DEVELOPMENT AND TESTING OF MINI TRACTOR OPERATED COLEUS DIGGER

By

CHINNU S R

MOHAMMED FAVAZIL

RACHANA C

DEPARTMENT OF FARM POWER MACHINERY AND ENERGY

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR – 679573

KERALA

2018

DEVELOPMENT AND TESTING OF MINI TRACTOR OPERATED COLEUS DIGGER

By

CHINNU S R

MOHAMMED FAVAZIL

RACHANA C

PROJECT REPORT

Submitted in partial fulfillment of the requirements for the degree of

BACHELOR OF TECHNOLOGY

IN

AGRICULTURAL ENGINEERING

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

DEPARTMENT OF FARM POWER MACHINERY AND ENERGY

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR – 679573

KERALA

2018

DECLARATION

We hereby declare that this project, entitled, **"Development and Testing of Mini Tractor Operated Coleus Digger"** is a bonafide record of project work done by us during the course of study and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of another university or society.

Place : Tavanur

Date :

Chinnu S R

(2014-02-016)

Mohammed Favazil

(2014-02-031)

Rachana C

(2014-02-036)

CERTIFICATE

Certified that the project report, entitled, **"Development and Testing of Mini Tractor Operated Coleus Digger"** is a record of project work done jointly by **Chinnu S R, Mohammed Favazil** and **Rachana** C under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

Place :Tavanur

Date :

Dr. Jayan P R

Professor and Head
Department of Farm Power
Machinery and Energy

ACKNOWLEDGEMENT

First of all, with an open heart, we thank the **“God, Almighty”** for His invisible helping hand that guided us through the right way to pursue our journey to the completion.

It is our prerogative to express profound gratitude and respect to our guide, **Dr. Jayan P.R.,** Professor and Head, Department of Farm Power Machinery and Energy, KCAET, Tavanur for his inexplicable support and guidance throughout our endeavor.

We are also indebted to **Dr. Santhi Mary Mathew**, Dean (Agrl. Engg.), Kelappaji College of Agricultural Engineering and Technology, Tavanur for providing us with the necessary support and permissions to carry out our work with ease.

We also thank **Dr. Shaji James,** Professor and **Er. Shivaji K.P.**, Assistant Professor, Dept. of FPME, Tavanur for their valuable advice and criticism during the study.

We cannot suffice enough to thank our beloved senior and teacher, **Er**. **Younus A,** Teaching Assistant (FPME), KCAET for his sincere support, aid and continuous guidance throughout our journey till the end which were definitely a motivational thrust for us to achieve accomplishment.

Our following hearty gratitude is to all the **Technicians** in the workshop and laboratories, KCAET, for their untiring effort and dedication to the fabrication of the unit and without whom our work would never have been completed.

The **Staff and Labourers** of KCAET, are well to remembered and greatly thanked for, for their dedicated involvement in the maintenance of the field with utmost care and meticulousness.

We also wish to remember and gratify our P**arents**, who always bless us for our betterment and pray for our success.

Finally, we thank **all those,** who directly or indirectly helped us.

Chinnu S R **Muhammed Favazil** **Rachana C**

Dedicated to our beloved parents….

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Agriculture plays a vital role in the Indian economy with 54% of the population being dependent on agriculture and allied sectors for livelihood. In 2015-16, agriculture contributed to 17.4% to India’s GDP with the annual food grain production of around 253.16 MT, recording an increase of 1.14 MT as compared to 2014-15 (Anon., 2016). Among the wide varieties of food crops cultivated in India, root and tuber crops become the most significant crops after cereals. They find an important place in the dietary habits of small and marginal farmers, especially in the food security of tribal population.

Solenostemon rotundifolius, commonly known as coleus/ Chinese potato/ hausa potato is one among the minor tuber crops which is being extensively cultivated in some parts of India since past few years. This under exploited tuber crop is believed to be originated in Africa and its cultivation has now spread to Sri Lanka and South East Asia (Otuwose, *et al.* 2014). In India it is known to be widely grown in most of the homestead gardens of Kerala and Tamil Nadu. Coleus is mainly confined to laterite soils of Central Kerala and Malabar, especially in the districts of Palakkad, Trissur and Malappuram constituting an area of about 200 ha and sandy coastal soils extending to Mangalore district of Karnataka (Edison, *et al.* 2006).The area and production of coleus and other tuber crops from the records of 2016-17 are shown in table 1.1.

Table 1.1 Area and production of tuber crops in Kerala (2016-17)

Root crops	Area (ha)	Production (tonnes)
Coleus	1370	26340
Ginger	5151	77265
Sweet potato	220	3086
Turmeric	2632	6506
Tapioca	68664	2529729
Yam	6814	272560

Source: Agricultural Statistics 2016-17, Dept. of Economics and Statistics, Govt. of Kerala

Coleus thrives well in tropical and subtropical regions with well drained medium fertile soil. Ideal season of cultivation in Kerala is from July to October. Three major varieties are available, viz., Nidhi (RARS, Pattambi), Suphala (KAU) and SreeDhara. Farmers usually grow the tubers on raised beds in fields. The nursery is first raised approximately one month before planting in an area of about 500 to 600 square meters to produce cuttings required for 1 ha of main field. Vine cuttings of length 10-15 cm are planted on beds at 30cm x 15cm spacing. Intercultivation operations are also provided at required intervals (Anon., 2016).

Harvesting-manual and mechanical methods

Traditionally, coleus is harvested when haulms dry up, i.e., 4 to 6 months after planting. This is done manually by digging out the soil containing tubers using hoes, forks, spades and other conventional tools followed by their separation and collection. This has been found to be a tedious, hectic, laborious and time consuming practice. It also required proper handling to avoid cuts, breakage, bruises and injury. To overcome these setbacks farmers tend to adopt alternative method of mechanical harvesting (Younus, 2014).

Mechanical harvesting of root crops involves digging out the tubers using implements which are attached to a prime mover. The prime mover can be a power tiller, tractor, etc. A mechanical coleus harvester must ensure the quality of tubers during operation. It must also be less time consuming and must have higher efficiency of performance. A major difficulty in developing suitable harvesters arises due to the irregular geometry of the tuber and soil conditions. No specific mechanical harvesting technique has been completely successful for coleus, contradictory to other root crops such as potato and cassava.

Various models of coleus harvesters were developed in KAU. A mini tiller operated coleus harvester developed at KCAET was studied and its performance was analyzed. It consisted of a rotary slasher and a cutter bar assembly. There were several problems associated with its construction. The harvester had the following disadvantages:

- The rotating element created high vibration resulting in scattering of the uprooted tuber.
- Low ground clearance

- Non detachment of the clumps hence it couldn't be used for beds having height more than 30 cm.
- The separation of coleus after harvest was difficult.

An attempt was made to resolve the above said problems in this project. Since coleus cultivation in Kerala is widely done on raised beds, a tractor operated harvester would be more practicable than a power tiller operated one. Attempts were done to develop a harvester that uprooted the coleus tubers from the soil and leave it on the field so that farmers can pick them up conveniently. These would ensure less labour and more yield.

An ideal mechanical harvesting machine should be such that:

- It achieves a reduction in the overall production cost
- It should lead to the reduction of drudgery and tedium associated with the manual process of harvesting.
- It must achieve decrease in root losses and damage.
- The cost of the machine should be affordable to farmers and cheaper than similar imported machines.
- The materials used for fabrication should be readily available.
- The machine should be adaptable to the common varieties of root crops and changing operational parameters.

The prototype of a ginger harvester developed in TNAU was taken as the base for the research work. It consisted of oscillating fingers and digger and was driven by a prime mover. The project aimed at developing a prototype of the above said implement by replacing the prime mover with a mini tractor. With these factors in view, the project was undertaken with the following objectives:

Objectives of the study

1. To determine the physical and mechanical properties of soil and crop.
2. To develop a prototype of mini tractor operated coleus digger.
3. To test the performance of the mini tractor operated coleus digger.

CHAPTER II

REVIEW OF LITERATURE

Various research works carried out in the past related to aspects of root crop harvesting were reviewed in this chapter. Many types of root crop harvesters were developed and tested in different parts of the country. To comprehend the research towards the development of root crop harvesters, literature reviews were conducted and are grouped under the following headings.

2.1 SOIL MECHANICAL PROPERTIES

Sinclair, *et al.* (1979) conducted an error analysis which identified three components of total variance attributable to location error with respect to soil water, calibration error and instrument error. Data from three locations illustrated that the location variance is the major source of random error in the total variance of an individual estimate. The instrument error and the error introduced by the use of count rate ratio were small and contributed in a very minor way to the total variance of the mean. The analysis revealed that the nature of the relationship between the magnitude of location error and the calibration error is dependent on site heterogeneity.

Schmugge, *et al.* (1980) discussed the methods of in situ soil moisture determination including gravimetric, nuclear and electromagnetic techniques. The soil physics models that track the behavior of water in the soil in response to precipitation and evapotranspiration were also studied. A conceptual scheme was proposed for merging these approaches to an integrated system.

Erbach, (1987) reviewed the techniques for measurement of soil bulk density along with their advantages and disadvantages. It was analyzed that there were no quick, easy and accurate methods for determination of soil bulk density or soil moisture meter. However, there were several methods for each that may be used successfully.

Brandelik and Hiibner (1996) develop the electromagnetic measurement techniques of soil moisture. Three new sensors were used which improved the accuracy of exiting measurement device and extent the range applications. The first one was in situ sensor, which evaluated soil moisture down to 2.5 m with a vertical resolution of 3 m and an accuracy of 1.5 absolute volumetric water content. The second sensor measured the water content in the surface layer of the soil. Third one was moisture sensitive cable. It used the technique of time domain reflectometry and frequency domain reflectometry.

Vaz, *et al.* (2001) developed a combined penetrometer- coiled TDR probe to determine simultaneously the depth distribution of penetration resistance and water content in a soil profile. Field experiments carried out for a Yolo soil allowed the fitting of the effect of both using a combined power- exponential equation.

According to Agodzo and Adama, (2003) the water content of the soil is an important property that controls its behavior. As a quantitative measure of wetness of a soil mass, water content affects the level of compaction of soil, which is indicated by its bulk density.

Thompson, *et al.* (2007) determined lower limit values for irrigation management using continuously monitored data from volumetric soil water content (SWC) sensors. Four indices were derived from SWC data viz., daily soil water loss, the reduction in SWC during 24 hour periods, previous overnight redistribution and ADCWU normalized for reference evapotranspiration. The indices were calculated for 0 – 20 and 20 – 40 cm soil depths in four drying cycles applied to melon and tomato crops.

2.2 ROOT CROP HARVESTING

Chamen *et al.* (1979) developed a high output rotary digger capable of working in heavy soils. The most important design variable selected was bite length (250 mm) which was determined by a subjective assessment over a number of years and on a range of soils. The most effective rotor design to provide the required bite length was 4 L- shaped blades bolted on flanges.

Al- Jubouri *et al.* (1984) developed a theory for a vibratory potato digger that employed orbital vibrations. The prototype was extensively tested in ridged fields at a forward speed of 3 kmph and a digging depth of 200 mm. The draught force- velocity ratio was satisfactory but poor agreement was obtained between predicted and experimental power ratios.

