"DEVELOPMENT AND PERFORMANCE EVALUATION OF MANUALLY OPERATED WHOLE STALK SORGHUM UPROOTER "

Thesis
submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI - 413 722, DIST. AHMEDNAGAR, MAHARASHTRA, INDIA

by

Mahale Hemant Trambak

(Regn.No. 2009/16)

In partial fulfillment of the requirements for the degree of

MASTER OF TECHNOLOGY

(AGRICULTURAL ENGINEERING)

in

FARM MACHINERY AND POWER

DEPARTMENT OF FARM MACHINERY AND POWER
DR ANNASAHEB SHINDE COLLEGE OF AGRICULTURAL ENGINEERING,
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI – 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA, INDIA.
MAY, 2013

"DEVELOPMENT AND PERFORMANCE EVALUATION OF MANUALLY OPERATED WHOLE STALK SORGHUM UPROOTER"

Thesis
Submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH,RAHURI – 413 722,
DIST. AHMEDNAGAR, MAHARASHTRA, INDIA

In partial fulfillment of the requirements for the degree of

MASTER OF TECHNOLOGY
(AGRICULTURAL ENGINEERING)
in
Farm Machinery and Power
by

Mahale Hemant Trambak

B. Tech. (Agril. Engg.)
is Approved

Prof. S. M. Nalawade
(Chairman and Research Guide)

Prof. A. B. Lende
(Committee Member)

Dr. P. A. Turbatmath
(Committee Member)

Prof. P. B. Kadam
(Committee Member)

Prof. P.T. Kolekar
(Committee Member)

DEPARTMENT OF FARM MACHINERY AND POWER
DR ANNASAHEB SHINDE COLLEGE OF AGRICULTURAL ENGINEERING,
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA, INDIA.
May,2013

CANDIDATE'S DECLARATION

I hereby declare that this thesis entitled **"DEVELOPMENT AND PERFORMANCE EVALUATION OF MANUALLY OPERATED WHOLE STALK SORGHUM UPROOTER"** or any part thereof has not been previously submitted by me or any other person to any other University or Institute for a degree or diploma.

Place: M.P.K.V., Rahuri. **Mahale Hemant Trambak**

Date: / /2013 (Reg. No. 09/16)

Prof . S. M. Nalawade
Research Guide and Associate Professor,
Department of Farm Machinery and Power,
Faculty of Agricultural Engineering,
Mahatma Phule Krishi Vidyapeeth,
Rahuri – 413722.

CERTIFICATE

This is to certify that the thesis entitled, “**DEVELOPMENT AND PERFORMANCE EVALUATION OF MANUALLY OPERATED WHOLE STALK SORGHUM UPROOTER**” submitted to the Faculty of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, District- Ahmednagar, Maharashtra State, in partial fulfillment of the requirement for the degree of **MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)** in **FARM MACHINERY AND POWER,** embodies the results of a piece of bonafide research work carried out by **Shri. Mahale Hemant Trambak** *(Reg. No.09/16)*, under my guidance and supervision. The results embodied in this thesis have not been submitted to any other University or Institute, for the award of any Degree or Diploma.

The assistance and the help received during the course of this investigation have been acknowledged.

Place: M.P.K.V. Rahuri. **(S. M. Nalawade)**

Date: / /2013

Dr. P. A. Turbatmath
Head,
Department of Farm Machinery and Power,
Faculty of Agricultural Engineering,
Mahatma Phule Krishi Vidyapeeth,
Rahuri- 413722.

CERTIFICATE

This is to certify that the thesis entitled, "**DEVELOPMENT AND PERFORMANCE EVALUATION OF MANUALLY OPERATED WHOLE STALK SORGHUM UPROOTER**" submitted to the faculty of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist - Ahmednagar, Maharashtra State, in partial fulfillment of the requirement for the degree of **MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)** in **FARM MACHINERY AND POWER,** embodies the results of a piece of bonafide research work carried out by **Shri. Mahale Hemant Trambak** *(Reg. No. 09/16)*, under the guidance and supervision of **Prof. S. M. Nalawade**, Associate Professor, Department of Farm Machinery and Power, Mahatma Phule Krishi Vidyapeeth, Rahuri and that no part of the thesis has been submitted to any other University or Institute for the award of any Degree or Diploma.

The assistance and the help received during the course of this investigation have been acknowledged.

Place: M.P.K.V. Rahuri

Date: / /2013

(P. A. Turbatmath)
Head,
Dept. of farm machinery and power,
Dr. A.S.College of Agril. Engg.
MPKV, Rahuri

Dr. P. A. Turbatmath
Dean,
Faculty of Agricultural Engineering,
Mahatma Phule Krishi Vidyapeeth,
Rahuri- 413722

CERTIFICATE

This is to certify that the thesis entitled, "**DEVELOPMENT AND PERFORMANCE EVALUATION OF MANUALLY OPERATED WHOLE STALK SORGHUM UPROOTER**" submitted to the faculty of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist-Ahmednagar, Maharashtra state, in partial fulfillment of the requirement for the degree of **MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)** in **FARM MACHINERY AND POWER,** embodies the results of a piece of bonafide research work carried out by **Shri.Mahale Heamnt Trambak** *(Reg. No. 09/16)* under the guidance and supervision of **Prof. S. M. Nalawade**, Associate Professor, Department of Farm Machinery and Power , Mahatma Phule Krishi Vidyapeeth, Rahuri and that no part of the thesis has been submitted to any other University or Institute for the award of any Degree or Diploma.

The assistance and the help received during the course of this investigation have been acknowledged.

Place: M.P.K.V. Rahuri

(P. A. Turbatmath)
Dean,
Faculty of Agricultural Engineering,
MPKV,Rahuri.

Date: / /2013

ACKNOWLEDGEMENTS

Emotions can`t be adequately expressed in words hence my acknowledgment is much more than what I am expressing here.

This memorable occasion provides me unique privilege to express my deep of gratitude and indebtedness to Prof. S. M. Nalawade, Assoc. Professor, Department of Farm Machinery and Power, Dr. Annasaheb Shinde College of Agricultural Engineering, M.P.K.V., Rahuri. Research Guide and Chairman of advisory committee for his valuable guidance, talented and candid suggestion, constant inspiration, keen interest and encouragement, right from the selection of my research problem up to the final shaping of thesis in the present form as well as for his keen interest in the preparation of this manuscript.

I express my sincere gratitude to Dr P.A. Turbatmath, Associate Dean , Dr. Annasaheb Shinde College of Agricultural Engineering, M.P.K.V., Rahuri, Head and advisory committee member, Department of Farm Machinery and Power for making available all necessary facilities for completion of this work and his useful suggestions and encouragements in accomplishment of this project.

I also wish to express my profound sense of gratitude towards Prof. L. V. Gharate, Ex.Head, Department of Farm Machinery and Power. Prof. A.B. Lende, Ex.Head, Department of Farm Machinery and Power and members of my advisory committee for his encouragement and valuable guidance, Prof. P. B. Kadam, Assit Professor, Department of Farm Machinery and Power, for immediate technical assistant throughout the investigation. I am also thankful to Prof. P. T. Kolekar for providing timely help and cooperation throughout my field trial.

I am also very much thankful to Prof. S.V. Rane, Prof. V. D. Deshmukh, Dr. V. R. Shelar, Prof. Gadakh, Prof. B.P. Bhosale, Mr. R.V. Sanglikar for their valuable guidance, timely help and suggestions during the study.

I also extende my thanks to Mr, D. P. Gaikwad, Mr. P.P.Kale, Mr. B.D. Pahadi, Mr.O.V. Suryawanshi, Mr.P.S. Borde, Mr.Yogesh Jadhav, Mr.Santosh Manglekar, Mr.S.R. Narote, Mr.B.V. Pawar for their help in the fabrication of the prototype and *conducting trials and evaluation of the machine. I am thankful to Mr. S. B. Kalamkar, Sr. Mechanic and Mrs. Y. K. Zagade for timely assistance and co-operation.*

I am greatly indebted to Mr. N.K. Kale for providing timely help and cooperation throughout my M. Tech programme.

It is very hard to express thanks to my friends Vikarm, Deepak, Kiran, Ganesh, Samsher, Santosh, Yogesh, Vijaykant, Devendra, Girish, Anand, Pradip, and all my seniors and juniors for their timely cooperation and instantaneous help throughout study.

Last but not least, no words are enough to express my immense indebtness to my parents who encouraged and helped me to build my educational carrier to this stage and their contribution is beyond my acknowledgement.

Place: MPKV, Rahuri **(Mahale Hemant Trambak)**

Date: / /2013

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

Abbreviation	Description
%	Per cent
i.e.	That is
Avg.	Average
B. Tech	Bachelor of Technology
CI	Cast iron
cm.	Centimetre
d.b.	Dry basis
dia	Diameter
Dr. ASCAE	Dr. Annasaheb Shinde College of Agricultural Engineering
Engg.	Engineering
etc.	Etcetera
Fig.	Figure
FIM	Farm Implements and Machinery
FMP	Farm Machinery and Power
h.	Hour
ha.	Hectare
m.	Metre
M.P.K.V.	Mahatma Phule Krishi Vidyapeeth
min.	Minute
mm.	Millimetre

No.	Number
pp.	Pages
sec.	Second
Wt.	Weight

ABSTRACT

DEVELOPMENT AND PERFORMANCE EVALUATION OF MANUALLY OPERATED WHOLE STALK SORGHUM UPROOTER

By

Mahale Hemant Trambak

(Reg. No. 09/16)

A candidate for the degree of

MASTER OF TECHNOLOGY

(AGRICULTURAL ENGINEERING)

in

Farm Machinery and Power

Dr Annasaheb Shinde College of Agricultural Engineering,

Mahatma Phule Krishi Vidyapeeth, Rahuri.

May, 2013

Research Guide	:	Dr. S. M.Nalawade
Department	:	Farm Machinery and Power

Sorghum (*Sorghum bicolor L. Monech*) is the most important cereal crop grown in India. The country covers 34% total sorghum area in the world and produces around 17% of the world production of sorghum grain per annum. At present the harvesting of dry land as well as irrigated rabi sorghum in Maharashtra is done manually by uprooting. The harvesting of rabi sorghum is not done by cutting the sorghum stem because sorghum stalk stored as fodder for cattle up to next year's harvesting and during rainy season there is fungus development at bottom open end of stem, due to which keeping quality of fodder is reduced. The lot of energy is required for uprooting of rabi sorghum. It is more cumbersome and laborious. The uprooting of irrigated rabi sorghum develops blister on hand and finally it develops wounds.

To overcome the harvesting problem of the sorghum the manually operated sorghum uprooter was developed for uprooting sorghum which can reduce the drudgery. The simple tool

Abstract Contd……

with main frame, tyne and uprooter unit was developed. The hinge was provided for attachment of uprooter unit to the main frame to facilitate easy movement of lever. Four tines were attached to foot pedal of uprooting unit for penetration in to the soil and uprooting stalk.

The manually operated sorghum uprooter was tested for its performance with irrigated and dry land condition. The performance was evaluated at the different crop moisture, different variety, root length and its effect on uprooting time. The actual field capacity was observed in dry region 124 m^2 –h^{-1} and in irrigated condition it was 129 m^2–h^{-1}. Average uprooting time per plant with uprooter for irrigated sorghum and dry sorghum were formed to be 8.29 seconds and 4.00 seconds respectively. In dry land actual field capacity and uprooting time was less as compared to irrigated condition. The pull force required to uproot plant was directly proportional of the taproot length and independent of stalk height and stalk diameter and uprooting time is inversely proportional to the soil moisture.

Pages 1 - 51

1. INTRODUCTION

Sorghum (*Sorghum bicolor L. Monech*) is the most important cereal crop in the world after, wheat (*Triticum aestivum*), rice (*Oryza sativa*)and maize (*Zea mays)* grown *in* semi-arid tropics. It belongs to family graminae. Cultivated sorghum are grouped in to two main types, based primarily on the use *viz*., grain sorghum and sweet sorghum *etc.* The country covers 34% of the total sorghum area in the world and produces around 17 % of the world production of sorghum grain per annum. In Maharashtra, it is mostly grown in kharif season as rainfed crop. The area occupied by grain sorghum is 5.50 M ha. and production is 1.10 $t\text{-}ha^{-1}$. It also supports a large population in Andhra Pradesh, Madhya Pradesh, Gujarat and Rajasthan (National Research Centre for Sorghum, 2011-12).

