MODIFICATION AND TESTING OF A COLEUS HARVESTER

By

YOUNUS. A
(2013 - 18 - 111)

THESIS
Submitted in partial fulfillment of the requirement for the degree of

MASTER 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 - 679 573
KERALA
2015

DECLARATION

I hereby declare that this thesis entitles **"MODIFICATION AND TESTING OF A COLEUS HARVESTER"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society

Tavanur

Date: 15/09/2015

YOUNUS. A

(2013-18-111)

Dr. Jayan, P.R
Associate Professor and Head
Department of Farm Power Machinery and Energy
Kelappaji College of Agricultural Engineering and Technology
Kerala Agricultural University
Tavanur, Malappuram, Kerala

Date: 15.9.15

CERTIFICATE

Certified that this thesis entitled **"MODIFICATION AND TESTING OF A COLEUS HARVESTER"** is a record of research work done independently by **YOUNUS. A (2013-18-111)** 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 him.

Tavanur

Dr. Jayan, P.R
Chairman
Advisory Committee

CERTIFICATE

We, the undersigned, members of the advisory committee of **Mr. YOUNUS. A.,** a candidate for the degree of Master of Technology in Agricultural Engineering majoring in Farm Power and Machinery agree that the thesis entitled **"MODIFICATION AND TESTING OF A COLEUS HARVESTER"** may be submitted by **Mr. YOUNUS. A.,** in partial fulfillment of the requirement for the degree.

Dr. Jayan P.R.
(Chairman, Advisory Committee)
Assoc. Professor & Head
Dept. of FPME
K C A E T, Tavanur

Dr. Jyothi M L
(Member, Advisory Committee)
Professor (Horticulture)
RARS, Pattambi

Dr. Sureshkumar, P. K
(Member, Advisory Committee)
Assistant Professor
Dept. of Agri. Engineering
CoH, Vellanikkara

Er. Renuka Kumari J
(Member, Advisory Committee)
Associate Professor
RARS, Pattambi

Er. Suma Nair
(Member, Advisory Committee)
Assistant Professor
Dept. of FPME
KCAET, Tavanur

(EXTERNAL EXAMINER) 15/9/15

ACKNOWLEDGEMENT

It is my prerogative to express profound gratitude and respect to **Dr. Jayan P. R.**, Associate Professor and Head, Department of Farm Power Machinery and Energy, KCAET, Tavanur and Chairman of the Advisory Committee for his keen and abiding interest, encouraging guidance and constructive suggestions during the period of this work. I express my heartfelt thanks to **Dr. M. Sivaswami**, Professor (Farm Power Machinery), Dept. FPME, KCAET, Tavanur for professional guidance and constrictive suggestions offered in this study.

I am indebted to **Dr. Hajilal M.S.**, Dean(Ag. Engg), Kelappaji College of Agricultural Engineering and Technology, Tavanur for providing essential support and permission to use various facilities for the field and analysis work.

I express my profound gratitude to the members of the Advisory Committee **Dr. Jyothi M L**, Professor (Horticulture), RARS, Pattambi, **Dr. Sureshkumar, P. K.** Assistant Professor, Dept. of Agri. Engg, CoH, Vellanikkara, **Er. Renuka Kumari J**, Associate Professor, RARS, Pattambi, **Er. Suma Nair**, Assistant Professor, Dept. of FPME, KCAET, Tavanur for their encouragement and constructive critism through out the study.

I express my sincere and well devoted thanks to **Dr. S. Krishnan,** Associate Professor and Head, Department of Agricultural statistics, College of Horticulture, Vellanikkara for his valuable suggestions, helpful advice and providing good facilities to carry out the statistical analysis of the research outcomes and its interpretations.

I offer my sincere and well devoted thanks to **Dr. Reni. M,** Farm Manager, RARS, Pattambi and **Sri. P. K Rajashekaran,** Farrm Superintendent (Retd.) for their immense helps and deemed support to complete the research successfully.

The valuable suggestions and motivations of **Er. Shivaji. K.P** and **Er. Sindhu Bhaskar,** Assistant Professor, Dept. of FPME, KCAET, Tavanur, is thankfully remembered.

I also take this opportunity to express heartfelt thanks to all the **Technicians** of KCAET, Tavanur for their help during the period of study and their technical help in fabrication and testing of the unit. The work would not have been completed successfully without their technical support.

I hereby acknowledge to all my M.Tech and B.Tech friends especially to **Sheeja.P.S., Ajnas Basher., Ajmal.T.M., Mirshad.M.,Vishnu.K.,** and **Rahul.P.K.,** students of Kelappaji College of Agricultural Engineering and Technology, Tavanur for their help towords this research work.