Obigol *et al.* (1986) developed a prototype of single row model-2 cassava harvester. Its design involved two rows of reciprocating P.T.O. driven diggers .It dug two opposite sides of the ridge from the furrow bottom to uproot cassava tubers .The design of the gang of digger ensured a clean harvesting operation by minimizing damage to the harvested tubers. It left a well pulverized row with good tilth. The harvester operated at a forward speed of about 2.5 kmph to 4 kmph and harvesting rate was 0.25 to 0.4 ha h^{-1}.

Saquib *et al*. (1986) designed and tested a vibratory digger blade for proposed use on a sweet potato harvester. Field operations caused most damage to sweet potatoes when they were dug in dry cloddy conditions. Vibration of a digger blade produced significantly smaller clods than without vibration, which imparted less damage to the sweet potato. Reduction of bulk density of soil was more in vibratory operation of the digger blade.

Jadhav *et al.* (1992) designed and evaluated a simple low cost self-propelled onion digger windrower. It was powered by a 5 hp diesel engine mounted on the frame along with the main gear box. The digging unit consisted of sweeps fitted to the front of the frame.

Baric *et al* (1994) conducted experiments on the utilization of rotary potato digger. It was found that a rotary digger could achieve good results on small plots with various row spacing. It was simple to operate and maintain and gave good performance with less labour requirement. The optimum working speed was 4.5 km h^{-1}.

Petrov *et al* (1994) developed the perspectives of mechanical sugar beet harvester. Several sugar beet harvesters from various countries were described and their technical parameters, including the engine power, number of driving wheels and operating width were compared.

Thakur *et al.* (1994) conducted performance evaluation of four different potato lifting shares, viz., rectangular, convex, triangular fork and V- scoop types under controlled soil- bin condition for the measurement of draft and field conditions by harvesting potatoes. The draft of shares of 500 mm width when operating in silty clay loam soil at 16 % (d b) moisture content and 1.51 gm cm^{-3} dry bulk density was found maximum with rectangular share, followed by convex, triangular fork and V- scoop share. An experimental oscillatory sieve potato digger windrower was used. The maximum recovery of potatoes at the velocity ratio of 1.38 for the different shares was evaluated.

Gupta *et al.* (1995) developed an engine driven potato digger with oscillating perforated disc type blade and a soil clod separator aimed to reduce draft requirement, minimize tuber damage and human drudgery. It was powered by a two wheel, single axle 8.6 kW tractor. The harvesting efficiency of the machine was observed to be 100 % with tuber exposure percentage of 88 % and field capacity of about 0.19 ha h^{-1}.

Agbeloyea *et al.* (1998) modified and evaluated the performance of three soil loosening devices for the purpose of pre- lift soil loosening in cassava harvesting. Loosening the soil in the root zone before lifting the tubers out of the soil is very important for efficient harvesting of cassava, in terms of both lifting force reduction and prevention of tuber damage. The three devices modified were L- tine, A- tine and a combination of a curved chisel tine working at a depth of 0.1 Â m ahead of L- tine. The results indicated that L- tines were most suitable for pre- lift soil loosening.

Azizi *et al.* (2014) designed and developed a semi- mounted one- row potato digger with rotary blade. It can be connected to a rotary potato grader. The transmission was mechanical from tractor PTO to the blade by belt and pulley, gear box, chain and sprocket. Helix containing bars were used for separating the soil. The average of damaged potatoes was 4 %.

Amponsah *et al.* (2014) assessed the response of five different cassava varieties to mechanical harvesting on rigid and flat land forms. Results from field trials using a TEK mechanical cassava harvester showed that the best performance was achieved on ridged land forms which had better tuber yield and root tuber orientation. The harvester worked best on fields with minimal trash or weeds and relatively dry soils with moisture content from 12 – 16 % db.

Singh (2014) developed and evaluated the performance of a digger used for onion harvesting. Tests were conducted to check the comparative performance of developed onion digger and manual labour in the field. Digger was operated in the speed ranging from 3.76- 4.83 kmph with minimum losses at 4 kmph in first gear at a field capacity of 0.46 ha h^{-1}. An average operating depth of 7.62 cm was found to be optimum for minimum damage to the onion bulbs. The digger efficiency was found to be 89.8 %. It was found that there 58% savings in labour and 49% in cost.

Younus (2014) modified and tested a self-propelled coleus harvester attached to a mini tiller. The digger pierced at a depth of 10 -15 cm to dig out the rhizomes that lie inside the soil.

The scattered soil lying in the raised beds were then collected easily. They reported that the excessive vibrations of the slasher caused high percentage of damage to the tubers.

2.3 PERFORMANCE EVALUATION

Perdok and Kouwenhoven (1994) described the soil- tool interactions at the simplest level of integration, i.e., the process level. The initial soil condition, tool shape, tool speed and the movement of drawn and driven implements were reviewed. At the next higher levels of integration i.e., operation and treatments, the field performance of implements was discussed. Energy and labour requirements are related to seed bed quality, achieved in terms of pulverization.

The field capacity of a farm machine was the rate at which it performs its primary function, i.e., the number of hectares that can be worked per hour or the number of tones of cassava that could be harvested per hour. Measurements or estimates of machine capacities were used to schedule field operations, power units and labour, and to estimate machine operating costs. The most common measure of field capacity for agricultural machines was expressed in hectares per hour of operation (Hanna, 2001).

CHAPTER III

MATERIALS AND METHODS

In this study it was aimed to develop and test a mini tractor driven coleus digger to harvest coleus tubers grown in raised beds. Earlier, a mini power tiller operated coleus harvester was field tested and performance was evaluated. However it had several disadvantages associated with its construction. This was because it used a rotary slasher which created excessive vibration. This caused the tubers to scatter in the field which was inconvenient for the farmers to collect. Also it caused damage to the coleus and thus yield was reduced. Accordingly the prototype of TNAU model ginger harvester was studied and was modified to make it suitable for harvesting coleus.

In this chapter, the site selection, field preparation and planting of the tuber were briefly explained. The methods followed to determine the physical and mechanical properties of soil and coleus were also explained in detail.

This chapter also included the detailed explanation of the components and working of the digger. The field tests were conducted in the experimental plot for different speed and depth of operation. Time of operation, fuel consumption and harvesting capacity for different depth and speed of operation were determined. Percentage of damage and field efficiency were also calculated using standard procedures.

3.1 COLEUS PLANTING

3.1.1 Site selection

The field was selected based on the irrigation facility and availability of sun light. The soil of the selected field was lateritic in nature. A total area of 0.0640 ha was chosen in the instructional farm of KCAET of latitude 10.85^0N and longitude 75.98^0E.

3.1.2 Field preparation

The selected field was initially tilled with tractor driven rotavator to obtain a good tilth. This was followed by bed formation using KAU Bed Former. Spades were used to level the beds to suitable height. Four rows of bed each of dimension 30 x 0.60 x 0.30 m respectively as length x width x height were prepared. Coleus cuttings, each of length 15-20 cm were collected from a coleus field near Chelakkara which were about two months old.

3.1.3 Field Layout

The field was divided into two equal plots of 0.036 ha each. In each plot, beds of sizes 30 m x 0.5 m respectively as length x breadth were prepared. The height of the bed selected was 30 cm. A water channel was made in the middle of the field to ensure drainage of the study area.

3.1.5 Planting

Good quality cuttings of “Nidhi” variety of coleus was selected for planting. They were planted by horizontally laying them into the soil with erected shoots at a depth of 5cm with a spacing of 30cm x 15cm. Hence the total number of cuttings per bed was 200. The planting was done in the month of June, after the onset of the South West Monsoon.

3.1.6 Intercultural operations

The weeding was carried out, 45 days after planting along with the application of fertilizers. The topdressing was done in the ratio urea : rajaphos : phosphate at 3:2:5.

Plate 3.1 Coleus cuttings

Plate 3.2 Planting of coleus

3.2 PHYSICAL AND MECHANICAL PROPERTIES OF SOIL

The physical and mechanical properties of soil had direct and indirect influence on the interaction between soil and the implement. It also influenced the growth of the plant. Two properties, viz., moisture content and bulk density were determined. Soil samples from different parts of the experimental plot were taken. The suitable tests were conducted in the Soil and Water Laboratory at KCAET, Tavanur.

3.2.1 Moisture content

Moisture content (W) is the percentage of water in a given soil sample. It was found out by following standard test procedures. The moisture content of the sample in percent dry basis was determined by using the equation,

$$W(\%) = (Wi - Wf)/Wf \times 100 \quad \text{........ (3.1)}$$

Where,

W_i= initial weight of the soil, g

W_f= final weight of the soil, g

Moisture content during the initial stages were determined using the oven dry method. Soil samples of six different locations were collected from the experimental plot at depths 0-10 cm, 10-15 cm and 15-20 cm. A known weight of soil sample was collected in a clean container and placed in an oven under controlled temperature between 105- 110 ^{0}C for a time period of 24 hours. The experiment was replicated for each sample and the mean value was determined. The weight before and after drying were found out using an electronic weighing balance. The determination of soil moisture during crop growth helped to find out the water requirement.

In situ moisture content was also recorded before uprooting the tuber using digital soil moisture meter. The meter was inserted into the soil at a depth of 10-15 cm for about 30 seconds. The percentage of moisture content of soil was displayed in the display board and was recorded. The moisture content of the soil just before the harvesting decided the easiness of operation of the implement (Schmugge, *et al.*, 1980).

3.2.2 Bulk density

The bulk density was found out by core cutter method using the formula,

$$\rho = \left(\frac{M}{V}\right) \qquad \text{.... (3.2)}$$

Where,

ρ – Bulk density, g cm^{-3}

M – Mass of the soil, g

V – Volume of the soil, cm^{3}

Initially the volume of the cylindrical core cutter was determined by measuring its internal diameter and height. Also the empty weight of the core cutter was recorded. A small area in the experimental plot was selected and the surface was leveled. The core cutter was driven into the soil to its full depth using a rammer with a dolly placed over the top of the core cutter. The soil surrounding the core cutter was excavated using a chisel and the cutter was gently lifted without disturbing the soil in it. Top and bottom of the surface of the cutter was carefully trimmed using a straight edge. The core cutter with the soil was weighed. The bulk density was then found using equation (3.2) (Erbac, 1987).

3.1 PHYSICAL AND MECHANICAL PROPERTIES OF COLEUS

The physical and mechanical properties of coleus were important in determining the spacing between the oscillating fingers in the finger assembly. The tubers had to fall through the gaps between the fingers without considerable damage. The physical properties of the coleus, viz., size, shape and sphericity were determined using the standard test procedures.

3.3.1 Size and shape

Six coleus samples were picked at random to determine the size and shape of the tuber. The size was determined by the Vernier caliper and the shape by graphical method. The maximum length and maximum width of each coleus was measured using the caliper and the average was calculated. To determine the shape, the coleus was placed on a graph sheet and the outline was traced.