Sorghum crop is grown in large area of Deccan plateau of Maharashtra. The crop is grown in two seasons, *viz*., Kharif and Rabi. Sorghum is a rabi season crop in western and southern India and in northern India it is grown as Kharif crop. Soils with clay loam or loam texture, having good water retention capacity are favourable for sorghum cultivation. It does well in pH range of 6.0-8.5 as it tolerates considerable salinity and alkalinity. The hybrid varieties of sorghum are dwarf and short duration of about 100-120 days as compared to the local varieties. The recommended hybrid varieties of state and national level are MS- 70, CSH-1, CSH-5, CSH-8, CSH-9,PKV-400, PKV-Kranti and SPSH-388. Out of which CSH-9 is adopted by farmers on large scale. In case of hybrid sorghum when the crop attains maturity, the stand is erect and the cobs at the top of the plant are nearly at uniform height. These factors are favourable for introducing harvesting device through a suitable machine in standing crops. (Agriculture Today, 2010).

The higher productivity in kharif is mainly due to large coverage under hybrid and high yielding varities. Rabi sorghum is also major source of food , fodder and has excellent grain quality in rain free cool climate. The higher market price makes it economically sustainable despite its low yield. The productivity of rabi sorghum could boost up through improved production technology ensuring security of food and feed.

It has strong root system to prevent the collapse. In addition epidermis of the stalk is covered with layer of wax powder; the leaf blade shrinks in itself in order to reduce the evaporation during the draught period.

Harvesting is the most labour intensive operation followed by weeding operation. This is because of the operation is done by manual method which involves, cutting whole stalk of Sorghum with sickles and separating ear-heads from stalk. In some cases ear-heads are separated first and stalk cut later on. The area under hybrid Sorghum increased dramatically in the early seventies in Maharashtra and Karnataka, due to major hybridization programmes under taken in 1970`s, the entire kharif Sorghum in Maharashtra was brought under hybrid varities. These hybrid verities grow to an average height of 2m. This increased height makes the harvesting operation, a tedious job.

The total harvesting of sorghum requires two stages cutting of plant, one at the top for separating cobs and second at the bottom for cutting stem for fodder. Hence double labour required for harvesting of this crop. Sorghum has created the possibility of mechanizing the harvesting of cobs could be achieved by tractor with separate mechanism for cutting the cobs and simultaneously cutting the plant from its bottom i. e. reaping (Kanafoiski and Karwowski, 1976).

At present, the harvesting of dryland as well as irrigated rabi sorghum is done manually. The harvesting of rabi sorghum is done manually by uprooting. The harvesting of rabi sorghum is not done by cutting the sorghum stem because sorghum stalk are stored as fodder for cattle up to next year harvesting and during rainy season there is fungus development at bottom open end of stem, due to which the keeping quality of fodder is reduces.

This requires lot of energy for uprooting of rabi sorghum. The harvesting of irrigated sorghum is more cumbersome and laborious. The uprooting of irrigated rabi sorghum develops blister on hand and finally it develops wounds. The labourers demand more money for harvesting of irrigated rabi sorghum than dryland rabi sorghum. To overcome the harvesting problem of rabi sorghum it is essential to develop the sorghum uprooter which can reduce the drudgery.

Mechanization has crept in the Indian agriculture. However, much is still to do. Sorghum is one where mechanization has hardly done anything. History indicates that the development in farm mechanization is very closely related to the shortage of human labour and industrial development in the country. One of the major constraints in the mechanization of Indian agriculture is the low investing capacity of farmers to buy machines. The effective mechanization contributes to increase production in two major ways; firstly the timeliness in operation and secondly the good quality of work along with reduced labour component. Agricultural mechanization not only helps in increasing production, productivity and profitability in agriculture by achieving timeliness in farm operations but also reduces drudgery during production, (Kepner and Baner, 1972).

Considering the present mechanization status in sorghum cultivation, various machines are available for different operations *viz*., mechanical planter for sowing, weeding hoes for inter culturing, mechanical thresher for threshing ear-heads. But till now there is no any perfect machine available for uprooting sorghum crop. Thus at present uprooting of sorghum is tedious, time consuming, labour intensive makes operation costly. Besides it is subjected to labour scarcity problems causing delay in the harvesting in of sorghum.

In view to give solution to the above cited problem the research project entitled, "Development and Performance Evaluation of Manually Operated Whole Stalk Sorghum Uprooter" was undertaken. This may reduce the cost of operation, labour requirement and drudgery of farmers.

Objective

1. To develop manually operated sorghum uprooter.
2. To evaluate the performance of developed sorghum uprooter.

2. REVIEW OF LITERATURE

This chapter deals with the studies which were previously conducted by several researches in relation to the harvesting of sorghum crop. Recently some improved and modified harvesters were developed and introduced for different crops. However, impact to the desired extremities yet to be achieved in case of sorghum.

In India the traditional practice of sorghum harvesting is to cut stalk at bottom using sickles and the ear heads are cut later. Sometimes the stalk ear-headed first and then the stalk cut. The published literature related to design aspects of sorghum harvester is reviewed.

2.1 Manual harvesting

Yoshida (1982) analyzed cutting action of common hand sickle and observed that the serrated type sickle requires more energy than smooth edge, as serrations intended to have dual purpose both for shear and for cut.

Devnani *et al.* (1985) defined harvesting as the process of cutting crops from the field. Harvesting involves plucking and cutting of the plant and gathering grain (stalk) from the plant.

Michel (1998) stated that manual harvesting generally involves slicing and tearing action that results in plant structure failure due to compression, tension or shear. The serrated sickle combines a slicing and sawing action. The serrated edge used in cutting devices restricts the sliding action of the plant on the blade edge and helps to retain the plant on the blade for adequate cutting. He also reported that sickle with serrated edge requires the resharpning rarely, as compared to smooth edge sickle.

2.2 Harvester design

Kepner *et al.* (1972) had described various grains harvesting equipment, types of threshing mechanisms, combine performance, field testing and power requirements etc.

Pari (1989) developed sweet sorghum harvester for use under European condition. The harvesting time and capacity of an adopted sugarcane harvester were studied, together with morphological character of sweet sorghum, which influences mechanical harvesting. In trails, the modified 2 m wide machine harvested 0.77 ha/h (60 tones/h). The working speed was 4.3km/h.

Metianu *et al.* (1990) had developed a whole crop harvester to harvest the whole cereal crop, thresh and clean the grain & process the straw into animal feed.

This basic design has been established with the prototype machines functioning successfully in wheat.

Rains *et al.* (1990) had designed and built a machine to cut whole stalk sweet sorghum. The machine cuts the sorghum, collects it in an accumulator and periodically stops to dump the accumulated bundle into a windrow. Atkinson sugarcane harvester was converted from three point hitch mounted to pull type machine. The rotary disc cutter cut the stalk at the base. Gathering chain captured the stalk as they were cut and elevated them at a 30^o angle. The stalk was gripped between two discs and flipped to horizontal position. Disc tangential velocity was 24% greater than chain velocity. Total power required was 33 kW (44 hp) with 67% for chains and 28% for drawbar pull.

Yadav (1990) studied the design concept for animal drawn cereal harvester. The earlier attempted design on animal drawn harvester has limitation of ground traction and high draft requirements. The design concept was based on reduction of total weight of machine a large mechanical lever system used in the cutter bar mechanism developed zero to near zero vertical load to reduce the knife cutter bar friction. The attempt has made to reduce the draft requirement. Also the cutting force available at the cutter bar had been increased by 6-8times approximately.

Nalawade (2000) developed tractor operated jowar reaper windrower. To achieve the objective of prototype consisting of cutting, conveying and power transmission unit developed. The reciprocating cutter bar mechanism was used for cutting of stalk from the base. The cutter-bar of length 2.25m was fitted on main frame at 5 cm above ground level. Conveying unit was consisted of three lugged-conveyer belts at different heights. Star wheel fitted on divider assembly spaced 30 cm apart from each other helped in conveying of cut crop. The reaper was operated with the help of 35 hp tractor and the ancillary power was provided from the PTO through universal shaft and gear box.

2.3 Uprooter design and development

Braid (1980) developed machine for sorghum gives a field capacity of 0.5 ha/h with heads fairly uniformly cut. The machine was of offset to the side of tractor. It had to rotary cutters, the top blade cuts the heads of sorghum while the lower one cut the base so as to ease the field movement.

Kemp and Matthews (1982) studied a tractor mounted four row machine has been developed for uprooting cotton stalks to facilitate hand gathering and burning diseases control measure. A comparison of the overall costs to the loosening stalks by the new machine by under cutting the plants with a tractor drawn blade implement and by the traditional hand pulling method has shown the pulling machine to be cheaper in every case.

Sumner *et al.* (1984) studied the pull force required for pulling a plant was a independent of stock diameter and stock height. He also studied the pull force didn't follow a particular trend as the pull angle increases. He observed that average pull force from 254 N to 614 N which related to plant size and soil condition.

Sumner *et al.* (1986) studied a counter rotating wheel plant puller was evaluated as method to harvest cotton stubble from the soil. Power required to rotate the pulling wheels in the laboratory increased with the decreased tire pressure and in an increasing force between the wheels. Static pull forces determined in the laboratory were useful in evaluating the units ability to pull cotton stubble in the field. They operated efficiently of tire pressure between 69 and 124 kPa with 2.7-3.6 kN of force between the pulling wheels while travelling at velocities up to 8 km-h^{-1} .

Anonymous (2007) Zonal Agricultural Research Station, Solapur developed the manually operated sorghum uprooter. The implement was light weight (1.8 kg) and low cost (Rs.185/-). The machine was very suitable for irrigated condition than dryland condition. Human drudgery was reduced in sorghum uprooter.

2.4 Performance Evaluation

Demian (1978) studied the magnitude of pull and lift requirements to uproot a single cotton plant are important parameters in designing and efficient stalk pulling machine. A magnitude of 121 kg pull, accompanied by short lift of 4.9 cm, was found necessary to loosen all plants completely. The investigations have also included the percentage of plants pulled and their root dimensions in relation to the yield point.

Braid (1980) studied the double cut concept for harvesting of tall variety of sorghum in Nigeria. ‘ The Short Kaura ` is usually 2-3 m tall variety of sorghum. The conventional harvester for paddy, maize cannot be used without major modification.

Deshmukh (1986) mentioned about direct relationship between tap root depth of cotton plant and pull force. He also observed that the reason for increasing pull force with increase in root depth might be due to fact that as tap root goes down vertically, the secondary and tertiary roots also develop and these roots together are held tightly by the soil offer higher resistance when pulled. Similar results were also obtained at 6.5% moisture content. He also indicated direct relationship between tap root depth of the plant and pull force.

Monroe *et al.* (1984) reported that plant removal was significantly better with pulling wheel angles of 15-30^0 from vertical than with a 45^0 angle. Average pulling force required to pull cotton plants for five field locations ranged from 256 to 373N. There was no significant difference in the pull force when plants were pulled at 0 and 45^0 angle from vertical.

Sumner *et al.* (1986) reported that the pulling wheels were effective in pulling 97 percent of the cotton stubble. They operated efficiently at tyre pressure between 69 and 124 KPa with 2.7 to 3.6 KN of force between the pulling wheels while travelling at velocities upto 3 km per hour.

Metianu *et al.* (1990) observed that under Pakistani conditions, the machine was able to operate at an overall output of 1 t/hr clean grain or an overall work rate of 0.4 ha/hr with rain losses from the cleaner of less than 0.5% and separation losses of 2%. The broken straw was acceptable to farmers as animal feed with a medium length of 20 mm and a bulk density of 60 kg/m^3. The separation efficiency of the threshing and separation drum was 98- 99%. Grain damage was typically around 2% BT can be controlled by reducing cylinder speed.

Rains *et al.* (1992) recorded that bund graph model of the accumulator dump drive showed that the hydraulic motor could dump a bundle 65% larger than the maximum size dumped in furls tests without over running at 3.56 km/hr, field capacity was 1.56 ha/day. The harvester operated best at 3.56 km /hr over a season with 30 operating days, 1620 mg could be harvested.

Yadav and Pandey (1995) studied design parameter of sorghum and pearlmillet harvester and found that both crops were different from other crops due to their physical characteristics. They had thick stem, which had base diameter of 25 mm tapering to 10 mm at top. The result obtained under quasi-static test show that both stems had similar strength characteristics. For both the crops mean values of modules of elasticity were found in the range of 0.59 to 0.63G Pa. Also the mean values of ultimate shear stress for these crops were observed in the range of 2.69 to 3.39 N/mm^2. This showed that the finding of one crop could be safely applied to the other crop taking in view its physical characteristics.

Miskin *et al.* (1999) examined the relationship of first degree of the form, y = a + bx, where y was pull force and x was a tap root depth, a and b were crop characteristics.

