Zaria March, 1986.

Agricultural Machinery management data. Agricultural Engineers Yearbook. 1980 PP. 245-247. ASAE, St. Joseph, Mich.

Akobundu, O (1981) Weed interference and contrcl in white yam (Dioscorea rotundata poot). Weed Res. 21: 267-276.

Anonymous, (1975) "Agricultural Machinery Development program". Terminal report for USAID/IRRI projects No Csd - 834 and Csd - 2541.

Anonymous (1990). National Centre for Agricultural Mechanization (NCAM pamphlet on their developed low - cost Farm equipment Technologies.

Choudhary, A.A., S.T.O. Lagoke and D.J. Charidra Singh (1986). "Control of Rothboellia Cochin clinensis, in groundnut (Arachis hypogea 1) in the Northern guinear savanna." Paper presented at the 16th Annual Conference of Nigerian Society of plant Protection A.B.U., Zaria. March 1986.

Deutsch, A. (1972) "New weed control equipment and techniques". Agricultural Mechanization in Asia. Vol. 3 No 2.

Ducker, H.C. and Hoyle S.T. (1974) "Some studies in cultivation practices, food crops and the maintenance of fertility in Nyasaland". East Africa Agricultural Journal No 13 PP. 107 - 113.

Enyinnia, T, R.P.A. Unamma and D. Nottidge (1986a) "Weed competition effects on the yield of Dioslorea rotundata pour in yam/maize/cassava intercrop combination." Paper presented at the 14th annual conference of weed scheme society of Nigeria University of Nigeria, Nsukka, December 1-3, 1986

Enyinnia, T, R.P.A Unamma and D. Nottidge (1986b) "Effects of different periods of weed competition on the tuber yield of cassava in a yam/maize/cassava intercrop." Paper presented at the 14th annual conference of Weed Screne society of Nigeria, University of Nigeria, Nsukka, December 1-3 1986.

Grist, D.H. (1975) "Rice" Longman Group Limited, London, PP. 177-94.

Gwani, E.S. (1988) "Animal Power for agricultural production in Nigeria." Animal Traction for Agricultural Development Proceedings of the Third Workshop of the West Africa Animal Traction Network held 7th-12th July, 1988, Saly Senegal.

Helgenson, E.A. (1957) "Methods of Weed Control" Food and Agricultural Organisation of the United Nations PP. 199.

Hettiarach, D.R.P. and Reece. A.R (1974) "The calculation of passive soil resistance." Geotechnique vol 24 No 3 PP. 289-310.

Ivy, H.W and Baker, R.S (1972) "Pricky sida competition and control in cotton. Weed Science vol 20 PP 187-139.

Jadhav, R.D and P.A Turbatmath (1991) "Development and performance evaluation of Bullock-drawn multipurpose Hoe "A.M.A Vol. 22 No 2 Spring PP 9-14.

John, L.H (1970) "Effect of weed competition depoliation and time of harvest on soyabeans." Experimental Agriculture vol. 8 pp 333.

Kasasian, L and J and J Seeyare (1968). "Critical periods for weed competition." PANS 15: 208-212.

Kepner, R.A., R. R. Bainer and E.L. Barger (1975) "Principles of Ferm Machinery." AVI publishing Company, Inc. Second Edition pp 277-234.

Kaul, R.N (1990) "Understanding crop protection Equipment from basic functional principles." Introduction to crop protection machinery ABUCONS (Nig.) Ltd Book Series No. 1 page 1.

Lagoke, S.T.O. Choudhary A.H. and Tanko Y.M (1981) "weed control in rainfall groundnut (Arachis hypogea L) in the Guinea Savanna zone of Nigeria. Weed Research vol 21 pp 119-125

Maiye, A. (1989) "Fabrication of low-profile inter-row weeder (tractor mounted) Unpublished HND report, A.B.U. Zaria.

Md. Syedul Islam and Khordaker Azharul Hq (1991) "Development of a low-cost weeder for lowland paddy." AMA. vol 22 No. 1 1991. pp 45-48.

Moody, K (1973) "Weed Control in Upland rice" Proceedings Weed Science Society of Nigeria Conference. July 9-14, 1973 Samaru. Nigeria.

Moody, K (1975) "Weed Control in Legumes" Unpublished mimeo, I.I.T.A Ibadan. Nigeria.

Nieto, J. M.A. Brando and J.T. Gonzaba (1968) "Critical periods of the crop growth cycle for competition for weeds PANS(c) 14: 139-166.

Ojuederic, B.M (1979) "The significance of weeds in oil palm plantations in Nigeria" Proceedings 9th Annual Conference: Weed Science society of Nigeria pp 7-12, 1979.

Okafor, L.I. and S.K. DeDalta (1976) "Competition between upland rice and perennial nutsedge for nitrogen, moisture and light." Weed Science 24: 43-46.

Okafor, L.I. (1987b) "Competition between weeds and irrigated wheat in the Nigerian Sahel Zone". Tropical pest management vol 33 No 1 pp 18-24.

Okafor, L.I (1987c) "Weed Control and the Nigerian Economy". Paper presented at the 15th Annual Conference of the weed science Society of Nigeria, Abubakar Tafawa Balewa College, A.B.U. Bauchi - Nigeria Nov. 29-Dec. 3 1982.

Onochie, B.E (1974). Critical period for weed control in yam plots. Nigerian Agric. Journal, 11:13-16.

Oni, K.C. (1991) "Performance Analysis of Ridge profile Rotary weeders" AMA vol 21 No 1 1990 pp 43-48

Phillips, T.A. (1977) An Agricultural Notebook (with Special reference to Nigeria)" Metric Edition. London Longman Group Ltd vi pp 312.

Shebayan, J.A.Y and S.T.O. Lagoke (1987) "Weed Control in Cowpea (Vigna unguiculata (L) Walp) var Achishuru at Samaru Zaria." Paper presented at the 15th Annual Conference of Weed Science Society of Nigeria at Abubakar Tafawa Balewa College A.B.U. Bauchi Nov 29-Dec 3 1987.

Stone, A.A. and Gulvin H.E (1977) "Machines for Power Farming" John Wiley and Sons. New York Third Edition pp 22 220-222: 323-327

Upadhyay, U.C and Kabe M.K. (1977) Indian Journal of Agronomy vol 22 pp 133 and 134.

Ututu, S.N (1984) "Critical Period of Weed Interference in oil palm seedlings". Nigeria Institute for oil palm research in House Reviieu pp 11-14 June, 1984

Webster, C.C and P.N. Nilson (1966) "Agricultural in the Tropics". Longman, Green and Company Ltd pp 145 and 146