3.3.2 Sphericity

The sphericity is defined as the ratio of the diameter of the largest circumscribing sphere (mm) to the diameter of the smallest circumscribing sphere (mm). Diameter of the tuber at the larger and smaller circumscribing sphere was recorded and sphericity calculated.

$$\text{Sphericity} = \frac{D_l}{D_s} \qquad \ldots (3.3)$$

Where,

D_l = diameter of largest circumscribing circle

D_s = diameter of smallest circumscribing circle

3.4 DEVELOPMENT OF TRACTOR OPERATED COLEUS DIGGER

A TNAU model of ginger harvester operated by a power tiller was studied in detail. Its design was modified to make it suitable to uproot coleus tubers. Thus a mini tractor operated coleus digger was developed and tested. The digger was operated by a 22 hp mini tractor by obtaining the drive from the tractor p.t.o through a gear box having gear ratio of 1.6:1. The digger consisted of a frame, share, finger assembly, cam drive and connecting rods, a gear box and a drive unit. The width of operation was maintained at 50 cm. The oscillatory movement of the finger assembly was found to be advantageous for various reasons such as easy forward movement, less scattering of uprooted tubers and less damage to the tubers. The drive from the tractor p.t.o was transferred to the gear box through a universal coupling. The gear box was welded on to the main frame with the two output shafts directed sideways. These were then connected to a pair of cam drives which provided the oscillatory movement. The movement was transferred to the finger assembly through connecting rods by means of the tie rods. A pair of side fingers welded to the land sides were placed on either side to prevent the scattering of coleus outward.

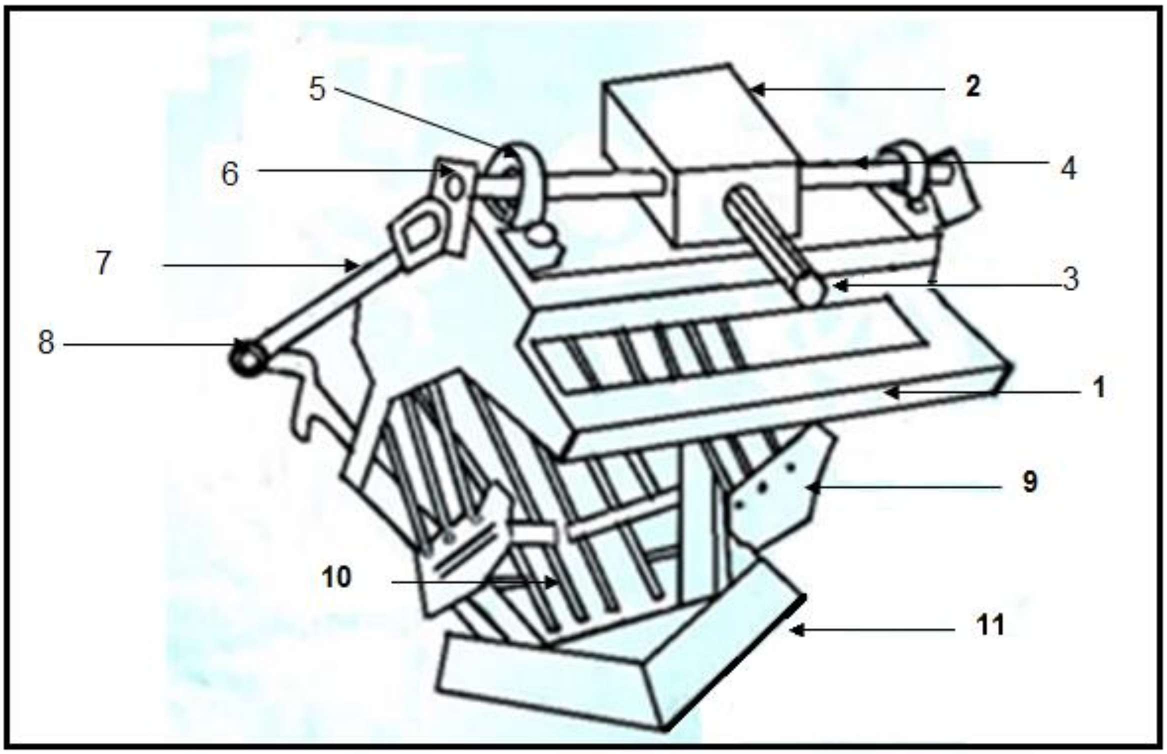

Fig.3.1. Schematic of mini tractor operated coleus digger

1. Frame
2. Gear box
3. Cam drive
4. Tie rod
5. Land side
6. Oscillating fingers
7. Share
8. Plumber block
9. P.T.O. input shaft
10. Connecting rod
11. Output shaft

Plate 3.3 Coleus digger

3.4.1 Prime mover

The prime mover was selected on the basis of its capacity to meet the power requirement for breaking the soil and uprooting the tuber. The TNAU ginger harvester used a 12 hp power tiller to harvest ginger. Also the total weight of the implement was around 80 kilograms. Taking these into consideration, VST Mitsubishi VT 224-1D tractor of 22 hp was found suitable and was selected as the prime mover. The specifications of the tractor is given in Appendix V.

3.4.2 Frame

Frame accommodated all the attachments and accessories of the digger. It was made up of mild steel of dimensions 1.05 m x 0.50 m x 0.065 m respectively, as length x breadth x height. The frame held the share and the fingers and was bolted to the three point hitch assembly of the tractor.

3.4.3 Share

The V-shaped share had an including angle of 135^0 with two arms of 25 cm each. It was made of mild steel. It was inclined at an angle of 33^0 with the horizontal surface to facilitate penetration. The penetration into the soil was achieved by the draft of the tractor and uplifted the soil along with the tubers. The share rested on a flat metal piece and was fastened by nuts and bolts.

3.4.4 Finger assembly

There were two parts of the assembly; the oscillating fingers and the land sides. The two sets of oscillating fingers, 3 fingers each, constituted the moving part of the digger. The oscillation was obtained from the drive unit. The fingers were made from MS rods of 0.01 m diameter and length 0.40 m. It was bent at the rear end to drop the soil lump on to the bed without much scattering. The fingers were drilled through square rods and welded in place.

The land sides were aligned at both sides of the share, orthogonal to the ground. It bore the side thrust imparted by the soil and prevented the scattering of soil side ward. They were 3 in number on each side. Two fingers were of length 0.30 m and lowest one was 0.40 m. They were attached at the front end to a flat metal sheet which is slightly bent outwards.

3.4.5 Cam drive and connecting rod

The cam drives connected to the output shafts of the gear box together with the connecting rods produced the oscillatory motion. The rotary motion of the gear shaft was converted to the oscillatory motion of the connecting rods by providing an eccentricity of 0.3m. The rods transferred this motion to the oscillating fingers connected to them.

3.4.6 Gear box

The gear box (Fig.3.2) was welded on the main frame with the input shaft connected to the tractor power take off and the two output shafts connected sideways to the cam drive. The gear box was necessary to provide the optimum rpm required for the operation without causing much scattering and damage. It had a reduction ratio of 1.6:1 and provided an rpm of about 340 to the output shafts. The calculation of the gear ratio of the gear box is illustrated in Appendix VI.

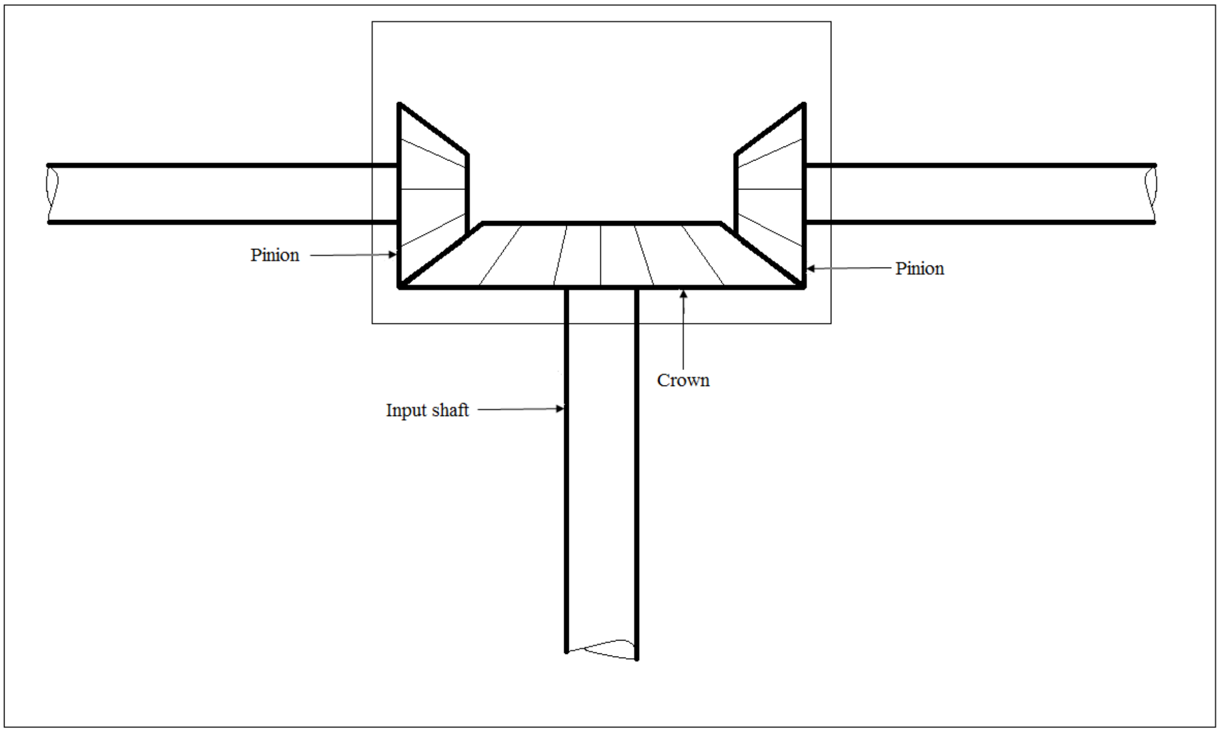

Fig 3.2. Schematic of gear box

3.4.7 Drive unit

The drive unit of the tractor provided the necessary power for the operation and consisted of the p.t.o shaft of the mini tractor and the universal coupling. The p.t.o provided two rpm, viz., 1000 and 540. The coupling was connected to the input shaft of the gear box of the implement. It also facilitated the easy movement during the lifting and lowering of the implement. The power transmission from the tractor p.t.o to the oscillatory fingers is shown in Fig.3.3.

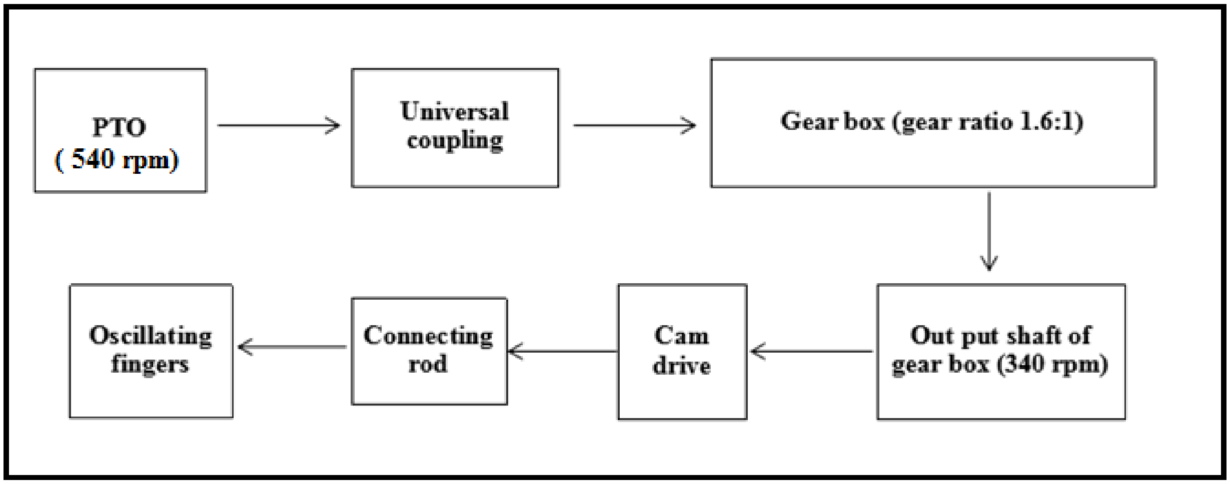

Fig.3.3. Power train of coleus digger

3.5 WORKING

The tractor PTO provided a rotational speed of 540 rpm which was reduced to 340 rpm by using the gear box. Reduction in rpm was required since higher rpm caused damage to the components. This reduced rpm was transferred to the cam drive through the output shafts. The cam drives and the connecting rods provided the required oscillatory motion to be imparted to the oscillating fingers.