Nalawade (2000) studied the performance evaluation of tractor operated jowar reaper windrower with travel speed of 2.5 km/h and 540 rpm of the PTO speed. With this condition at crop moisture content of 15 %, the actual field capacity of the reaper windrower was observed to be 0.4 ha per h. The machine gave 72% field efficiency. The cost of machine was Rs.21076.00 (including power transmission, auxiliary hydraulic and mounting attachment) and it involved the cost of operation of Rs.421.15 per ha. depending upon the different field conditions.

Kadu *et al.* (2003) observed that pulling force requirement in stationary condition was done in heavy soils having 24 % moisture content and at that time average moisture content of cotton stem is 65 % on dry basis. The relationship of taproot depth with pulling force requirement was studied. From the analysis of the study, it was observed that pulling force was function of taproot depth.

2.5 Ergonomic evaluation

Corlett and Bishop (1976) described a technique which enables the distribution of discomfort in the body and its change during the work period to be recorded. The recorded data indicate points of in adequate man-machine capability as well as permitting the evaluation of the effectiveness of machine designs. When used in the conjunction with measures of production performance the technique provides direct evidence of the benefits of ergonomics changes. Its use is illustrated in relation to a study of spot welders.

Solanki *et al*., (2006) evaluated three types of hand operated maize shellers ergonomically. The performance in respect of cardiac cost, overall tiredness, body part discomfort and output were evaluated. The heart rate while working with all maize shellers indicates moderate workload on the subjects. The overall discomfort score varied from 3.5 to 4 i.e. 'more than light discomfort and body part discomfort score was 51 for all the maize shellers. The highest output was observed with maize sheller having serrated tins than other two maize shellers. Also the use of this maize sheller could help to reduce the drudgery by 18.75 and 45.13 %than tubular and octagonal shaped maize shellers respectively having plain fins, as calculated from the heart rate data.

3. MATERIALS AND METHODS

On the basis of the information collected from the research studies of the earlier workers and after studying the crop parameters of the existing sorghum varieties and prevailing operational needs of the sorghum growing farmers, a manually operated whole stalk sorghum uprooter was developed (Fig. 3.1).

3.1 Design considerations

The manually operated whole stalk sorghum uprooter was developed for uprooting of rainfed as well as irrigated sorghum with the following design consideration.

1. Suitability for the harvesting of all varieties of sorghum.
2. Simplicity in manufacturing.
3. Minimum energy requirement per unit for uprooting of crop.
4. Low cost and light weight.
5. It should be easy to operate and transport.
6. It should reduce the drudgery in uprooting of sorghum.

3.2 Fabrication of manually operated sorghum uprooter

The machine manually operated, was designed keeping in view all the above points and based on the review of literature and experience of past researchers. A simple machine was fabricated in the ‘Workshop Technology Laboratory’of the Dr. Annasaheb Shinde college of agril. Engg. MPKV, Rahuri. The required material and standard parts such as hinge pins, springs, pipes, bars, flats etc. were purchased from the local market.All these part are connected to the frame, which would be transported by manual labour.

3.3 Construction of the sorghum uprooter:

The manually operated whole stalk sorghum harvesterhas following parts.

1. Main frame and handle
2. Uprooting unit (tines)
3. Foot paddle
4. Spring
5. Pins (Hinge)
6. Rivet

7. Anchoring bar
8. Lever

3.3.1 Main frame

The main frame as shown in Fig.3.4and Plate no.3.1 was fabricated from M.S. square pipe of size 25 x 25 x 2 mm. Length of the main pipe was 1070 mm. The handle,250 mm long, was attached at top of mainpipe. The handle made up of M.S. pipe having 25.4 mm diameter, for gripping. The hinge was provided for attachment of uprooter unit to the main frame to facilitate easy movement of the lever.

3.3.2 Uprooter unit (Tines)

Uprooting unit as shown in Fig.3.5 and Plate no.3.2was fabricated from the mild steel flat for better strength. Three or four tines were attached to the uprooting unit for penetration in to the soil. Tines were fabricated from M.S. flat of size 25 x 5 mm. andit’s total width was 60 mm.

3.3.2.1 Development of tines

Tines were fabricated from Mild steel flat (specification 25 x5 mm). The tines were made with the suitable dimensions. Four in number of blades were made with the suitable angles and all these tines welded together.

3.3.3 Foot pedal

It was fabricated from M.S. flat of size 50 x 5 mm. It was used for keep leg during operation. During operation it was used for pressing the uprooter unit in to the soil and uprooting stalk. It is shown in Fig.3.5.

3.3.4 Pins

Pins were made up ofM.S. of size 6 mm in diameter and 50 mm in length as shown in Fig.3.6 and Plate no.3.4 these act as hing for easy movement of tines and spring during operation

3.3.5 Rivets

Rivets of 15 mm in length and 6 mm in diameter were used. The main function of rivet was to anchor the springs.

3.3.6 Tension springs

Tension springs facilitate the efficient working of uprooter unit by holding tines in vertical position. There were two springs provided on both side. One end of spring was attached to tine with help of rivet and another end was attached to the square pipe with help of pins.It is shown in Plate no.3.3.

3.3.7 Anchoring bar

Anchoring bar was made up of hardened steel rod of diameter 10 mm 160 mm length. It was welded to square pipe at one end with supporting flats of M.S. 25 x 5 mm on both sides of pipe and other end is pointed. The main function is to hold the uprooter in the soil when tines are moving.

3.4 Measurement of physical parameters

The physical parameters of the sorghum stalk were measured for development of the uprooter.

3.4.1. Length

A steel tape with 1 mm division was used in measuring stalk height and root length. Stalk height and root length measurement are shown in Plate no.4.1 and 4.2.

3.4.2 Diameter

A vernier caliper with least count of 0.05 mm was used in measuring the minor and major stalk diameter at height of 5 cm above ground level.

3.4.3 Weight

The weight of the soil samples were recorded using weight balance with accuracy of 0.001 kg.

3.4.4 Moisture content

The moisture content of the soil sample was measured using oven . The sample was kept in oven for 24 hours at105 ^{o} C. The loss in weight of the sample was recorded and the moisture content in percent was determined as in equation.

$$M.C.(db) = (Wi – Wd / Wi) \times 100$$

Where,

M.C.(db) = moisture content (%); Wi= initial weight of sample (kg); Wd= dried weight of sample(kg).

3.4.5 Time of uprooting

A digital stopwatch having least count of 0.01 second and with maximum capacity of 10 hrs was used for recording the time.

3.5 Working of modified sorghum uprooter

The sorghum uprooter is placed exactly near the stalk just above the soil surface. The anchor bar is inserted into the soil surface just in the line of sorghum plant (parallel) near the stalk. A stationary handle is being provided to the uprooter (equipment) at the apex end so as to immerse it in the soil beneath the roots with the help of manual power. After the adoption of above procedure a foot paddle is pressed by the operator and hence the sorghum plant uprooted.

3.6 Ergonomic study of manually operated whole stalk sorghum uprooter

The Performance of manually Operated whole stalk sorghum uprooter was conducted at Workshop Technology Laboratory (College Workshop), Dr. A.S. College of Agril. Engg. MPKV, Rahuri. The tests were analyzed to determine the working of machine, Body Part Discomfort Score (BPDS**).** Five male subjects in the age group of 24 to 27 were selected for the study. Their age, stature, weight and Body Mass Index (BMI) are presented in Table no 3.1.

3.6.1 Protocol to conduct this experiment with the subjects

Following points were considered for developing the protocol to conduct this experiment with the subjects.

1. The subjects chosen for the study were physically fit for performing the activities. Subject having age of 20 to 45 years was taken for the study.
2. Subject was given training of using the machine with complete operational techniques involved in it.

3.6.2 Evaluation of Postural Discomfort (Body Part Discomfort Score)

1. To measure localized discomfort, Corlett and Bishop (1976) technique was used. In this the subject body is divided into 27 regions (Fig. No. 3.6).

2. Each body region numbered differently to avoid confusion and subject marking one body region only.
3. The number of different groups of body parts, which are identified, from extreme discomfort to no discomfort represented the number of intensity levels of pain experienced.
4. The maximum number of intensity levels of pain experienced under different treatments was six categories.
5. The rating was assigned to these categories in an arithmetic order, viz., 1^{st} category (body parts experiencing maximum pain) rating was allotted as '6' and for 2^{nd} category (body parts experiencing next maximum pain) rating was allotted as '5' and so on, finally for the sixth category (body parts experiencing least pain) rating was allotted as '1 '.
6. It was found that the number of intensity levels of pain experienced by different subjects might vary. For example, if one subject has experienced '4' categories,1^{st} category rating was allotted as '6' and for 2^{nd} category rating was allotted as '4.5' and so on for fourth category rating was allotted as '1.5'.
7. In order to get an ideal analysis of results after ranking, each data was marked in a numerical way. All the marks were added for each body part. The body discomfort score of all the subjects is added and averaged to get mean score.

For calculating body mass index following formulae are used:

Body Mass Index (kg/m^2) =Weight, kg / $(Height)^2$, m^2

Table 3.1 Anthropometric data of subjects

Subject	Name	Age years	Weight Kg	Stature Cm	BMI Kg/m^2
S1	Mahale Hemant	26	64	164	23.79
S2	JadhavYogesh	25	58	157	23.53
S3	KanguneAnand	25	67	169	23.45
S4	Gadhari Ganesh	27	62	171	21.20
S5	Patil Pradip	24	58	167	20.79
Average		25.4	61.8	165.6	22.55

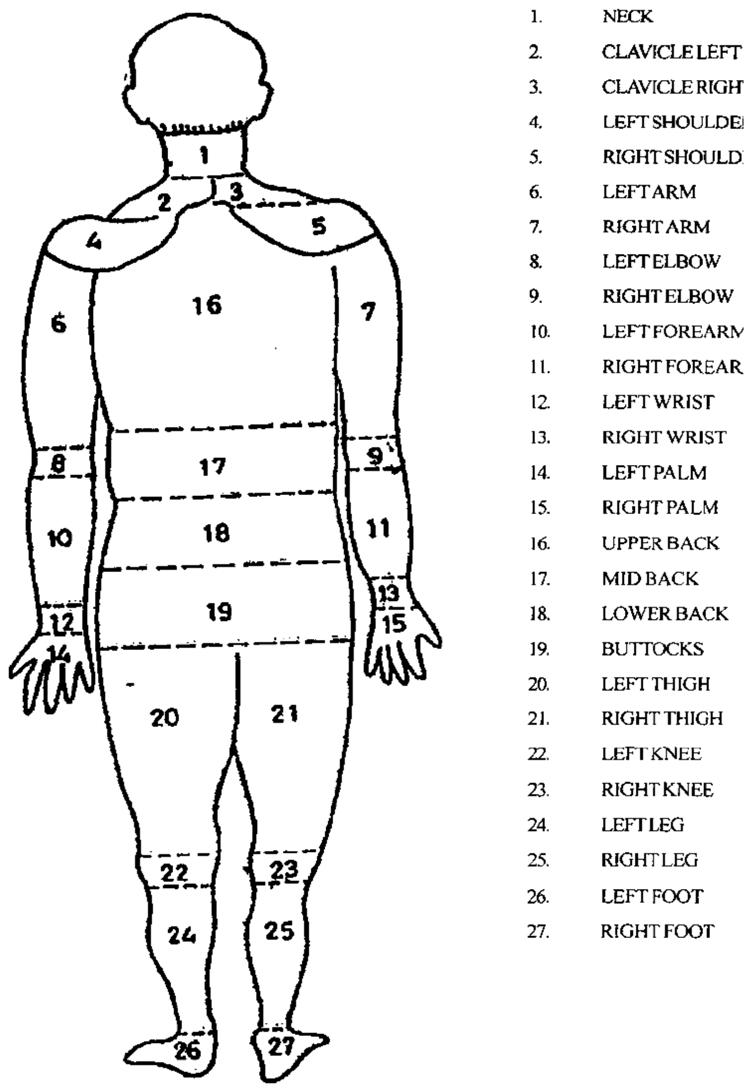


Fig. No. 3.1 Regions for evaluating body part discomfort score using Corllet and Bishop (1976) technique

3.7 Test procedure

The testing of the experimental sorghum uprooter was done according to test code and procedure as suggested by standard test code.

3.7.1 Laboratory Test

The main objective of the laboratory tests were to confirm the dimensions and to study the performance of the component designed. Such study was used in the modification and improvement in the design of machine.

The items examined were as follows:

1. Specification
2. Visual observations and checking of provisions

3.7.1.1 Specification

The sorghum uprooter was kept on the firm, level and horizontal surface of the workshop floorand various dimensions were measured as reported in Table 3.1

Table 3.1 Specification sheet for Manually operated sorghum uprooter

Name and Address of manufacturer	Developed in Workshop Technology Laboratory (College Workshop) Dr. A.S.C.A.E.,M.P.K.V. Rahuri, Dist Ahmednagar, Maharashtra.
Model	Experimental prototype
Type	Manually operated whole stalk sorghum uprooter
Uprooter unit	Tines mounted on square pipe with help of hing pins
Overall dimensions Total weight of machine	Length 250 mm Height 1070 mm Width 70 mm 2.20 kg

3.7.1.2 Visual observations and checking of provisions

The manually operated sorghum uprooter was inspected thoroughly paying attention in particular to the moving parts, correctness and ease of operation, various adjustment, tightness of pins etc.

3.7.2 Field tests

The field test of the manually operated sorghum uprooter were carried out for its overall performance, which includes,

1. Field capacity
2. Ergonomics evaluation

4. RESULT AND DISCUSSION

The newly developed manually operated whole stalk sorghum uprooter was evaluated for its field performance in comparison with manual uprooting practice. The analysis and interpretation of data obtained during the laboratory and field test are presented in this chapter. The different aspects studied are discussed as follows.

4.1 Laboratory test

Laboratory tests were conducted at workshop, MPKV, Rahuri. The main objective of laboratory test to study the specifications, observe the performance of the components developed and to undertake such study that would assist in the modification and improvement in the developed machine. The result indicated that:

1. Machine was suitable for sorghum uprooting.
2. Easy to operate in standing position.
3. The strength of the parts was satisfactory.

4.2 Field test in irrigated sorghum

The field test carried out at Seed Technology Research Unit and Sorghum Improvement Project, M.P.K.V., Rahuri. in the sorghum field to ensure the proper operation of the machine and failures of parts, if any. The field trials conducted as per the standard procedure. The field and crop condition existed during the trials are presented in Table 4.1. The data of the field test were analyzed to determine the field capacity, actual operating hours etc. The observations of the trials are given in performance evaluation Table 4.6. Table 4.2 gives the summery of all trials. Table 4.2 reveals that.

Table 4.1 Effect of plant physiology on time required for uprooting

Sr.no	Height of Plant(mm)	Diameter of stalk(mm)	Root length(mm)		Time req. for uprooting(sec)	
			Sorghum Uprooter	Manual Method	Sorghum Uprooter	Manual Method
Name of variety KSR 6194						
1.	914.4	30	203.2	215.9	14.50	15.48
2.	1310.64	28	228.6	228.6	15	17.59
3.	640.08	32	127	177.8	8.30	12
4.	1158.24	24	254	254	19.85	18
5.	1157.52	36	203.2	203.2	9	14
Average	1116.17	30	203.2	215.9	13.13	15.48
Name of variety KSMS 263						
1.	1158.24	16	203.2	127	4.66	2.33
2.	1432.56	21	254	203.2	9.51	5
3.	1402.08	18.5	127	127	4	1.50
4.	1341.12	16.5	203.2	177.8	8	4.15
5.	1219.2	18	203.2	177.8	7.13	3.52
Average	1310.64	18	198.12	162.50	6.66	3.30
Name of variety JJ 741						
1.	1219.2	18	203.2	101.6	14.30	3.14
2.	2133.6	19.5	228.6	177.8	16.45	5.32
3.	2346.96	24	203.2	152.4	9.30	4.12
4.	2133.6	17	127	254	16.93	6.30
5.	2438.4	21.5	254	139.7	10.12	3.52
Average	2054.35	20	203.2	165.1	13.42	4.48
Name of variety GFS 4						
1.	1737.36	8	177.8	203.2	5.48	8.54
2.	1828.8	5.6	228.6	177.8	6.48	7
3.	1889.76	6	101.6	101.6	4.59	4.12
4.	1706.88	8.3	246.38	152.4	12.25	5.43
5.	1219.2	11.1	246.30	152.4	9.30	4.25
Average	1676.4	7.8	200.66	196.75	7.62	5.85

Table 4.2 Test data of sorghum uprooter .

Location – Seed Technology Research Unit, MPKV, Rahuri.

Date-14/12/2012.

Sr. No.	Trials	I		II		III		IV	
	Particulars	Sorghum Uprooter (S.U)	Manual Method (M.M)	S.U	M.M	S.U	M.M	S.U	M.M
1.	Variety	KSR 6194		KSMS 263		JJ 741		GFS 4	
2.	Height of crop(mm)	1116.17		1310.64		2054.35		1676.4	
3.	Spacing(cm)	60 x 40		65 x 30		45 x 30		60 x 45	
4.	Soil type	Medium black soil							
5.	Length of roots(mm)	203.2	215.9	198.12	162.56	203.2	165.1	200.66	196.75
6.	Dia. Of stalk(mm)	30		18		20		7.8	
7.	Tiller	7	6	6	4	9	9	9	10
8.	Moisture content (%)	2.1	0.98	3.7	9.2	5.06	7.5	3.4	5.6
9.	Time req./plant (sec)	13.33	15.48	6.66	3.30	7.89	4.48	7.62	5.82
10.	Time req./line (min)	3.33	2.66	1.5	1	1.05	0.81	1.79	1.29
11.	Plant/plot	90	60	81	109	76	87	85	80
12.	Time req./plot(sec)	1200	960	540	360	600	390	648	468
13.	Avg. Plant/ Line	15	10.33	13.5	18.16	9.5	10.87	14.16	13.13
14.	Plant line/plot	6		6		8		6	

Table 4.3 Average values of sorghum varieties

Name of Variety	Height of Plant(mm)	Diameter of stalk(mm)	Root length(mm)		Time req. for uprooting(sec)	
			S.U	M.M	S.U	M.M
KSR 6194	1116.17	30	203.20	215.90	13.13	15.48
KSMS 263	1310.64	18	198.12	162.56	6.66	3.30
JJ 741	2054.35	20	203.20	165.10	13.42	4.48
GFS 4	1676.4	7.8	200.66	196.75	7.62	5.85

4.2.1 Varieties of sorghum

For conducting test on irrigated sorghum four types of varieties namely, KSR 6194, KSMS 263, JJ 741 and GFS 4 were used. The uprooting time for different varieties was studied.

4.2.2 Height of plants

The height of the plants uprooted varied from 1000 mm to 2500 mm. While height of the majority plant was found in variety of JJ 741 and it is 2054.35 mm. Height of plant was 1676.4 mm in GFS 4 variety in KSMS 263 height of plant was 1310.64 mm and KSR 6194 plant height was 1116.17 mm. In this case uprooting time was not affected by height of plant. It is shown in Fig 4.3.

4.2.3 Root length of plants

The root length of sorghum plant was in the range of 150 mm to 220 mm. While major root length was found in variety of KSR 6194, it is 215.9 mm in manual uprooting and it is 203.2 mm in sorghum uprooting method. Root length 200.66 mm in sorghum uprooter and 196.75 mm in manual uprooting in GFS 4 variety in KSMS 263, root length of plant was 198.12 mm in sorghum uprooter and 162.56 mm in manual method and JJ 741 root length was 203.2 mm in sorghum uprooting and 165.1 mm in manual method. From root length and respective time for uprooting, it was observed that there exist significant relationship between root depth and uprooting time. The uproot time increases with increase in root depth. It was presented graphically in Fig.4.1.

4.2.4 Time required for uprooting

Time required for sorghum plant uprooting was affected by moisture content and root length. The relationship between root length and uprooting time has been presented graphically in Fig 4.1 It was observed that the uproot time increases with increase in root depth. Fig 4.2 showing the relationship between the soil moisture and uprooting time. From the graph, the uprooting time increases with moisture depletion in the soil.

4.3 Root length and its effect on uprooting time

The root length of sorghum plant was in the range of 150 mm to 220 mm. Majority of the plants uprooted had root length of 190 mm to 200 mm. The relationship between root length and uprooting time has been presented graphically in Fig 4.1. From the graphs plotted it is clear that, time increase with increase in root length. This indicates a near linear relationship between root lengths and uprooting time. The reason for increasing the time with increase in root length might be due to fact that roots held tightly by the soil offer higher resistant while uprooting. From the analysis of the result, it was observed that there exist significant relationship between root length and uprooting time. The uproot time increases with increase in root length. These results are in agreement with the findings of Deshmukh (1986). In this study he reported that there exist a direct relationship between tap root depth of cotton plant and pull force.

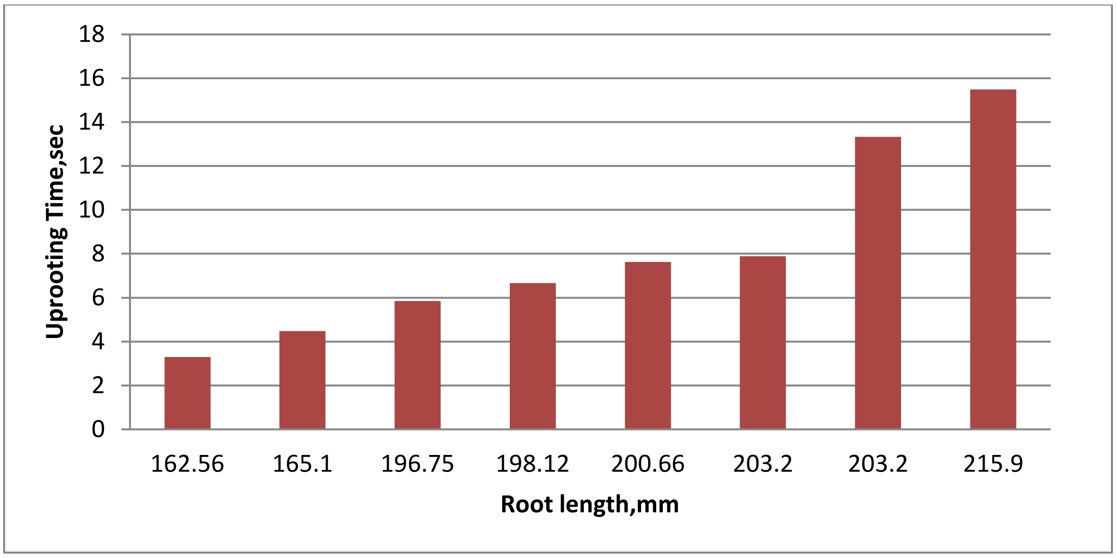


Fig.4.1 Relationship between uprooting time Vs root length

4.4 Effect of soil moisture and uprooting time

Figure 4.2 showing the relationship between the soil moisture and uprooting time. From the graph, the uprooting time increases with moisture depletion in the soil. The reason for higher uprooting time at low moisture might be due to that at low moisture content the soil is hard and very adherent because of cementation effect between the dried particles. As result of cementation effect the roots of the plants are tightly held by the soil. Thus, soil offers more resistance during uprooting of plants. But when the soil moisture increases with irrigation, the water molecules are absorbed on the surface of the particle and decreases the soil coherence and impart friability to soil mass, thus loosing the roots of the plants which result in easy uprooting due to less resistance offered by the soil under loose soil condition.

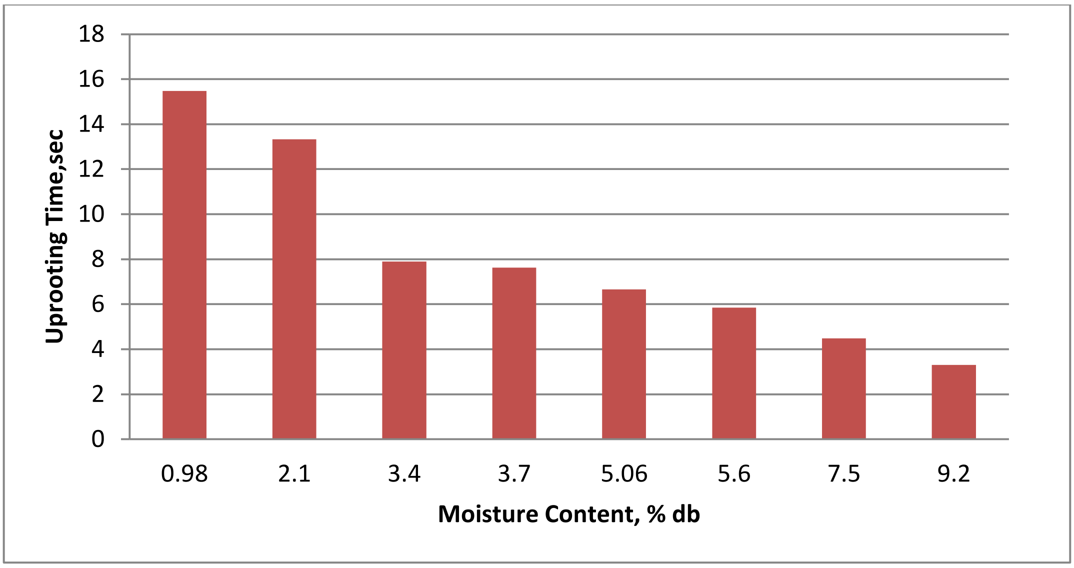


Fig.4.2 Relationship between uprooting time Vs moisture content

Table 4.4 Effect of stalk diameter and stalk height on uprooting time

Variety	Stalk diameter	Stalk height	Uprooting time
KSMS 263	18	1310.64	4.98
GFS 4	7.8	1676.4	6.73
JJ 741	20	2054.35	8.95
KSR 6194	30	1116.17	14.4

4.5 Stalk height and its effect on uprooting time

The height of the plants uprooted varied from 1000 mm to 2500 mm. while height of the majority plant was found in the range of 1100 mm to 2300 mm. The graph showing relationship between stalk height and uprooting time are depicted in fig 4.3. In this case the result indicates that uprooting time was not affect by increase in stalk height. In many cases, it is observed that in spite of lower stalk height the uproot time was found on higher side and vice-versa. The uprooting time is found to change abruptly without following a particular trend. Hence, it can be said that there is no relationship between stalk height and uproot time. Similar results were reported by Sumner *et al* (1986). In this study he concluded that plant pull force was independent of stalk height.