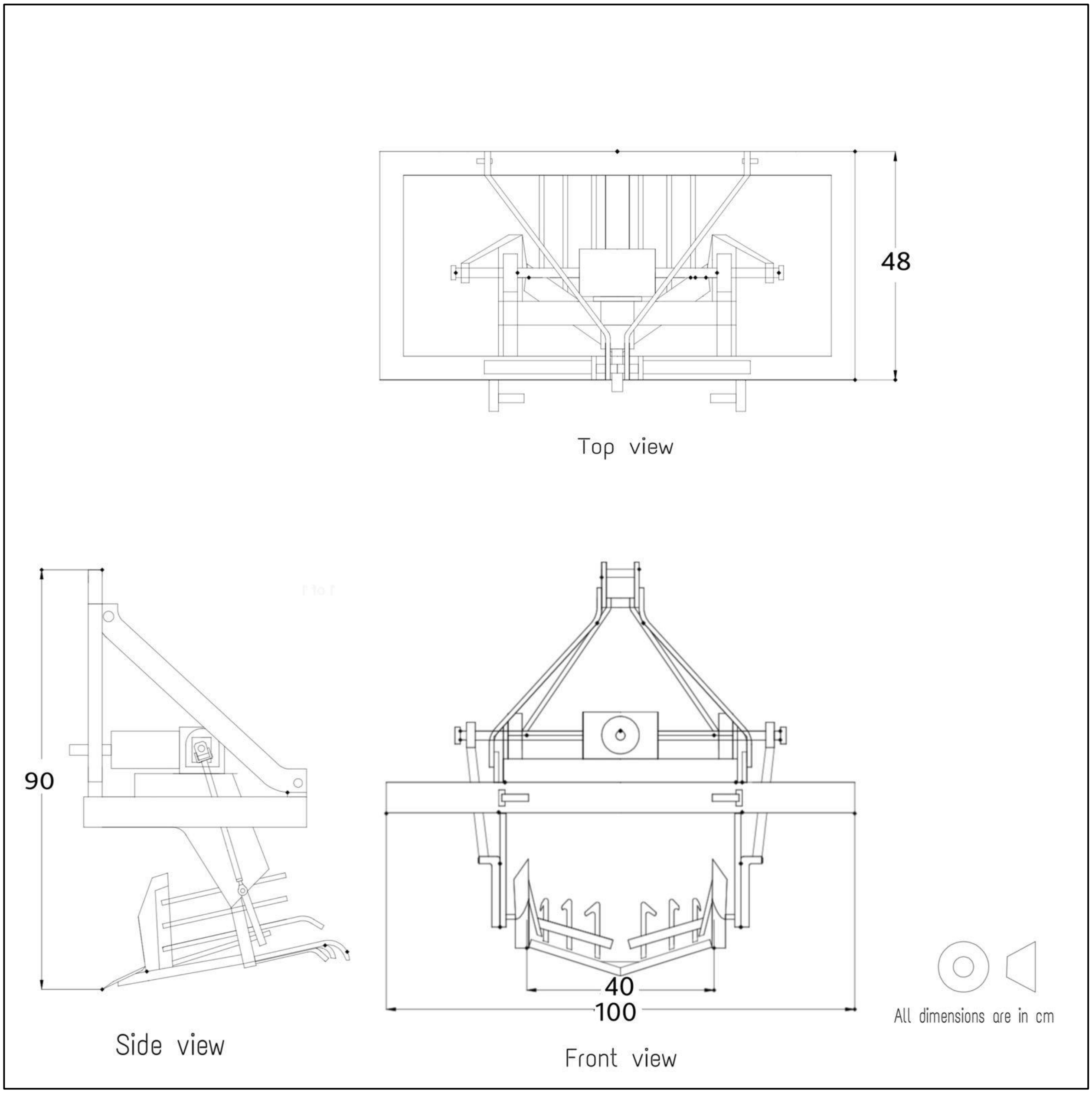

Fig.3.4 Coleus digger attached with the three point linkage of mini tractor

During operation, the two sets of oscillating fingers, hinged at the outer ends oscillated vertically while the share penetrated into the soil up to the root depth of the tubers and uprooted them. Due to the forward motion of the implement, the soil lump containing the tubers moved towards the fingers, where they got separated. Also, the fingers broke the soil lumps and deposited the tubers on the bed along the length. The side fingers with the land sides prevented the scattering of the mass side-ward.

Plate 3.4 Field testing of mini tractor operated coleus digger

Table.3.1 Specifications of the coleus digger

Components	**Specifications**
Main Frame	Dimension - 1.05 m x 0.50 m x 0.065 m
Weight of implement	81.05 kg
Share	Tilt angle- 33°, Included angle between the 2 arms (25cm each)- 135°, cutting width- 50 cm
Finger assembly	Diameter- 10 mm, Oscillating fingers: Length- 40 cm, 2 sets (3 fingers each), land sides: 2 sets (3 fingers each)
Cam drive	2 No., Eccentricity- 30 mm
Connecting rod	2 No., length- 40 cm
Gear box	Gear ratio- 1.6 : 1, 2 pinions and 1 crown

3.6 SELECTION OF VARIABLES

Several parameters such as bed width, bed height, operating speed and depth of operation affected the performance of the digger for uprooting the tuber from soil. The bed width and height were kept the same for all the beds. Testing was carried out in two different speeds and operating depths. The speed of operation was varied at 1.0, 1.5 and 2.0 kmph. The depth of operation selected were 10 cm and 15 cm. These parameters were optimized to achieve maximum efficiency of the digger in the laterite soil for a bed width of 60 cm and a bed height of 30 cm.

The observations were statistically analysed using two way analysis of variance using F-test. The various factors and their levels are furnished in the Table 3.2.

Table 3.2 Factors selected for two way analysis of variance

Soil type	**Bed width (cm)**	**Bed height (cm)**	**Speed of operation (kmph)**	**Depth of operation (cm)**
Laterite	60	30	1	10
			1.5	20
			2	
Replications – 3				

Total number of treatments = 1 x 1 x 3 x 2 = 6

Total number of experiments = 6 x 3 = 18

3.6.1 Speed of operation

The speed of operation determined the thrust acted on the finger assembly exerted by the soil mass and the uprooted coleus. The tuber yield obtained also varied with the change in the speed of operation. Three speeds were selected, viz., 1.0 kmph, 1.5 kmph and 2.0 kmph respectively.

3.6.2 Depth of operation

The depth of operation affected the draft of the implement and the performance of the machine. Various levels of depth of operation were selected viz., 10 and 15 cm for the study.

3.7 PERFORMANCE EVALUATION OF COLEUS HARVESTER

The performance of the tractor operated coleus digger was evaluated in the experimental plot in the instructional farm of K.C.A.E.T, Tavanur during the month of November. The testing was carried out for the determination of time of operation, fuel consumption and harvesting capacity with respect to various independent parameters. The parameters selected were respectively speed of operation viz., 1.0, 1.5 and 2.0 kmph and depth of operation viz., 10 and 15 cm. The actual field capacity, theoretical field capacity, field efficiency and percentage of damage of the coleus were calculated using standard procedures.

3.7.1 Time of operation

The time taken to operate the machine for different speeds of operation and depths of were observed using a stop watch. The results were statistically analysed using two way ANOVA.

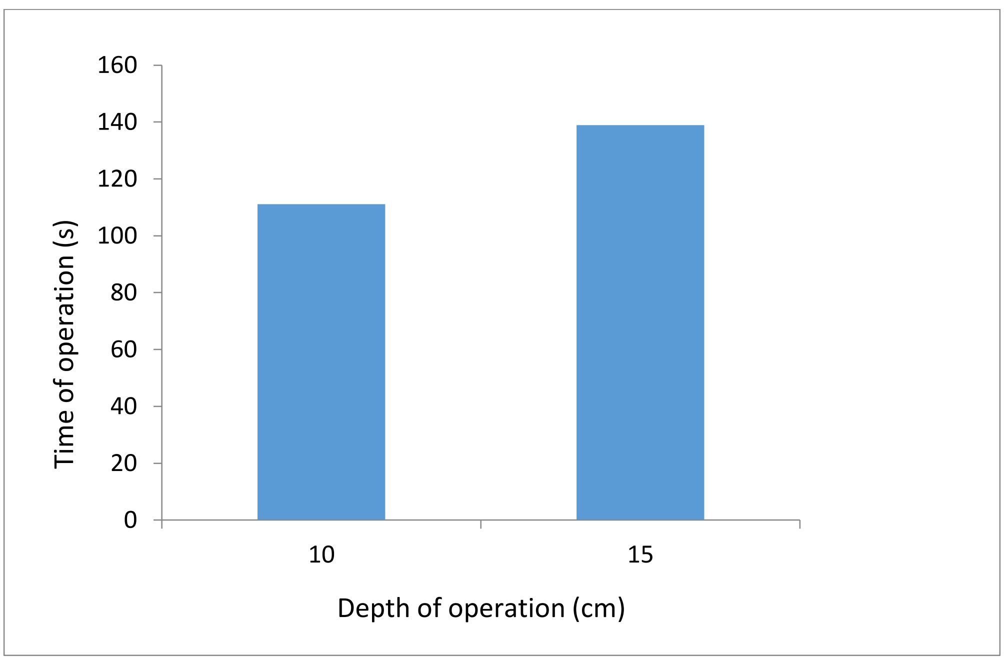

Fig.3.5. Variation of time of operation with respect to depth of operation

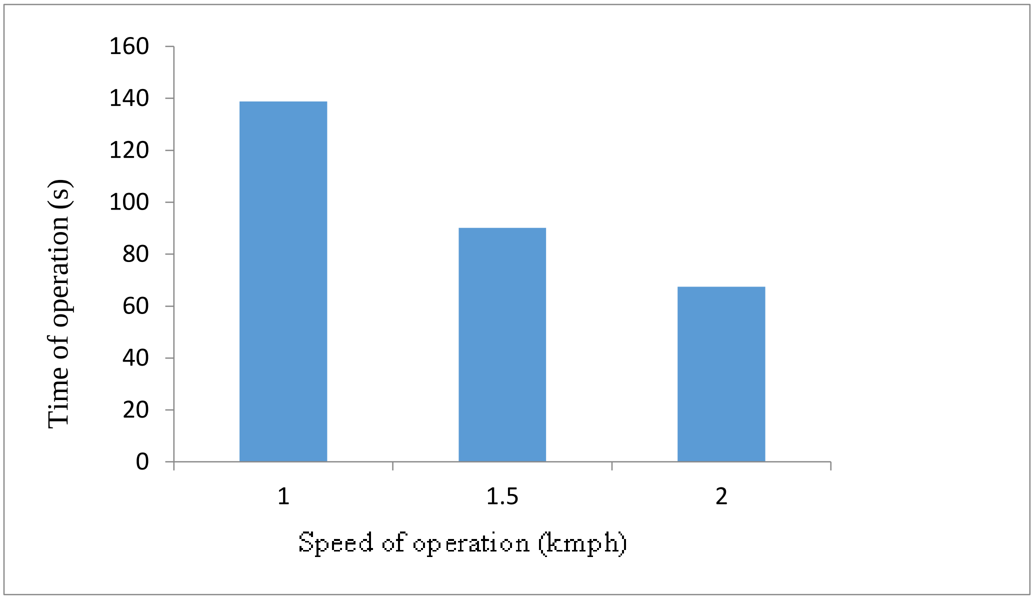

Fig.3.6. Variation of time of operation with respect to speed of operation

3.7.2 Fuel consumption

The fuel consumption of the tractor was found out using top fill method. The tractor with the implement was placed on a level ground and the fuel tank was fully filled. It was then operated for the selected area and brought back to the same level ground. A known quantity of fuel was filled using a 1000 ml graduated measuring cylinder until the tank got filled. Thus the fuel consumed by the tractor engine for operating the implement was recorded. The results were statistically analysed using two way ANOVA.

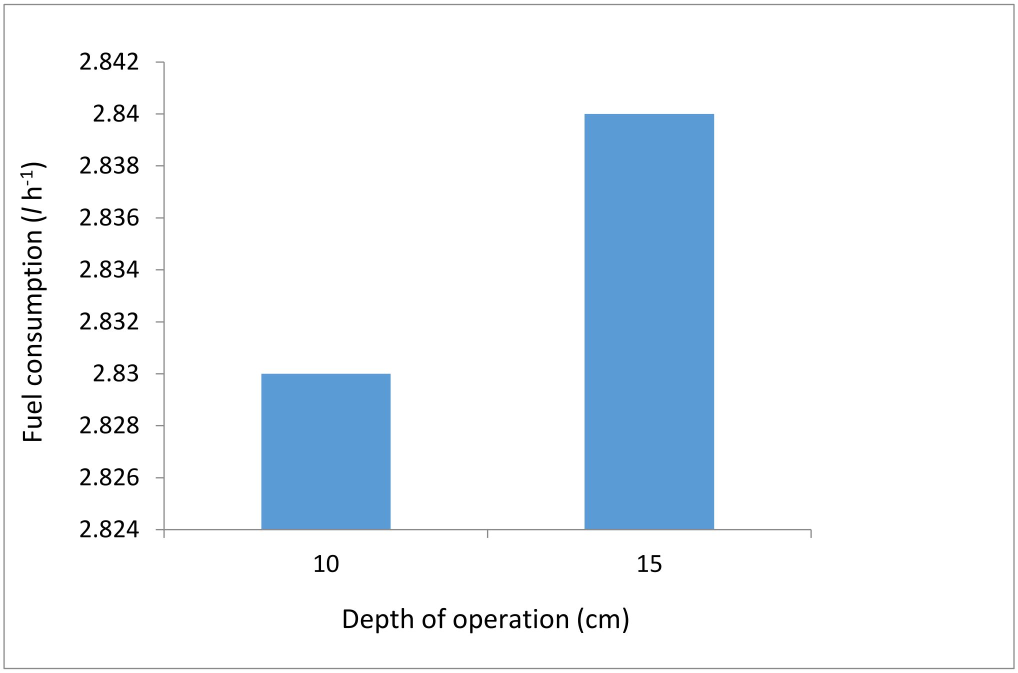

Fig.3.7 Variation of fuel consumption with respect to depth of operation

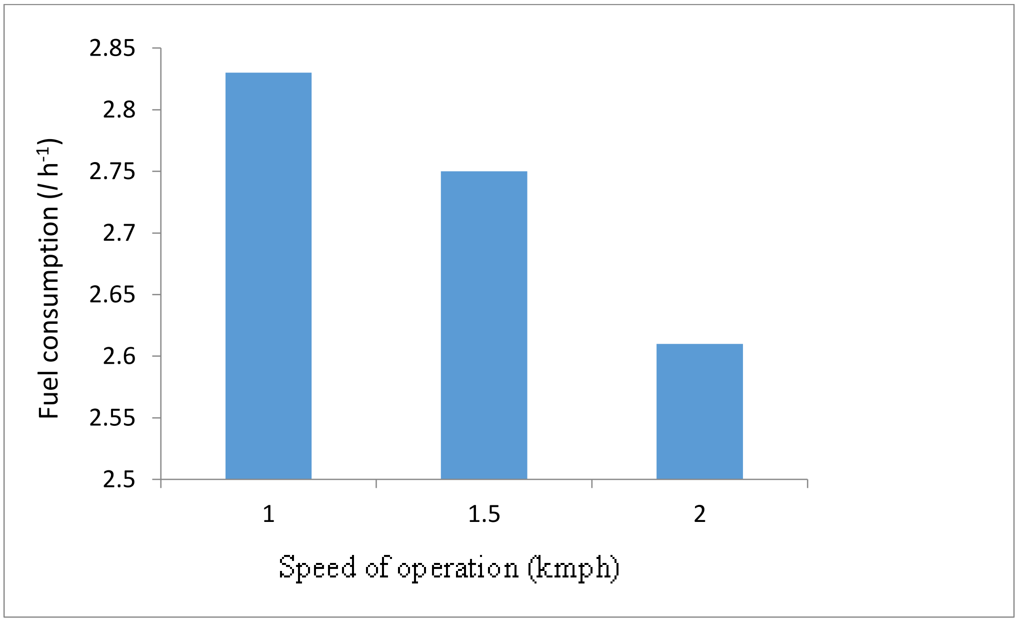

Fig.3.8. Variation of fuel consumption with respect to speed of operation

3.7.3 Harvesting capacity

The harvesting capacity of the implement was determined by weighing the total amount of coleus collected after operation and dividing by the total time of operation. The results were statistically analysed using two way ANOVA.

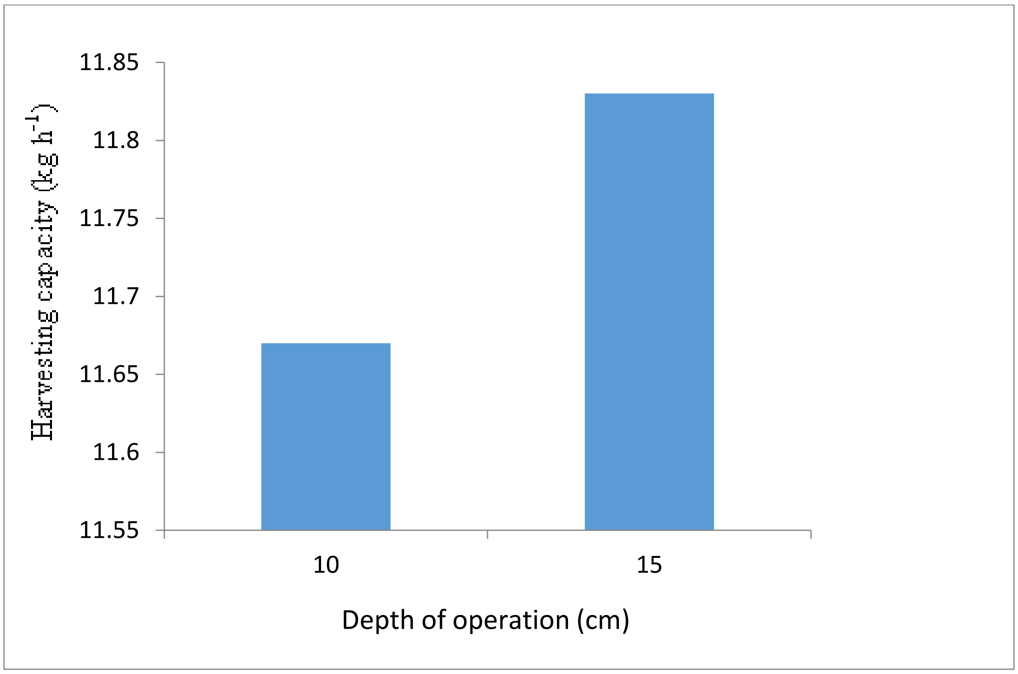

Fig.3.9 Variation of harvesting capacity with respect to depth of operation

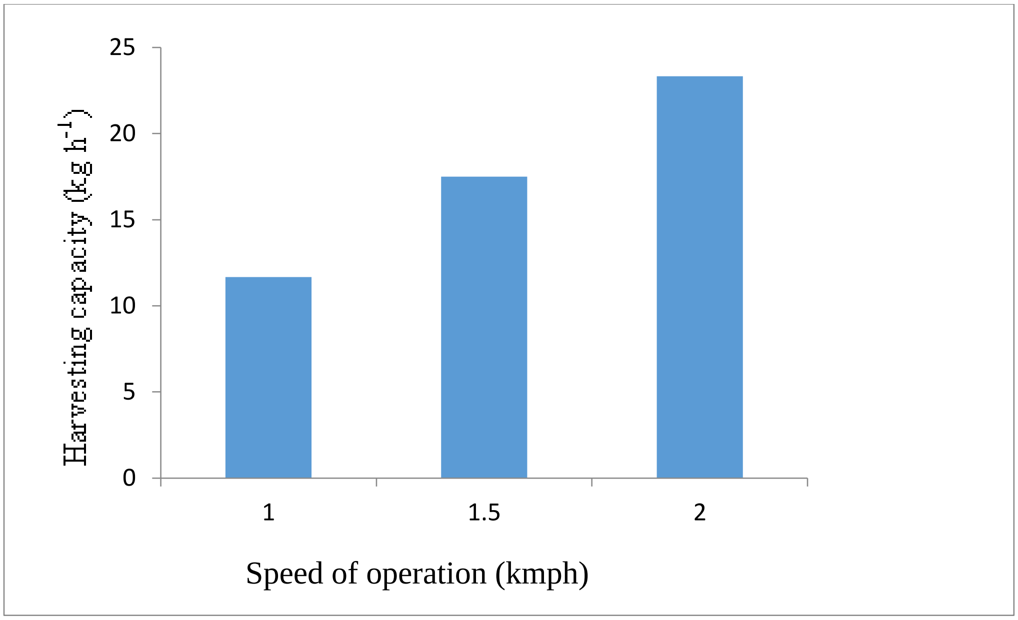

Fig.3.10 Variation of harvesting capacity with respect to speed of operation

3.8 PERCENTAGE OF DAMAGE

It represented the damage of the tubers occurring due to cutting by blade or bruising during the harvest. According to farmers, damage to the coleus occurred when the whole roots did not come out while harvesting, which was unsuitable for selling. After harvesting, damaged tubers were separately weighed using an electronic weighing balance. The percentage of damage of coleus during the operation was calculated by the equation:

$$Damage\ (\%) = \frac{Mass\ of\ damaged\ coleus\ (kg)}{Total\ yield\ (kg)} \times 100 \qquad \ldots.(3.4)$$

3.9 FIELD EFFICIENCY

Field efficiency (FE) is the ratio of theoretical field capacity to the actual field capacity. Actual field capacity (AFC) was determined by recording the time taken to harvest a predetermined specified area. The theoretical field capacity (TFC) was calculated as per the equation,

$$TFC = \frac{SW}{10000}\ \text{ha h}^{-1}$$

Where,

S = Speed of operation of machine, $m.h^{-1}$

W = Width of operation of machine, m

Field efficiency (FE) in percentage was calculated by the equation:

$$FE = \frac{AFC}{TFC} \times 100$$

3.10 COST ECONOMICS

Based on the materials used and the labour requirement for the fabrication of the coleus harvester, the cost of operation was calculated. The saving in cost in the field operation with coleus harvester was worked out in comparison with the conventional method of harvesting coleus. The capacity of the manual labourers for the harvesting (man-hours ha^{-1}) was determined by recording the total time taken to harvest the coleus.