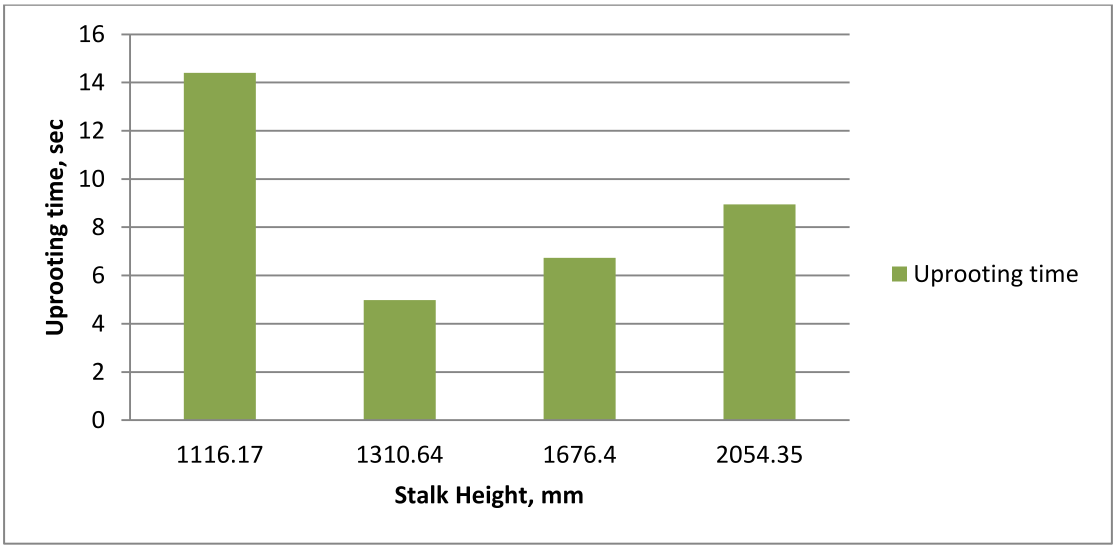


Fig.4.3 Relationship between uprooting time Vs stalk height

4.6 Stalk diameter and its effect on uprooting time

The diameter of the plant uprooted varied from 5 mm to 30 mm. The relationship between stalk diameter and uprooting time has been presented graphically in Figure 4.4 From the graph, it is clear that with the increase in diameter of the plants, the uprooting time does not increases. It may be due to non-homogeneity of soil from place to place, plant roots structure and uneven depth of root branches. Thus, it could be said that there is no relationship between stalk diameter and uprooting time. The results of this study are in agreement with the findings of the study conducted by Sumner *et al* (1986). In this study he observed that the pull force required for pulling plant is independent of stalk diameter.

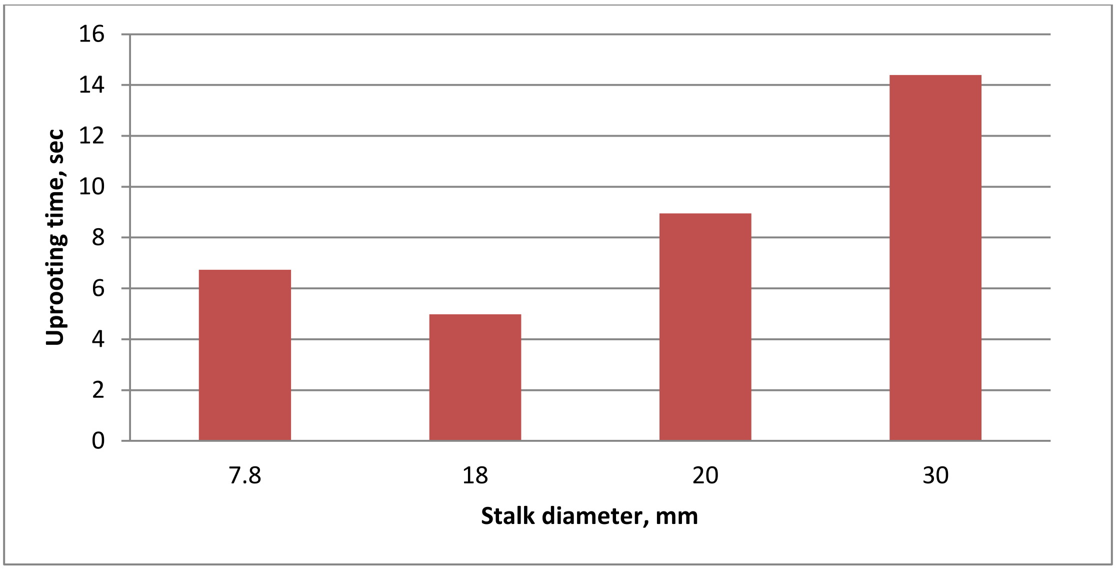


Fig.4.4 Relationship between uprooting time Vs stalk diameter

4.7 Field test in dry region sorghum

This field tests were conducted in the Sorghum Improvement Project, MPKV, Rahuri. The field and crop condition existed during the trials are presented in Table 4.5. The average root length of uprooted sorghum plant was 70 mm. Average stalk length of sorghum plant was 1854 mm.

Location : Sorghum Improvement project.

Date : 14/02/2012

Variety : Maldandi

Root length(mm)	Stock length(mm)	Ear-heads(mm)
60	1950	190
70	1950	200
60	1720	195
80	1850	210
90	1800	184

Table 4.5: Uprooting time for individual plant in dry region

No. of plants uprooted	Uprooting time for individual plant, sec			
1	2.1	2.9	3.6	4.4
2	2.9	2.1	1.4	2.2
3	2.42	3.22	3.92	4.72
4	2.24	1.44	2.14	2.94
5	2.68	3.48	2.78	3.59
6	3.48	2.68	3.38	4.18
7	3.28	4.08	3.38	2.58
8	4.21	3.41	4.11	4.91
9	3.8	4.6	3.91	3.11
10	4.29	3.49	4.19	4.99
11	5.3	6.1	5.49	6.29
12	4.45	3.65	4.35	3.55
13	2.72	3.52	2.82	3.62
14	5.59	4.59	5.29	4.49
15	3.93	4.73	4.03	4.83
16	4.2	3.4	4.1	3.3
17	2.32	3.12	2.42	3.22
18	4.3	3.5	4.2	3.42
19	4.5	5.3	4.6	5.42
20	4.25	3.45	4.15	3.35
21	4.52	5.32	4.62	5.42
22	3	2.2	2.9	2.12
23	3.13	3.93	3.23	4.03
24	4.18	4.98	5.68	4.08
25	3.48	2.68	1.98	2.78
26	2.59	3.39	4.09	3.29
27	3.12	2.32	3.09	3.89
28	4	4.8	5.5	4.7
29	4.13	3.33	2.63	3.43
30	4.13	4.93	5.63	4.83

Table 4.6 Overall field performance data of manually operated sorghum uprooter

Particulars	Dry Region		Irrigated	
	Sorghum uprooter	Manual method	Sorghum uprooter	Manual method
Time of start	11	12	1	2.30
Time of end	11.23	12.23	1.48	3.10
Spacing,cm	45 x 20		45 x30	
Duration of test,hr	0.38	0.38	0.81	0.68
Total area covered,m^2	48	48	96	96
Avg. uprooting time/plant,sec	4.05	3.96	8.87	7.27
Total plants uprooted	340	352	332	338
Actual field capacity, m^2-h^{-1}	125	123	118	140

4.8 Time required for uprooting each plant

Time required for uprooting each plant was measured with stop watch. The average time required for uprooting per plant was 3.96 sec in dry region and 7.27 sec. in irrigated region in manual method and time required for uprooting sorghum plant with sorghum uprooter was 4.05 sec. in dry region and 8.87 sec in irrigated region.

4.9 Actual field capacity

The actual field capacity was observed was 125 m^2-h^{-1} for uprooting sorghum with sorghum uprooter and that of 123 m^2-h^{-1} for uprooting sorghum manually in dry region and 118 m^2-h^{-1} for uprooting sorghum with sorghum uprooter and 140 m^2-h^{-1} for uprooting sorghum manually in irrigated region . The actual field capacity observed was more in case of sorghum uprooter than that of manual method of uprooting in dry region.

4.10 Ease of operation

During the field test it was observed that ease of operation was satisfactory. However, sometimes it difficult in manual uprooting and sometimes it was difficult in sorghum uprooting when tillering was more.

4.11 Ergonomic evaluation of sorghum uprooter

The ratings of body part discomfort for manually operated sorghum uprooter and traditional uprooting by hand are presented in appendices - A to J. Appendices-A to E represented uprooting by sorghum uprooter and Appendices-F to J shown uprooting by manual method. The body discomforts after working for 30 minutes with tool and without tool were studied. The discomfort to the operation was checked with scales developed by York University. The practices evaluated for which uprooting method is drudgeries to human. On the basis of Appendices-A to J, it was observed that manual uprooting method was more cumbersome, drudgeries and laborious as compared to developed sorghum uprooter because traditional uprooting method required lot of energy for uprooting. Uprooting by hands develops blister on hands and finally it develops wounds and by using new developed sorghum uprooter we can say that it reduces human drudgery and to raise the output of farmer. By using sorghum uprooter it was more affect on dominant leg, hand and shoulder and by using manual uprooting method it was more affect on both hand, shoulder and middle low back.

Table 4.7 BPDS scores during sorghum uprooting operation

Subject	Sorghum Uprooting	Manual Uprooting
S1	25	40
S2	36	36
S3	32	38
S4	30	41
S5	28	44
Average	30.2	39.8

4.11.1 Body part discomfort scores

From Fig. 3.1. and Table 4.7 body part discomfort rating as reported by the subjects, indicate that most frequent body parts reported were lower back, left and right palm, left and right shoulder, left and right arm, left and right thigh. Most of the subject reported maximum discomfort in lower back. The BPDS in case of both type of uprooting has been reported in Table no 4.7 It was found that the BPDS score for manual uprooting was 36 to 44 and sorghum uprooter was 25 to 36 Solanki *et al*., (2006).

4.11.2 Body Mass Index (BMI)

The average Body Mass Index of subjects, operating the machine was found 25.4. The calculations are shown in Table no 3.1.

4.12 Actual operating hours

It was the total time required to complete whole operation. It was recorded by stop watch.

4.13 Area covered and duration of test

The total area covered during the functional test was 288 m^2 hectare and the duration of test was 2.25 hour.

4.14 Soil and soil moisture content

The test was conducted in medium black soil. The soil sample collected during the test was analyzed to measure the moisture content.

5. SUMMARY AND CONCLUSION

The manually operated whole stalk sorghum uprooter was designed and developed with the objective to perform the sorghum uprooting having functioned to uproot the stalk. Using material available in local market manually operated whole stalk sorghum uprooter was fabricated. Its field performance was evaluated, and ergonomics evaluation was studied.

The newly developed prototype of sorghum uprooter was tested in the laboratory as well as in the field and its ergonomics evaluation was studied.

The field trials of newly developed machine indicate that it performed the intended function satisfactory with an actual field capacity observed was more in case of sorghum uprooter than that of manual method of uprooting in dry region.Based on the analysis of result, the following conclusions were made.

1.The newly developed prototype wassuitable to any sorghum variety.

2. Machine wassuitable under dry land as well as irrigated condition.

3. Uprooting time was dependent on sorghum variety, root length and moisture content of the soil.

4. During operation the tool penetrated in to the soil properly.

5. Average uprooting time per plant with uprooter for irrigated sorghum and dry sorghum were formed to be 8.29 sec. and 4.00 sec respectively.

6. The weight of the tool was 2.20 kg. It was easy to operate.

7. If diameter of stalk was more, by manual method it was not possible or tedious to uproot sorghum plant as compared to modified sorghum uprooter method.

8. Human drudgery was reduced in sorghum uprooter.

9. The uprooting time required to uproot plant was directly proportional to the taproot Length and independent of stalk height and stalk diameter.

10. Uprooting time increases with soil moisture depletion. This indicated that uprooting time is inversely proportional to the soil moisture.

11. BPDS score for Manual uprooting was 36 to 44 and for Sorghum uprooter was 25 to 36.

12. The cost of fabrication of the developed sorghum uprooter was Rs 202.

13. The cost of operation of the developed sorghum uprooting method was Rs 151.33 / day.

6. SUGGESTION FOR FUTURE WORK

The problems that observed while operating the machine in the field shows that there are some areas in the present design needs improvement. The overall performance of the machine could improve by incorporating following points in the newly designed manually operated sorghum uprooter,

1. Exhaustive trials of newly developed sorghum uprooter should be carried at different locations.
2. The field trials for the other crops need to be conducted to check the feasibility and performance of uprooter.
3. Gripping mechanism could be incorporated in the uprooter.

7. BIBLIOGRAPHY

Annonyms. 2012. *Discomfort Diagram*. York University.

Annonyms. 2008. *Research Review Committee meeting report (2007-08)*, Mahatma Phule Krishi Vidyapeeth, Rahuri .

Annonyms. 2010. *Agriculture Today*.

Annonyms. 2011-12. *National Research Center for Sorghum*.

Braid. 1980. *Double cut concept for Sorghum harvesting in Nigeria*. Sorghum and millets abstracts.

Corlett. E.N., Bishop. R.P. 1976.*A Technique for Assessing Postural Discomfort.*Ergonomics, Vol. 19, No.2.175-182.

Demin, T.F.1978. *The pull and lift required to remove cotton stalks in sudan*. Experiment agril.Vol. 14, page no 129.

Deshmukh B.P. 1986. *Testing and evaluation of cotton stalk uprooter*. M.Sc.Thesis, PDKV, Akola , Maharashtra.

Devnani, R. S. and M.M. Pandey, 1985. *Design, development and field evaluation of vertical conveyor reaper windrower* . *AMA* 16(2):41-52.

Kadu, V. M, A.P. Jaiswal and L.V. Gharte. 2003 . *Study of pulling force requirement for cotton stalk* . Proceedings of National Symposium on Cotton Mechanization , p 38.

Kanafoiski and Karwowski. 1976. *Agricultural machines, theory and construction. Vol. 2* Foreign scientific publication Department of the National Center for Scientific Technical and Economic information, Warsaw, Polland : 141 - 228 and 627 -726.

Kemp, D.C. and M.D.P. Matthew, 1982. *The development of cotton stalks pulling machines.* J. Agricultural Engg. Research, vol. 27, p 201.

Kepner, R. A., Baner and E.L. Barger, 1972. *Principles of farm machinery*. 2nd ed. Westpert, CT, AVI : 80 -112 & 392 -432.

Metianu, A.A, I. M. Johnson, A.J. Sewell. 1990. *A whole crop harvester for the developing cereal crop*. J. Agri. Engg., Vol.47, 187-195.

Michael, A. M. and T.P. Ojha. 1998. *Principals of Agricultural Engineering. Vol. 1*. 3rd edition, Jain Brothers, New Delhi.

Miskin, R.B, P.D. Khorade , D.S. Sonkusle and P.R. Fulzele. 1999. *Effect of tap root* *depth on pulling force of cotton stalk uprooter* . Journal of soils and crops, vol. 9, P 137.

Monroe, G. E. and Summer, R.E. Hellwing. 1986. *Pullar for plant stubble* . *Transactions of ASAE* 28 (2) : 562- 567.

Nalawade, S.M. 2000. *Development and performance evaluation of tractor operated Jowar reaper windrower*, MPKV , Rahuri, Maharashtra.

Pari (1989) *Development of sweet sorghum harvester for use under European condition* .Sorghum and millet abstracts.

Rains, G.C., J.S. Cundiff and D. H. Vaughan. 1990. *Development of a whole stalk sweet sorghum harvester.* Transactions of ASAE , Vol.33(1): 56-62.

Sumner H.R , G.E. Monroe and R.E. Hellwing. 1984. *Design elements of cotton plant puller*'. Transactions of ASAE vol. 27 , p 366.

Sumner H.R , G.E. Monroe and R.E. Hellwing. 1986. Energy in Agriculture. Vol.6, Issue 2, August 1987, Pages- 153-195.

Solanki.S.N., Ramteke. R.T.,Kawade. S.C., Gite. L.P.2006.*Ergonomic Evaluation of Hand Operated Maize Shellers* .Journal of Agricultural Engineering Vol. 43(4): October-December, 2006

Yadav. 1990. *A new design concept for animal drawn cereal harvester*. AMA, Vol.22No.4:33-60.

Yadav G.C. and K.P. Pandey. 1995. *Design parameter of sorghum and pearl millet harvester*. Journal of Agricultural Engineering, Vol. XXXII No.1-4: 32-40.

Yoshida K. 1982. *Analysis of energy requirement for serrated type sickle*. Trans. of ASAE, 7 : 57-64.

8. APPENDICES

Appendix – A

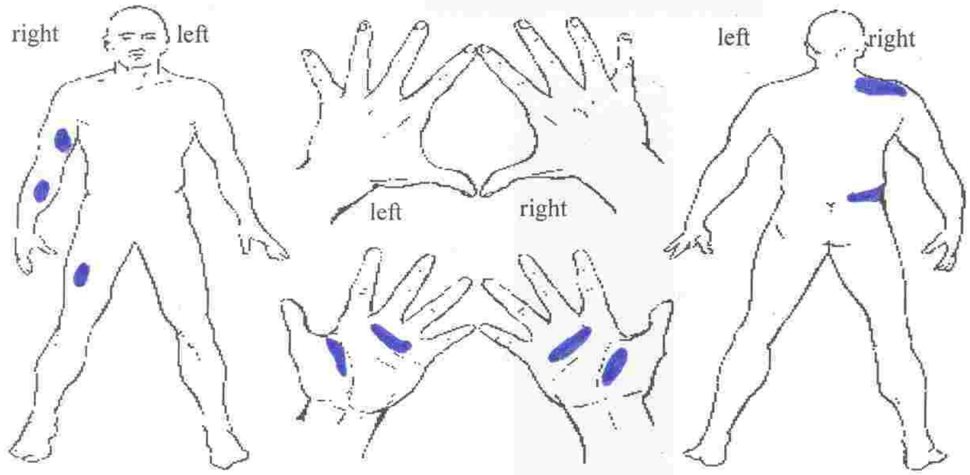
York University
Discomfort Diagram

Revised March 5, 2007

Name: Mahale Hemant Trambak (Sorghum uprooter) Date: 14/02/2012

1) Dominant Hand? ☑right ☐left ☐both

2) Shade the parts of the body where you feel discomfort.



3) For each shaded body part above, describe the discomfort in the table below.

	Body Part (circle ONE in each table cell)	Side	In the past week, number of days you were uncomfortable	Rating of discomfort when it has been at its worst in the past few days: 0 = no discomfort, 5 = unbearable pain
Body part #1	leg low back arm hand head eye neck shoulder	left right middle	1 2 3 4 5 6 7	Before work: 0 1 2 3 4 5 At work: 0 1 2 3 4 5 After work: 0 1 2 3 4 5
Body part #2	leg low back arm hand head eye neck shoulder	left right middle	1 2 3 4 5 6 7	Before work: 0 1 2 3 4 5 At work: 0 1 2 3 4 5 After work: 0 1 2 3 4 5
Body part #3	leg low back arm hand head eye neck shoulder	left right middle	1 2 3 4 5 6 7	Before work: 0 1 2 3 4 5 At work: 0 1 2 3 4 5 After work: 0 1 2 3 4 5
Body part #4	leg low back arm hand head eye neck shoulder	left right middle	1 2 3 4 5 6 7	Before work: 0 1 2 3 4 5 At work: 0 1 2 3 4 5 After work: 0 1 2 3 4 5
Body part #5	leg low back arm hand head eye neck shoulder	left right middle	1 2 3 4 5 6 7	Before work: 0 1 2 3 4 5 At work: 0 1 2 3 4 5 After work: 0 1 2 3 4 5

Appendix – B

York University
Discomfort Diagram

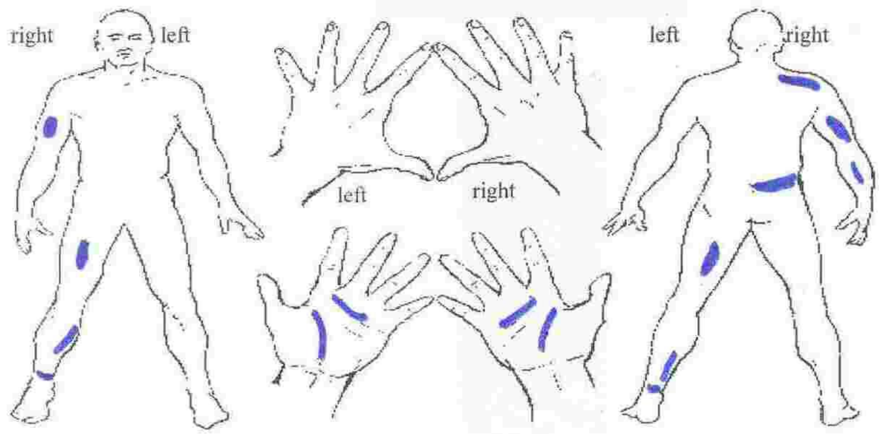
Revised March 5, 2007

Name: Yogesh Jadhav Date: 14/02/2012

(Sorghum uprooter)

1) Dominant Hand? ☑right ☐left ☐both

2) Shade the parts of the body where you feel discomfort.



3) For each shaded body part above. describe the discomfort in the table below.

	Body Part (circle ONE in each table cell)	Side	In the past week, number of days you were uncomfortable	Rating of discomfort when it has been at its worst in the past few days: 0 = no discomfort, 5 = unbearable pain
Body part #1	**leg** low back arm hand head eye neck shoulder	left **right** middle	**1** 2 3 4 5 6 7	Before work: 0 **1** 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 1 **2** 3 4 5
Body part #2	leg **low back** arm hand head eye neck shoulder	left **right** middle	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 **1** 2 3 4 5
Body part #3	leg low back **arm** hand head eye neck shoulder	left **right** middle	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 **1** 2 3 4 5
Body part #4	leg low back arm **hand** head eye neck shoulder	left **right** middle	**1** 2 3 4 5 6 7	Before work: 0 **1** 2 3 4 5 At work: 0 1 **2** 3 4 5 After work: 0 1 **2** 3 4 5
Body part #5	leg low back arm hand head eye neck **shoulder**	left **right** middle	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 **1** 2 3 4 5

Appendix – C

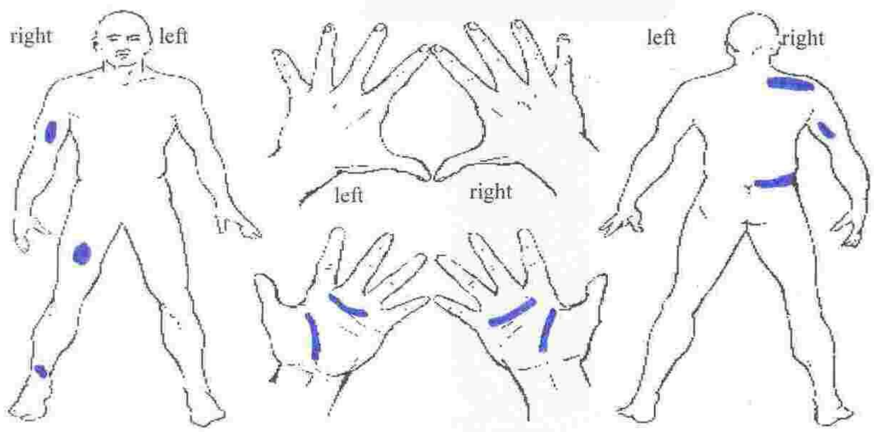
York University
Discomfort Diagram

Revised March 5, 2007

Name: Kangune Anand shivaji (sorghum uprooter) Date: 14/02/2012

1) Dominant Hand? ☑right ☐left ☐both

2) Shade the parts of the body where you feel discomfort.