CHAPTER 1V

RESULTS AND DISCUSSION

This chapter deals with the analysis of the field experiments carried out to evaluate the performance of the mini tractor operated coleus digger. Various parameters were measured and the results were statistically analysed using the two way analysis of variance by F-test. The results and inferences are explained in detail in this chapter.

4.1 PHYSICAL AND MECHANICAL PROPERTIES OF SOIL

Physical properties viz., the moisture content and bulk density which influenced the performance of the coleus digger were determined. The moisture content is an important property which determines the soil compactness. More compact soil was observed to be more difficult to operate. The bulk density is another important property which influences the water holding capacity of the soil during the growth of the tuber.

4.1.1 Moisture content

Moisture content was determined as percentage by weight by two methods, viz., oven drying method and in situ method. The average moisture content from the oven dry method was found out as 29.43 per cent. The recorded values and a sample calculation is given in Appendix I. The average in situ moisture content was recorded by the soil moisture meter and was found out as 11.67 per cent. It was observed that the soil must be fairly dry for easy operation of the implement. Higher moisture content resulted in sticking of soil on to the fingers and the share. It also affected the forward movement of the implement and thereby reducing the yield. Thus an optimum moisture content of about 12 per cent was found to be suitable for the easy operation of the implement.

4.1.2 Bulk density

The bulk density of the soil in the experimental field was found out by core cutter method. The mean bulk density of the soil was found to be 1.81 g cm^{-3}. The observations and calculations are given in Appendix II. It was observed that with an increase in the bulk density of soil, the porosity decreases and hence the water holding capacity increases. Higher amount of water in the soil during the harvesting was observed to be unfavourable for the operation of the digger.

4.2 PHYSICAL PROPERTIES OF COLEUS

The physical and mechanical properties of the coleus *viz*., size, shape and sphericity were found out using standard test procedures. These properties were important in determining the load bearing capacity of the implement during operation. The performance of the machine is also affected by these properties.

4.2.1 Size of coleus

The size of coleus was determined using Vernier calipers. The maximum and minimum lengths were measured. The observations and calculations are given in Appendix III. The average maximum length of a tuber was found out as 4.83 cm and the average maximum width was 2.75 cm.

4.2.2 Shape of coleus

The shape of coleus was determined using graph paper as explained in section 3.3.1. The shape of coleus variety 'Nidhi' was almost oblong. The shape of the coleus was an important parameter that determined the convenience of collecting it from the soil. Very small tubers became unnoticed in the soil whereas oblong tubers were easy to notice and for collection. The tracing of the tubers on graph paper is shown in Fig. 4.1.

Plate.4.1 Coleus collected after harvesting

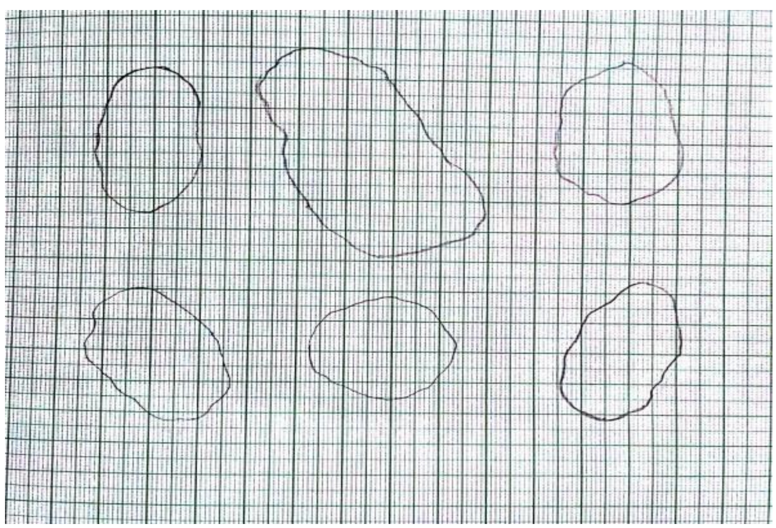

Fig. 4.2 Shape of coleus

4.2.3 Sphericity

This parameter influenced the falling of coleus tubers on to the bed after they were lifted by the finger assembly. The average maximum and minimum sphericity calculated were 2.08 and

1.13 respectively. The calculations are given in Appendix IV. The sphericty influenced the spacing of the fingers to ensure the tubers untrapped between the fingers.

4.3 PERFORMANCE EVALUATION

The field performance of coleus digger was evaluated at Instructional Farm, KCAET, Tavanur during November 2017. The field testing of the digger was conducted to find out time of operation, fuel consumption and harvesting capacity with respect to operating speed and depth of operation. The results for different levels of the parameters were statistically analysed. The performance of damage and field capacity were also determined.

4.3.1 Time of operation

The observations for the time taken to uproot the coleus with respect to the operating speed and depth of operation is given in Appendix VII. The analysis based on these observations was carried out by two way analysis of variance using F-test. The ANOVA table showing the calculation results are shown in Table 4.1. It was observed that the speed and depth of operation had a significant effect on the time taken to dig out coleus. The detailed procedure of the statistical analysis is presented in Appendix VII. The results inferred that more the operation in progressive depths, more time for uprooting than shallow depths. This may be due to more resistance offered by the soil at larger depths.

Table 4.1 ANOVA for the effect of speed and depth of operation on time of operation (s)

Source	DF	SS	MSS	F_c	F_t
Speed of operation (kmph)	2	4310.3119	2155.2	81.06	19.00
Depth of operation (cm)	1	585.7	585.7	22.03	18.51
Error	2	53.17	26.585		
Total	5	4949.185			

CV = 0.3229   Level of significance = 5%

The operating speed also had a direct influence on the time of operation. Higher speed offered less time to uproot the coleus. It was also inferred that the time taken for operation was maximum when the digger was operated at 1.0 kmph and a depth of 15 cm. The minimum time was taken at a speed of 2.0 kmph and a depth of 10 cm. However the yield of operation varied with variation in speed and depth.

4.3.2 Fuel consumption

The fuel consumption was determined as explained in section 3.8.2. The statistical analysis based on these observations were carried out by two way analysis of variables. The ANOVA table showing the variation of fuel consumption with respect to the speed and depth of operation is depicted in Table 4.2. The results showed that the treatments provided, i.e., operating speed and depth of operation had no considerable effect on the fuel consumption of the mini tractor driven coleus digger at 5 per cent level of significance. It was also inferred that the effects of the treatments on the fuel consumption were not significant.

Table 4.2 ANOVA for the effect of speed & depth of operation on fuel consumption (*l* ha^{-1})

Source	DF	SS	MSS	F_c	F_t
Speed of operation (kmph)	2	0.0186	0.0093	5.47	19
Depth of operation (cm)	1	0.007	0.007	4.117	18.51
Error	2	0.0034	0.0017		
Total	5	0.029			

CV = 0.0286 Level of significance = 5%

Thus, it is concluded that the speed of operation or the depth of operation were not significant factors with regards to the fuel consumption by the tractor. This may be due to the fact that the fuel consumed by the tractor to operate is dependent on time taken for operation and not on speed and depth.

4.3.3 Harvesting capacity

The harvesting capacity of the tractor driven coleus digger was the weight of the uprooted coleus with respect to the time taken for each operating speed and depth of operation. The observations for the harvesting capacity for the operating speed of 1.0, 1.5 and 2.0 kmph and for the depths 10 and 15 cm were recorded and statistically analysed using two way analysis of variance. The result of the analysis is shown in Table 4.3.

Table 4.3 ANOVA for the effect of speed & depth of operation on harvesting capacity (kgh^{-1})

Source	DF	SS	MSS	F_c	F_t
Speed of operation (kmph)	2	1293.421	646.74	2.00	19.00
Depth of operation (cm)	1	331.229	331.229	1.02	18.51
Error	2	0.0034	0.0017		
Total	5	0.029			

CV = 0.2732 Level of significance = 5%

The results showed that the harvesting capacity did not have any considerable variation with respect to the operating speed of 1.0, 1.5 and 2.0 kmph. The effect of the treatment of operating width on the harvesting capacity were also not significant. This is inferred from the fact that the calculated F- value is lesser than the F- value from the statistical table for 5 per cent level of significance. There was only a little change in the harvesting capacities obtained at the depths of 10 and 15 cm.

Thus it was observed that both the operating speed and the depth of operation did not influence the harvesting capacity of the coleus digger. This may be due to the inherent characteristics of the tubers. The tuber do not penetrate deeper into the soil. Hence negligible amount of tubers may be present at depths more than 15 cm.

4.4 PERCENTAGE OF DAMAGE

The procedure to determine the percentage of damage of coleus were illustrated in the section 3.9. The damaged coleus was identified as those with cuts, bruises and damages that make them unsuitable to be sold. Under these conditions, it was found out that the number of damaged coleus collected were negligibly small. It was almost one damaged among 100 tubers collected. Also the scattering of the tubers away from the bed was also found negligible. This clearly indicated that the mini tractor operated coleus digger did not produce damaged coleus. This may be due to the oscillatory motion of the implement which produced lesser impact on the coleus than due to its rotary motions.

4.5 FIELD EFFICIENCY

The field capacity of the mini tractor operated coleus digger was the ratio of the actual field capacity to the theoretical field capacity. The actual field capacity was calculated by determining the total area harvested and the total time taken for the harvest. It was observed that the total time taken to harvest an area of 0.0072 ha was 0.19 hours. Hence the actual field capacity of the digger was found to be 3.65 x 10^{-2} ha h^{-1}. The theoretical field capacity was determined as explained in section 3.9. It was found to be 4.1 x 10^{-2} ha h^{-1}. The calculation of the field efficiency is presented in Appendix VIII. The field efficiency of the digger was found out as 89 per cent.

4.6 COST ECONOMICS

The field capacity of the coleus digger was found out as 0.0365 ha h^{-1}. The manual harvesting of coleus was carried out using spades. At the present wage rate of Rs 650 per day, the total cost of operation of harvesting by manual method is Rs 31,250 per hectare. By mechanical harvesting using the mini tractor driven coleus digger, the total cost of operation was estimated as Rs 16,400 per hectare. Hence the savings on harvesting by tractor operated coleus digger over the conventional method was found to be about Rs 14,850 per hectare. The detailed cost analysis of the coleus digger is given Appendix IX.