3) For each shaded body part above, describe the discomfort in the table below.

	Body Part (circle ONE in each table cell)	Side	In the past week, number of days you were uncomfortable	Rating of discomfort when it has been at its worst in the past few days: 0 = no discomfort, 5 = unbearable pain
Body part #1	leg low back arm hand head eye neck shoulder	left right middle	1 2 3 4 5 6 7	Before work: 0 1 2 3 4 5 At work: 0 1 2 3 4 5 After work: 0 1 2 3 4 5
Body part #2	leg low back arm hand head eye neck shoulder	left right middle	1 2 3 4 5 6 7	Before work: 0 1 2 3 4 5 At work: 0 1 2 3 4 5 After work: 0 1 2 3 4 5
Body part #3	leg low back arm hand head eye neck shoulder	left right middle	1 2 3 4 5 6 7	Before work: 0 1 2 3 4 5 At work: 0 1 2 3 4 5 After work: 0 1 2 3 4 5
Body part #4	leg low back arm hand head eye neck shoulder	left right middle	1 2 3 4 5 6 7	Before work: 0 1 2 3 4 5 At work: 0 1 2 3 4 5 After work: 0 1 2 3 4 5
Body part #5	leg low back arm hand head eye neck shoulder	left right middle	1 2 3 4 5 6 7	Before work: 0 1 2 3 4 5 At work: 0 1 2 3 4 5 After work: 0 1 2 3 4 5

Appendix – D

York University
Discomfort Diagram

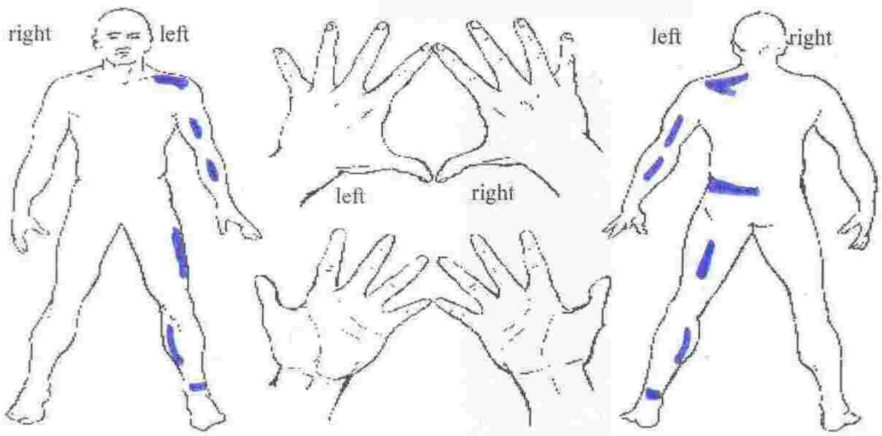
Revised March 5, 2007

Name: Gadhari Ganesh G. Date: 14/02/2012

(Sorghum uprooter)

1) Dominant Hand? ☐right ☑left ☐both

2) Shade the parts of the body where you feel discomfort.



3) For each shaded body part above, describe the discomfort in the table below.

	Body Part (circle ONE in each table cell)	Side	In the past week, number of days you were uncomfortable	Rating of discomfort when it has been at its worst in the past few days: 0 = no discomfort, 5 = unbearable pain
Body part #1	**leg** low back arm hand head eye neck shoulder	**left** right middle	**1** 2 3 4 5 6 7	Before work: 0 **1** 2 3 4 5 At work: 0 1 **2** 3 4 5 After work: 0 1 **2** 3 4 5
Body part #2	leg **low back** arm hand head eye neck shoulder	**left** right middle	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 1 **2** 3 4 5
Body part #3	leg low back **arm** hand head eye neck shoulder	left right **middle**	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 **1** 2 3 4 5
Body part #4	leg low back arm **hand** head eye neck shoulder	**left** right middle	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 1 **2** 3 4 5
Body part #5	leg low back arm hand head eye neck **shoulder**	**left** right middle	1 **2** 3 4 5 6 7	Before work: 0 **1** 2 3 4 5 At work: 0 1 **2** 3 4 5 After work: 0 1 **2** 3 4 5

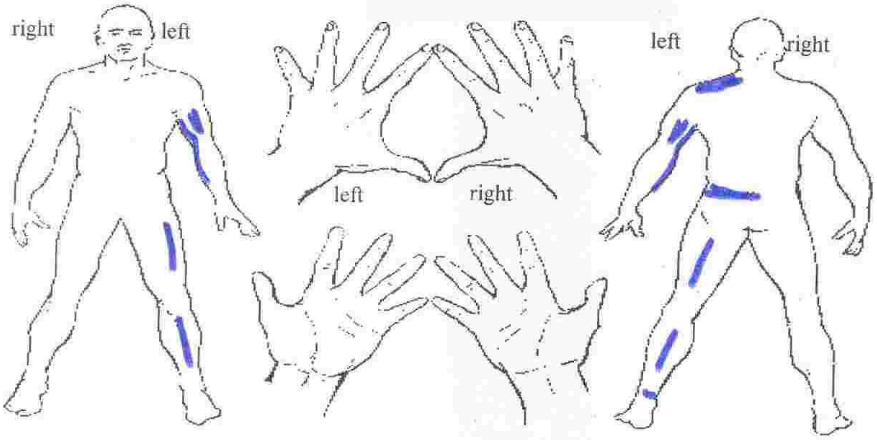
Appendix – E

York University
Discomfort Diagram
Revised March 5, 2007

Name: Patil Pradip Date: 14/02/2012
(Sorghum uprooter)

1) Dominant Hand? ☐right ☑left ☐both

2) Shade the parts of the body where you feel discomfort.



3) For each shaded body part above, describe the discomfort in the table below.

	Body Part (circle ONE in each table cell)	Side	In the past week, number of days you were uncomfortable	Rating of discomfort when it has been at its worst in the past few days: 0 = no discomfort, 5 = unbearable pain
Body part #1	**leg** low back arm hand head eye neck shoulder	**left** right middle	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 1 **2** 3 4 5 After work: 0 **1** 2 3 4 5
Body part #2	leg **low back** arm hand head eye neck shoulder	**left** right middle	**1** 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 **1** 2 3 4 5
Body part #3	leg low back **arm** hand head eye neck shoulder	**left** right middle	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 **1** 2 3 4 5
Body part #4	leg low back arm **hand** head eye neck shoulder	**left** right middle	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: **0** 1 2 3 4 5
Body part #5	leg low back arm hand head eye neck **shoulder**	**left** right middle	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 **1** 2 3 4 5

Appendix – F

York University

Discomfort Diagram

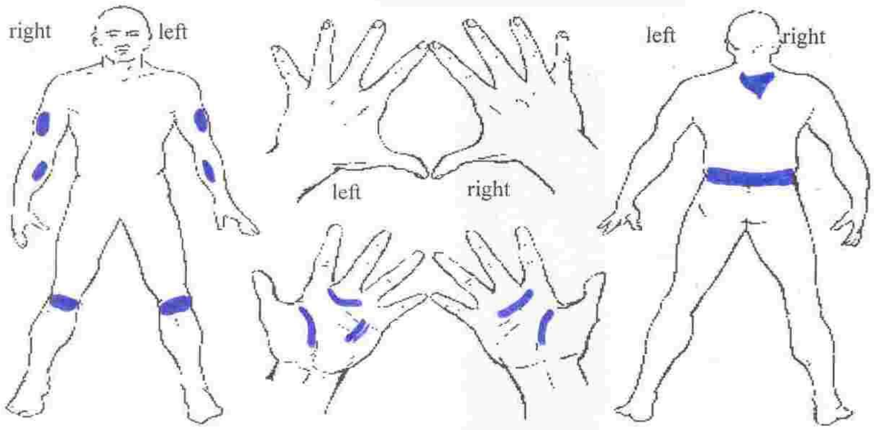
Revised March 5, 2007

Name: Mahale Hemant Trambak Date: 14/02/2012

(Manual uprooting)

1) Dominant Hand? ☑ right ☐ left ☐ both

2) Shade the parts of the body where you feel discomfort.



3) For each shaded body part above, describe the discomfort in the table below.

	Body Part (circle ONE in each table cell)	Side	In the past week, number of days you were uncomfortable	Rating of discomfort when it has been at its worst in the past few days: 0 = no discomfort, 5 = unbearable pain
Body part #1	leg low back arm hand head eye neck shoulder	left right middle	1 2 3 4 5 6 7	Before work: 0 1 2 3 4 5 At work: 0 1 2 3 4 5 After work: 0 1 2 3 4 5
Body part #2	leg low back arm hand head eye neck shoulder	left right middle	1 2 3 4 5 6 7	Before work: 0 1 2 3 4 5 At work: 0 1 2 3 4 5 After work: 0 1 2 3 4 5
Body part #3	leg low back arm hand head eye neck shoulder	left right middle	1 2 3 4 5 6 7	Before work: 0 1 2 3 4 5 At work: 0 1 2 3 4 5 After work: 0 1 2 3 4 5
Body part #4	leg low back arm hand head eye neck shoulder	left right middle	1 2 3 4 5 6 7	Before work: 0 1 2 3 4 5 At work: 0 1 2 3 4 5 After work: 0 1 2 3 4 5
Body part #5	leg low back arm hand head eye neck shoulder	left right middle	1 2 3 4 5 6 7	Before work: 0 1 2 3 4 5 At work: 0 1 2 3 4 5 After work: 0 1 2 3 4 5

Appendix – G

York University
Discomfort Diagram

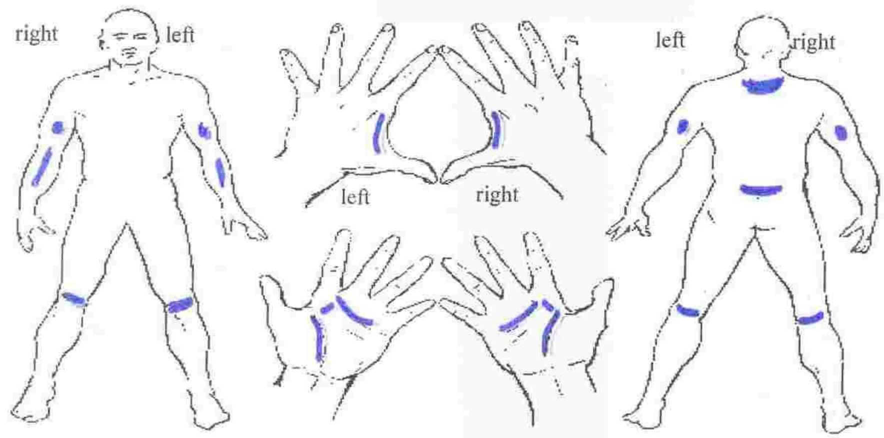
Revised March 5, 2007

Name: Yogesh Jadhav   Date: 14/02/2012

(Manual uprooting)

1) Dominant Hand? ☑right ☐left ☐both

2) Shade the parts of the body where you feel discomfort.



3) For each shaded body part above, describe the discomfort in the table below.

	Body Part (circle ONE in each table cell)	Side	In the past week, number of days you were uncomfortable	Rating of discomfort when it has been at its worst in the past few days: 0 = no discomfort, 5 = unbearable pain
Body part #1	**(leg)** low back arm hand head eye neck shoulder	left right **(middle)**	**(1)** 2 3 4 5 6 7	Before work: 0 **(1)** 2 3 4 5 At work: 0 **(1)** 2 3 4 5 After work: 0 1 **(2)** 3 4 5
Body part #2	leg **(low back)** arm hand head eye neck shoulder	left right **(middle)**	1 2 3 4 5 6 7	Before work: **(0)** 1 2 3 4 5 At work: 0 **(1)** 2 3 4 5 After work: 0 1 **(2)** 3 4 5
Body part #3	leg low back **(arm)** hand head eye neck shoulder	left right **(middle)**	1 2 3 4 5 6 7	Before work: **(0)** 1 2 3 4 5 At work: 0 **(1)** 2 3 4 5 After work: 0 **(1)** 2 3 4 5
Body part #4	leg low back arm **(hand)** head eye neck shoulder	left right **(middle)**	**(1)** 2 3 4 5 6 7	Before work: 0 **(1)** 2 3 4 5 At work: 0 **(1)** 2 3 4 5 After work: 0 1 **(2)** 3 4 5
Body part #5	leg low back arm hand head eye neck **(shoulder)**	left right **(middle)**	1 2 3 4 5 6 7	Before work: **(0)** 1 2 3 4 5 At work: 0 **(1)** 2 3 4 5 After work: 0 1 **(2)** 3 4 5

Appendix – H

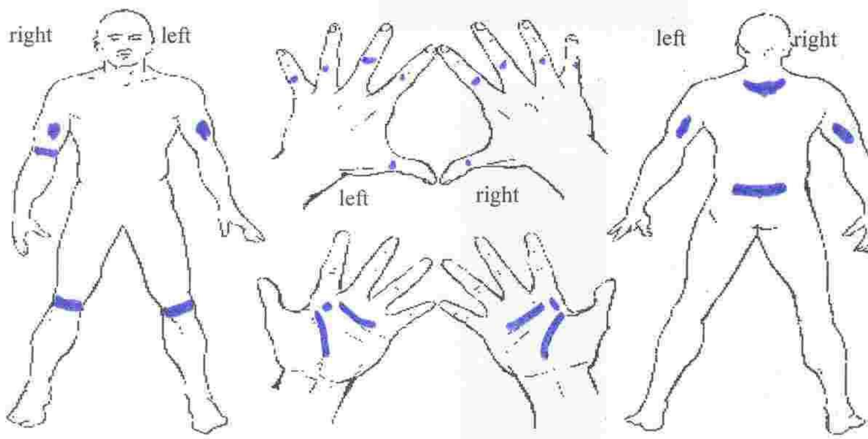
York University
Discomfort Diagram

Revised March 5, 2007

Name: Kangune Anand Shivaji (Manual uprooting) Date: 14/02/2012

1) Dominant Hand? ☑right ☐left ☐both

2) Shade the parts of the body where you feel discomfort.



3) For each shaded body part above, describe the discomfort in the table below.

	Body Part (circle ONE in each table cell)	Side	In the past week, number of days you were uncomfortable	Rating of discomfort when it has been at its worst in the past few days: 0 = no discomfort, 5 = unbearable pain
Body part #1	**leg** low back arm hand head eye neck shoulder	left right **middle**	**1** 2 3 4 5 6 7	Before work: 0 **1** 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 1 **2** 3 4 5
Body part #2	leg **low back** arm hand head eye neck shoulder	left right **middle**	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 1 **2** 3 4 5
Body part #3	leg low back **arm** hand head eye neck shoulder	left right **middle**	**1** 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 1 **2** 3 4 5
Body part #4	leg low back arm hand head eye neck **shoulder**	left right **middle**	**1** 2 3 4 5 6 7	Before work: 0 **1** 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 1 **2** 3 4 5
Body part #5	leg low back arm **hand** head eye neck shoulder	left right **middle**	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 **1** 2 3 4 5

Appendix – I

York University
Discomfort Diagram

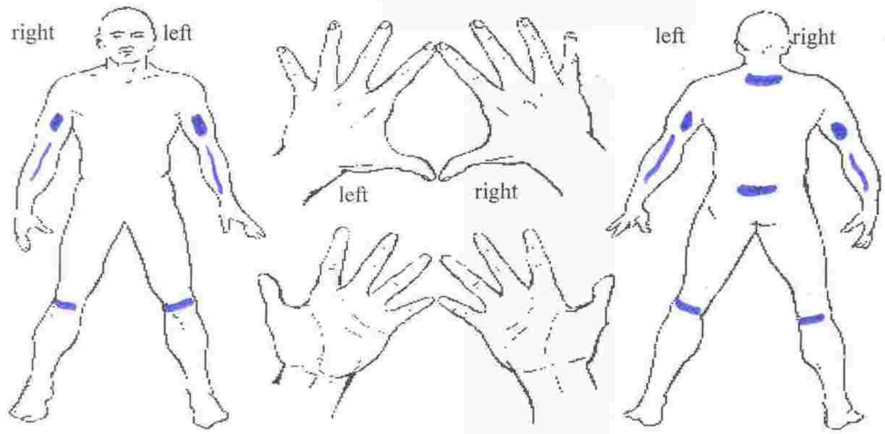
Revised March 5, 2007

Name: Gabhari Ganesh G. Date: 14/02/2012

(Manual uprooting)

1) Dominant Hand? ☐right ☑left ☐both

2) Shade the parts of the body where you feel discomfort.



3) For each shaded body part above, describe the discomfort in the table below.

	Body Part (circle ONE in each table cell)	Side	In the past week, number of days you were uncomfortable	Rating of discomfort when it has been at its worst in the past few days: 0 = no discomfort, 5 = unbearable pain
Body part #1	(leg) low back arm hand head eye neck shoulder	left right (middle)	(1) 2 3 4 5 6 7	Before work: 0 (1) 2 3 4 5 At work: 0 1 (2) 3 4 5 After work: 0 1 (2) 3 4 5
Body part #2	leg (low back) arm hand head eye neck shoulder	left right (middle)	1 2 3 4 5 6 7	Before work: (0) 1 2 3 4 5 At work: 0 (1) 2 3 4 5 After work: 0 1 (2) 3 4 5
Body part #3	leg low back (arm) hand head eye neck shoulder	left right (middle)	1 2 3 4 5 6 7	Before work: (0) 1 2 3 4 5 At work: 0 (1) 2 3 4 5 After work: 0 (1) 2 3 4 5
Body part #4	leg low back arm (hand) head eye neck shoulder	left right (middle)	1 2 3 4 5 6 7	Before work: (0) 1 2 3 4 5 At work: 0 (1) 2 3 4 5 After work: 0 (1) 2 3 4 5
Body part #5	leg low back arm hand head eye neck (shoulder)	left right (middle)	1 (2) 3 4 5 6 7	Before work: 0 (1) 2 3 4 5 At work: 0 (1) 2 3 4 5 After work: 0 1 (2) 3 4 5

Appendix – J

York University
Discomfort Diagram

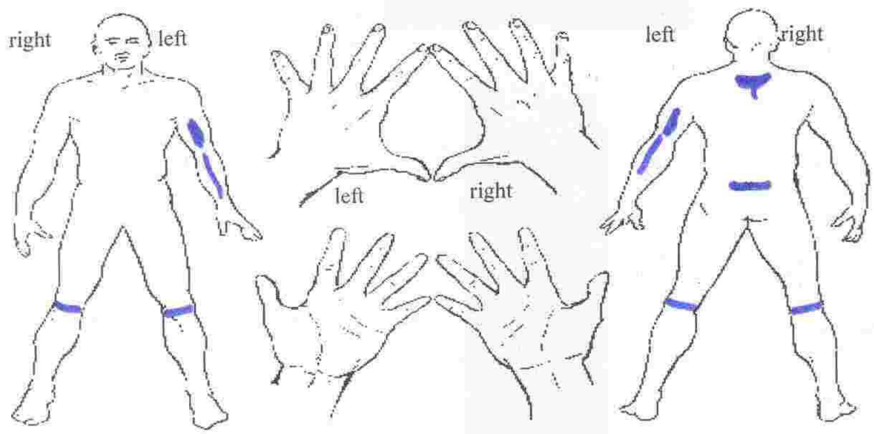
Revised March 5, 2007

Name: Patil pradip Date: 14/02/2012

(Manual uprooting)

1) Dominant Hand? ☐right ☑left ☐both

2) Shade the parts of the body where you feel discomfort.



3) For each shaded body part above, describe the discomfort in the table below.

	Body Part (circle ONE in each table cell)	Side	In the past week, number of days you were uncomfortable	Rating of discomfort when it has been at its worst in the past few days: 0 = no discomfort, 5 = unbearable pain
Body part #1	**leg** low back arm hand head eye neck shoulder	left right **middle**	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 **1** 2 3 4 5
Body part #2	leg **low back** arm hand head eye neck shoulder	left right **middle**	**1** 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 1 **2** 3 4 5 After work: 0 1 **2** 3 4 5
Body part #3	leg low back **arm** hand head eye neck shoulder	**left** right middle	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 1 **2** 3 4 5 After work: 0 **1** 2 3 4 5
Body part #4	leg low back arm **hand** head eye neck shoulder	**left** right middle	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 **1** 2 3 4 5
Body part #5	leg low back arm hand head eye neck **shoulder**	left right **middle**	1 2 3 4 5 6 7	Before work: **0** 1 2 3 4 5 At work: 0 **1** 2 3 4 5 After work: 0 **1** 2 3 4 5

Appendix - K

Details of cost of fabrication of manually operated whole stalk sorghum uprooter.

Sr. No.	Component	Material Specification	Size mm	Qty	Weight kg	Rate/kg	Amount Rs
1	Main frame	M.s. square pipe 25 x 25 x 5 mm	880	1	1.250	50	62.5
		M.s. Round pipe 25 mm dia.	250	1			
		M.s. round bar	185	1			
2	Foot pedal	M.s. flat 25 x 5 mm	420	2	0.840	50	42
			160	2			
3	Support	M.s. round bar 8 mm dia.	100	1			
4	Pedal	M.s. sheet 16 SWG	80 x 50	1			
		M.s. Flat 50 x 5 mm		1			
5	Pin	8 mm dia.	80	1 No.		8 Rs/No	8.00
6		8 mm dia.	60	1 No.		8 Rs/No	8.00
7	Rivet	6 mm dia.	15	2 No.		0.50Rs/No	1.00
8	Spring		60	2 No.		10 Rs/No	20.00
9	Paint	Red oxide		0.050 ml		170 Rs/lit	8.5
		Colour		0.050 ml		280 Rs/lit	14
		Turpentine		0.050 ml		100 Rs/lit	5
						Cost	169
10	Labour	@ 10 % of cost					16.9
11	Electricity	@ 10 % of cost					16.9
		Total cost					202.3
		i.e.					202

Appendix - L

Cost of operation of manually operated whole stalk sorghum uprooter.

1. Price to modify this uprooter P = Rs. 202 /-
2. Annual use in hrs H = 300
3. Average life A = 10 yrs
4. Junk value S = Rs 20.2 (i.e.10 % of price of uprooter)
5. Total useful hrs L = H x A = 300 x 10 = 3000

A) Fixed cost

Depreciation $= \frac{P-S}{L} = \frac{202-20.2}{3000}$ = Rs 0.0606/hrs

Interest @ 10% $= \frac{P+S}{2H} \times \frac{10}{100} = \frac{202+20.2}{2 \times 300} \times \frac{10}{100}$ = Rs 0.0370

Insurance @ 5% $= \frac{P}{H} \times \frac{5}{100} = \frac{202}{300} \times \frac{5}{100}$ = Rs 0.0336

Total fixed cost = Depreciation + Interest @ 10% + Insurance @ 5 %
= 0.0606 + 0.0370 + 0.0336
= Rs 0.127 / h.

B) Operational cost

Repair & maintenance @ 6 % of purchase price

$= \frac{P}{H} \times \frac{6}{100} = \frac{202}{300} \times \frac{6}{100}$ = Rs 0.0404 / h

Labour cost @ Rs. 150 per day of 8 hrs = 150 / 8 = Rs 18.75 / h

Total operational cost = Repair, maintenance and Lubrication + Labour cost
= 0.0404 + 18.75 = Rs 18.79 / h

C) Total cost = Fixed cost + Operational cost
= 0.127 + 18.79 = Rs 18.91 / h

Cost of operation Rs = 18.91 / h
Cost of operation Rs = 151.33 / day
Manual uprooting rate Rs = 200 / day

9. VITA

MAHALE HEMANT TRAMBAK

A candidate for the degree

of

MASTER OF TECHNOLOGY
(AGRICULTURAL ENGINEERING)

in

FARM MACHINERY AND POWER ENGINEERING

Title of thesis	:	DEVELOPMENT AND PERFORMANCE EVALUATION OF MANUALLY OPERATED WHOLE STALK SORGHUM UPROOTER
Major field	:	Farm Machinery and Power Engineering
Personal	:	Son of Sou. Jyoti and Shri. Trambak Pandurang Mahale. Born at Nashik, Tal: Nashik Dist. Nashik on 11th March, 1987.
Educations	:	Passed S.S.C. from C.D.O.Meri High school, Nashik. Passed H.S.C. from K.T.H.M.College, Nashik. Passed B. Tech. (Agricultural Engineering) degree programme in June 2009 from K.K.Wagh College of Agricultural Engineering& Technology, Nashik.
Address	:	Rajhans, P.No-84, Swami Nagar, Banganga Soc. Kishor Suryawanshi Marg, Meri, Nashik-422004. Mob. No. : 9403276970.
E.mail	:	hemantmahale2u@gmail.com