CHAPTER V

SUMMARY AND CONCLUSIONS

Solenostemon rotundifolius, commonly called as coleus / Chinese potato/ hausa potato is a minor tuber crop widely cultivated in the homestead gardens of Kerala and Tamil Nadu. In Kerala, coleus is extensively cultivated in the districts of Palakkad, Thrissur and Malappuram. It grows well in the regions with well drained medium fertile soil. In Kerala, the ideal cultivation is from July to October every year. The farmers grow the tubers on raised beds in fields. Nursery is generally raised one month before planting. This is followed by planting the cuttings of length 10-15 cm on beds of spacing 30 x 15 cm. Traditionally coleus is harvested manually when haulms dry up. The tools used are hoes and spades. This is time consuming and labourious and require proper handling to reduce damage of coleus. Hence farmers prefer for mechanical harvesting to save time and cost. Several models of mechanical coleus harvesters were developed in KAU. However, the results were not satisfactory because of the higher damage of tuber caused by the excessive vibration. Thus a mini tractor operated coleus digger was developed that uprooted the coleus tubers and left on the bed itself which can then be conveniently collected by farmers.

An area of 0.0640 ha in the instructional farm of KCAET was selected as the study area based on irrigation facility and availability of sun light. The selected field was tilled with a rotovator followed by making beds using the KAU Bed Former. Four rows of bed of dimension 30 x 0.50 x 0.30 m respectively as length x breadth depth were prepared. Good quality cuttings of "Nidhi" variety were selected and planted into the beds at a depth of 5 cm.

Various physical and mechanical properties of the soil were determined both prior to and during uprooting of the coleus. The moisture content of the soil was determined conventionally by oven dry method at a temperature of 105°C to 110°C for 24 hours. Soil samples were collected from six different parts of the field at depths 0- 10cm, 10-15cm and 15-20cm. The soil moisture content during the time of operation was also determined using a soil moisture meter. The moisture meter was inserted into the soil at a depth of about 10- 15 cm for about 30 seconds. The moisture content displayed was recorded. The bulk density of the soil was determined using the core cutter method. The core cutter was driven into the soil at different places of the experimental plot using a rammer. The weight of the core cutter with the soil was recorded and the bulk density was determined.

The physical properties of coleus such as shape, size and sphericity were determined using appropriate methods. The size of the coleus tubers were determined using Vernier calipers and the shape by the graphical method. The sphericity was determined by recording the larger and smaller diameters of the tuber.

The coleus digger was developed as an attachment to a 22 hp mini tractor to uproot the coleus from raised beds and leave it in the soil itself. It consisted of a frame, share, finger assembly, cam drive and connecting rods, gear box and a drive unit. The width of operation was maintained at 50 cm. Oscillatory motion was provided to the finger assembly which was found advantageous because it caused less scattering of the tubers. All the attachments and accessories were accommodated by the frame of dimension 1.05 x 0.50 x 0.065 m. The V-shaped share made contact with the soil first and penetrated into the soil to uplift the soil along with tubers. There were two sets of fingers, oscillating fingers and side fingers. The oscillatory motion created the necessary movement to separate the soil and tubers. The separated tubers then get deposited on the soil. The oscillatory motion was provided to the fingers by means of cam drives and connecting rods. The cam drive was connected to the output shaft of the gear box and converted its rotational motion to the oscillatory motion of the fingers. Tie rods were used between connecting rods and fingers to facilitate this power transmission.

The performance of the coleus digger was tested and evaluated in the experimental plot of the instructional farm of KCAET, Tavanur. Trials were conducted for operating speed of 1.0, 1.5 and 2.0 kmph and depth of operation of 10 and 15 cm. the number of experiments were eighteen. The observations were statistically analysed using two way analysis of variance. The performance evaluation of the digger was carried out for time of operation, fuel consumption and harvesting capacity for different depth of operation and operating speed. The percentage of damage and the field efficiency were also found out.

The performance of the digger for time taken (s) to dig out coleus revealed that the time taken for operation was maximum when the digger was operated at 1.0 kmph at a depth of 10 cm whereas the minimum time was observed for the operating speed of 2.0 kmph at a depth of 15 cm. The fuel consumption for uprooting coleus was found out same for the combinations of operating speed and depth of operation. The effect of treatments on the fuel consumption was not significant. The harvesting capacity of the coleus digger was also found as the same for all the treatments. The weight of coleus did not differ much at depths of 10 and 15 cm. The percentage of damage of coleus due to the operation of the digger was little. The percentage of damage for the different operating speed and depth of operation was negligible.

The field capacity of the coleus digger was 0.0365 ha h^{-1}. The area covered by manual method is about 6.2 x 10^{-5} ha h^{-1}. At the present wage of Rs 500 per day, the total cost of operation by manual method is about Rs 31,250 per ha. By mechanical harvesting using the mini tractor operated coleus digger, the total cost of operation was about Rs 16,400 per ha. Hence the savings over conventional method was Rs 14,850 per ha. The filed efficiency of the mini tractor operated coleus digger was calculated to be 89 per cent.

Future works

The main concern regarding the development of the mini tractor operated coleus digger is the actual bed size at which the farmers grow coleus in fields. The bed width is almost 1.0 m with a bed height of 50 cm. The mini tractor operated coleus digger cannot be operated in such fields. However, with respect to percentage of damage and easiness of operation, the coleus digger operated with a tractor having greater than 35 hp is a better option.

REFERENCES

Al-Jubouri, K.A.J. and McNulty, P.B. 1984.Potato digging using orbital vibration. *J. Agric. Engng. Res.* 29:73-82.

Agbetoyea, L.A.S., Kilgourb, J. and Dysonb, J., 1998. Performance evaluation of three pre- lift soil loosening devices for cassava root harvesting. *Soil Tillage and Results*.48 (4): 297-302.

Agodzo, S.K. and Adama, I. (2003). Bulk density, cone index and water content relations for some Ghanaian soils. Kwame Nkrumah University of Science and Technology, Kumasi-Ghana.

Amponsah, S.K., Bobobee, E.Y.H., Agyare, W.A., Okyere, J.B., Aveyire, J., King, S.R. and Sarkodie- Addo, J. 2014. Mechanical cassava harvesting as influenced by seed bed preparation and cassava variety. *Applied Engineering in Agriculture.* 30(3): 391-403.

Azizi, P., Dehkordi, Sakenian, N. and Farhadi, R. 2014. Design, construction and evaluation of potato digger with rotary blade. *Certetări Agronomice în Moldov*. Vol. XLVII, 3:159.

Anonymous, 2016. Package of Practices, Kerala Agricultural University, Thrissur.

Baraic, J., Stefanele, E., and Lulcac, P. 1994.Utilization of rotary potato digger. Proceedings of 22 International meeting on Agricultural Engineering conference, Croatia, Europe.

Brandelik, A. and Hibner C.1996.Soil moisture determination – accurate, larger and deep. *Phys.Chem. Earth*. 21(3): 157-160

Chamen, W.C.T., Cope, R.E. and Patterson, D.E. 1979. Development and performance of a high output rotary digger. *J. Agric. Engng. Res.* 24: 301-318.

Erbach, C.D. 1987. Measure of soil bulk density and moisture. *Transactions of the ASAE*.30 (4): 922-931

Edison, S., M. Unnikrishnan, Vimala, B., Pillai, Santha, V., Sheela, M.N., Sreekumari, M.T., and Abraham, K. 2006. Biodiversity of Tropical Tuber Crops in India. Central Tuber Crop Research Institute, Thiruvananthapuram. pp: 11-12.

.

Gupta, C.P. and Wolf, D. 1995. Engine driven potato digger with oscillating blade for small farm use. Submitted to The Office of the Science Advisor, U.S. Agency for International Development.

Hanna, M. 2001.Estimating Field Capacity of Field Machines. Cooperative Extension Service, Iowa State University of Science and Technology, PM 696, pp 14.

Jadhav, R.V and Gharte. 1992. Design, development, and performance evaluation of an onion digger windrower. AMA, 26 (2).35-38.

Obigol, E.U. 1986. Single row Model-2 cassava harvester.*AMA*.22 (2):63-66.

Otuwose, A.E., Jayeola, A.A., Bashir, A.A and Blessing, J.M. 2014. Exo- morphology of vegetative parts support the combination of *Solenostemonrotundifolius (*Poir) J.K. Morton with *Plectranthusesculentus*N.E.Br. Natal (Lamiaceae) with insight into infra specific variability. *AAB Bioflux*6 (1): 16-17.

Perdok, U.D. and Kouwenhoven, J.K. 1994. Soil- tool interaction and field performance of implements. *Soil Tillage Research.*30 (2): 283-326.

Petrov, G.D., Karienko, A.V. and Nanaeko, A.K. 1994. Perspective of mechanical sugar beet harvesting. Sakharraya Svelta, Russia, no.9. pp: 5-9.

Sinclair, D.F. and Williams, J. 1979. Components of variance involved in estimating soil water content change using a neutron moisture meter. *Australian J. Soil Res.* 17(2): 237-247.

Schmugge, T.J., Jackson, T.J. and McKim, H.L. 1980. Survey of methods for soil moisture determination. *Wiley Online Library*.

Saqib, G.S. and Wright, M.E. 1986. Vibratory diggers for harvesting seed potatoes in cloddy soils. *J. Agric. Engng. Res.* 34:53-61.

Singh, Mahesh Chand. 2014. Development and performance evaluation of a digger for harvesting onion (*Allium cepa*L.).*Internat. J. Agric. Engg.*, 7(2): 391-394.

Thakur, T.C. and Tiwari, P.S. 1994.Soil bin investigation and field performance evaluation of lifting shaves used on potato harvester. J. Agric Engg. 31(9). pp: 19-21.

Thompson, R.B., Gallardo M., Valdez L.C. and Fernandez, M.D. 2007. Determination of lower limit for irrigation management using in situ assessments of apparent crop water uptake made with volumetric soil water content sensors. *Agricultural Water Management*.92: 13-28

Vaz, C. M. P., Bassoi, L. H. and Hopmans, J. W., 2001.Contribution of Water content and Bulk density to field Penetration Resistance as measured by a Combined Cone penetrometer – TDR Probe. *Soil and Tillage Research*, 60: 35-42.

Younus, A., 2014. Modification and testing of a coleus harvester. Unpublished Mtech Thesis. Kelappaji College of Agricultural Engineering and Technology, Tavanur.

APPENDIX I

Determination of moisture content

Mass of container, m_1	Mass of container + wet soil, m_2	Mass of container + dry soil ,m_3	Moisture content, $\frac{m2-m3}{m3-m1}$	Moisture content in percentage
24.70	54.70	47.31	0.32	32.00
28.74	58.74	52.92	0.24	24.07
30.50	60.50	53.62	0.29	29.75
22.83	52.83	45.92	0.30	30.00
25.67	55.67	48.40	0.32	32.00
36.58	66.58	59.87	0.28	28.80

Sample calculations:

Mass of container, m_1 (g) = 24.70

Mass of container + wet soil, m_2 (g) = 54.70

Mass of container + dry soil, m_3 (g) = 47.31

Moisture content (%) $= [\frac{m2-m3}{m3-m1}]$ x 100

$= [\frac{54.70-47.31}{47.31-24.70}]$

=0.32 x100

Moisture content (%) = 32.00

APPENDIX II

Determination of bulk density of soil

Mass of core cutter, (gm)	Mass of core cutter + wet soil, (gm)	Mass of wet soil, (gm)	Height of core cutter, (cm)	Internal diameter, (cm)	Volume, (cm^3)	Bulk density, (g/cm^3)	Bulk unit weight, (kN/m^3)
1000	2800	1800	12.5	10	981.25	1.834	18.00
1000	2750	1750	12.5	10	981.25	1.783	17.49
1000	2780	1780	12.25	10	981.25	1.814	17.79

Sample calculations:

Mass of core cutter, gm = 1000

Mass of core cutter + wet soil, gm = 2800

Mass of wet soil, gm = 1800

Height of core cutter, cm = 12.5

Internal diameter, cm = 10

Volume, cm^3 = 981.25

Bulk density, g/cm^3 $= \frac{Mass}{volume}$

$= 1.834$

APPENDIX III

Size of coleus

Number	Length (cm)	Width (cm)
Sample 1	4.8	2.3
Sample 2	7.0	3.4
Sample 3	4.6	2.7
Sample 4	3.5	3.1
Sample 5	4.5	2.7
Sample 6	4.6	2.3

APPENDIX IV

Determination of sphericity

Sl. No.	Diameter of largest circumscribing circle, (cm)	Diameter of smallest circumscribing circle, (cm)	Sphericity
Sample 1	7.0	3.4	2.06
Sample 2	4.8	2.3	2.08
Sample 3	4.6	2.7	1.70
Sample 4	3.5	3.1	1.13
Sample 5	4.5	2.7	1.67
Sample 6	4.6	2.3	2.00

APPENDIX V

Specifications of the mini tractor

Make and model	Mitsubishi Shakthi VT 224-1D
Engine	V3D, 4Stroke, Diesel
Horse power	22
No. of cylinders	3
Cubic capacity	2940 cc
No. of gears	6 Forward and 2 reverse
Brake	Water proof internal expanding shoe type
Power take off	SAE std spline shaft, 2speed
	690,1020 rpm @ 3000 engine rpm
Tyres	Front 5- 12, Rear 8- 18
Fuel tank capacity	18 L
Cooling system	Water cooled radiator with compensatory tank
Overall dimension	
i. Total dry weight	740 kg (without ballast weight)
ii. Wheel base	1420 mm
iii. Overall length	2540 mm
iv. Overall width	1085 mm
v. Ground clearance	190 mm
vi. Turning radius a. With brake b. Without brake	 2100 mm 2500 mm

APPENDIX VI

Determination of speed of output shaft

Specifications of gear box,

No of teeth on pinion gear	= 16
No of teeth on crown gear	= 10
Speed reduction ratio of gear box	= 1.6 : 1
Speed of input shaft (PTO), rpm	= 540
Therefore, speed of output shaft, rpm	$= \frac{540}{1.6} = 337.5$
Rounded value	= 340 rpm

APPENDIX VII

Determination of effect of variables on harvesting

Time of operation (s)

Depth of operation (cm)	Speed of operation (kmph)								
	1 kmph			**1.5 kmph**			**2 kmph**		
10 cm	110.73	115.31	107.29	72	73.41	70.92	50	54	58
15 cm	140.28	139.49	136.84	92.35	89.5	88.51	68.31	66.9	67.29

Sample calculations:

F test (two-way ANOVA)

Let H_0: The treatments have no effect on the time of operation

H_1: The treatments have significant effect on the time of operation

(i) T = sum of all observations

= 111.1 + 72.11 + 54 + 138.87 + 90.12 + 67.5

= 533.7

(ii) N = total number of observations = 6

(iii) TSS = sum of squares of all observations $-\frac{T^2}{N}$

$= \sum x_i^2 - \frac{T^2}{N}$

$$= 111.1^2 + 72.11^2 + 54^2 + 138.87^2 + 90.12^2 + 67.5^2 - \frac{533.7^2}{6}$$

= 4949.185

(iv) SST = sum of square due to treatments

$$= \left(\frac{(\sum x_1)^2}{n_1} + \frac{(\sum x_2)^2}{n_2} + \cdots - \left(\frac{T^2}{N}\right)\right)$$

$$= \frac{(111.1 + 138.87)^2}{2} + \frac{(72.11 + 90.12)^2}{2} + \frac{(54 + 67.5)^2}{2} - \frac{533.7^2}{6}$$

= 4310.3119

(v) SSB = sum of squares due to blocks

$$= \left(\frac{(\sum x_1)^2}{n_1} + \frac{(\sum x_2)^2}{n_2} + \cdots - \left(\frac{T^2}{N}\right)\right)$$

$$= \frac{(111.1 + 72.11 + 54)^2}{3} + \frac{(138.87 + 90.12 + 67.5)^2}{3} - \left(\frac{533.7^2}{6}\right) = 585.7$$

(vi) SSE = sum of squares due to error

$= TSS - (SSB + SST)$

= 4949.185 - (585.7 + 4310.3119) = 53.17

(vii) b = no. of blocks

(viii) t = no. of treatments

(ix) MST = mean square due to treatments

$$= \frac{SST}{no.of\ treatments - 1}$$

$$= \frac{4310.31}{3 - 1} = 2155.2$$

(x) MSB = mean square due to blocks

$$= \frac{SSB}{no.of\ blocks - 1}$$

$$= \frac{585.7}{2 - 1} = 585.7$$

(xi) MSE = mean square due to error

$$= \frac{SSE}{(b-1)(t-1)}$$

$$= \frac{53.17}{1 \times 2} = 26.585$$

(xii) Calculated values

F_T $= \frac{MST}{MSE}$

$$= \frac{2155.2}{26.585} = 81.06$$

F_B $= \frac{MSB}{MSE}$

$$= \frac{585.7}{26.585} = 22.03$$

From statistical table,

$$F_T = F_{(t-1,(t-1)(b-1))} = F_{(2,2)} = 19 \text{ and}$$

$$F_B = F_{(b-1,(t-1)(b-1))} = F_{(1,2)} = 18.51$$

Here the calculated value of F_T and F_B are greater than the table value.

Therefore reject H_0 and accept H_1.

APPENDIX VIII

Determination of field efficiency of coleus digger

Total area covered	= 0.0072 ha
Total time taken to harvest	= 0.19 hr
Field capacity	$= \frac{0.0072}{0.19}$
	= 0.0365 ha h-1
Theoretical Field capacity	$= \frac{W \text{ x } S}{10}$
	$= \frac{0.50 \text{ x } 0.82}{10}$
	= 0.041 ha h-1
Field efficiency	= 89 %

APPENDIX IX

Cost analysis of the mini tractor operated coleus digger.

1. Mini tractor (VST MT 224)

A. Basic information

(i)	Cost of the mini tractor, Rs	:	370000
(ii)	Useful life, year	:	10
(iii)	Hours of use per year	:	400
(iv)	No.of skilled labours required	:	1
(v)	Rate of interest	:	10%
(vi)	Salvage value(10% of investment cost)	:	37000
(vii)	Field capacity of coleus harvester, ha h^{-1}	:	0.0365
(viii)	Fuel requirement, *l* h^{-1}	:	2.2

B. Various costs

I. Fixed cost

(i) Depreciation cost per year, Rs : $\frac{initialcost - salvagevalue}{usefullife}$

: $\frac{370000-37000}{10} = 33300$

(ii) Interest on investment per year, Rs : $\left(\frac{(costofminitractor + salvagevalue)}{2}\right) x interestrate$

: $\left(\frac{370000+37000}{2}\right)$ x $0.10 = 20350$

(iii) Taxes, insurance and sheltering per year : (cost of mini tractor) x 0.03

: 11100

(iv) Total fixed cost per year, Rs : 33300 + 20350 + 11100

: 64750

(v) Total fixed cost per hour, Rs : $\frac{Total fixed cost per year}{hours of use per year}$

:161.8

II. Variable cost

(i) Repair and maintenance per hour, Rs : $\frac{cost of minitractor \text{x } 0.05}{400}$

: $\frac{370000\text{x } 0.05}{400}$ = 46.25

(ii) Fuel cost per hour, Rs : Fuel requirement x rate of fuel

: 148.5

(iii) Cost of lubricant per hour, Rs : Fuel cost x 0.30

: 44.5

(iv) Labour cost per hour, Rs : 150

(v) Total variable cost per hour, Rs : 148.5 + 44.5 + 150 + 46.25

: 389.25

III. Total cost per hour, Rs : Fixed cost + variable cost

: 162 + 389.25 = 551.25

2. Coleus digger

A. Basic information

(i) Cost of the coleus digger, Rs : 45,000

(ii) Useful life, year : 10

(iii) Hours of use per year : 200

(iv)	Rate of interest	: 7 %
(v)	Salvage value (10 % of investment cost)	: 4500
(vi)	Field capacity of coleus digger, ha h^{-1}	: 0.0365

B. Cost calculation.

I. Fixed cost

(i) Depreciation cost per year, Rs : $\frac{initialcost-salvagevalue}{usefullife}$

: $\frac{45000-4500}{10}$

: 4050

(ii) Interest on investment per year, Rs : $(\frac{initialcost+salvagevalue}{2})$ x Interest rate

: $\frac{45000+4500}{2}$x 0.07

: 1732.5

(iii) Taxes, insurance and shelter per year, Rs : cost of implement x 0.03

: 45000 x 0.03

: 1350

(iv) Total fixed cost per year, Rs : 4050 + 1732.5 + 1350 = 7132.5

(v) Total fixed cost per hour, Rs : $\frac{fixedcostperyear}{workinghoursperyear}$

: $\frac{7132.5}{200}$ = 36

II. Variable cost

(i) Repair and maintenance per hour, Rs : $\frac{45000}{200}$x 0.05 = 11.25

III. Total cost per hour, Rs : Fixed cost + variable cost

$: 36 + 11.25 = 47.25$

Total cost per hectare, Rs

$$:\frac{totalcostperhourforcoleus\,uprooter + minitractor}{fieldcapacity}$$

$$: \frac{47.25+551.25}{0.0365} = 16397.26$$

Round to the value, Rs : 16,397.00

Cost for manual harvesting is Rs 12,500 per acre

Total manual cost per hectare = Rs 31,250

DEVELOPMENT AND TESTING OF MINI TRACTOR OPERATED COLEUS DIGGER

By

CHINNU S R

MOHAMMED FAVAZIL

RACHANA C

ABSTRACT

Submitted in partial fulfillment of the requirements for the degree of

BACHELOR OF TECHNOLOGY

IN

AGRICULTURAL ENGINEERING

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

DEPARTMENT OF FARM POWER MACHINERY AND ENERGY

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR – 679573

KERALA

2018

ABSTRACT

Solenostemon rotundifolius, commonly known as coleus/ Chinese potato/ hausa potato is an under exploited minor tuber crop grown extensively in several parts of India. In Kerala it is widely grown in districts of Palakkad, Thrissur and Malappuram. The coleus is usually grown in raised beds by planting the cuttings after the onset of South West Monsoon. The growing period of coleus in Kerala is from June to October. Manual harvesting involves digging out the tubers using spades and forks which is found to be time consuming and tedious. A coleus digger attached to a mini tractor was developed and its performance was tested in the instructional farm, KCAET, Tavanur. The performance of the digger was tested for various parameters such as time of operation, fuel consumption and harvesting capacity. The independent variables selected were operating speed and depth of operation. Determination of percentage of damage of the coleus tubers and the field efficiency were also carried out. The results were analysed statistically using two way analysis of variance. It was inferred that different operating speed and depth of operation had a significant effect on the time of operation of the digger. However, the fuel consumption and harvesting capacity showed little effect on the selected variables. The percentage of damage of coleus was negligible and the field efficiency was found to be 89 per cent. Cost analysis was also carried out for the mini tractor operated coleus digger based on the total cost of materials and labour requirements. There was a saving of 40 per cent in cost for the digger in comparison with manual harvesting.