My sincere thanks all Diploma students of RARS, Pattambi for their invaluable help during my study. I sincerely acknowledge the help and operation rendered by all the labours, RARS, Pattambi.

I express my thanks to all the **staff members of library**, KCAET, Tavanur for their ever willing help and cooperation. I express my sincere thanks and gratitude to **Kerala Agricultural University** for providing the KAU merit fellowship for my M.Tech degree programme.

The last, but not the least, I express my indebtedness to my parents for their love and blessings which gave strength to complete the study.

Above all, the blessings of the almighty made me to materialize this endeavour.

YOUNUS. A

DEDICATION

This project is dedicated to the Almighty God most Merciful and most Beneficent who has seen me through for period of my course.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF SYMBOLS AND ABBREVATIONS

%	Percentage
°C	Degree Celsius
ANOVA	Analysis of variance
cm	Centimeter (s)
CV	Coefficient of variation
CD	Critical difference
et. al	And others
Fig.	Figure
FRBD	Factorial Randomized Block Design
g	Gram (s)
g cm^{-1}	Gram per centimeter
ha	Hectare
ha h^{-1}	Hectare per hour
hp	Horse power
i. e.	Tat is
IS	Indian standard
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
kg	Kilogram
kg h^{-1}	Kilogram per hour
kg cm^{-2}	Kilogram per centimeter square
kg ha^{-1}	Kilogram per hectare
kgf	Kilogram force

km h^{-1}	Kilometer per hour
KAU	Kerala Agricultural University
NS	Not significant
PoP	Package of Practice
rpm	Rotations per minutes
RARS	Regional Agricultural Research Station
Rs.	Rupees
s	second
TNAU	Tamil Nadu Agricultural University
viz.	Versus
w.r.t.	with respect to

INTRODUCTION

CHAPTER I

INTRODUCTION

Traditionally and till date, agriculture has been the main pillar of India's economy. Over 70 per cent of the rural households depend on agriculture as their principal means of livelihood. Agriculture and allied sectors accounted for 13.7 per cent of GDP in 2013. Nowadays, the agriculture sector is moving by leaps and bounds resulting in tremendous increase in crop production due to emerging technologies and techniques. However about 20 per cent of the produce is wasted at the site of production, mainly due to losses resulting from mechanical injury, improper handling and lack of timely harvest. These can be mitigated to an extend by developing harvesters suitable for each crop thereby saving energy, time, money and labour.

In India, a major share of agriculture is contributed by fruits, vegetables, cereals, pulses, tuber crops and spices. Of these, tuber crops and spices contribute about 30 per cent of the production. Tuber crops, which are an important food crop after cereals. Though most of the tuber crops are nutritionally and medicinally rich, they are under exploited. Coleus is one among this category. Coleus tubers are mainly used as a vegetable.

Coleus (*Solenostemon rotundifolius*) commonly known as Chinese potato, is a major tuber crop of the low tropical regions of India, Indonesia, Malaysia, Sri lanka and Africa. The nutritive value of coleus can be favorably compared with that of other major crops. Low cost of cultivation, high production potential, consumer preference, good market demand and almost assured high returns make the crop highly popular among vegetable growers in Kerala, as evidenced by the steady increase in its area and production. Coleus is important from the medicinal perspective also, as flavonoids present in the tuber are said to lower the blood cholesterol level. It is nutritionally rich in 14.7 to 20.8, 0.04 to 0.31 and 0.57 to 0.96 percent starch, proteins and sugar respectively. Three popular high yielding varieties of coleus are Nidhi, Suphala and Sree Dhara, all having a tuber yield of above 25 $t.ha^{-1}$. Nidhi and Suphala are the varieties of Kerala Agricultural University and Sree Dhara is the variety released by Central Tuber Crops Research Institute, Thiruvananthapuram. Suphala is unique in its ability to produce tubers round the year.

Coleus is grown in most of the homestead gardens of Tamil Nadu, Kerala, Karnataka, Madhya Pradesh and tribal areas all over the country. In Kerala, it is mainly cultivated in Thrissur, Palakkad and Malappuram districts. Coleus grows well in warm humid climate and in drained medium fertile soils. It is raised purely as a rain fed crop in the State from June to December. The crop is photosensitive and requires short day conditions for tuber development. The first step in coleus cultivation is preparation of nursery, which is usually done during May-June every year. Herbaceous cuttings of coleus from nursery are planted on raised beds at a spacing of 15 cm at a depth of 5 to 10 cm. Harvesting is done when haulms dry up, i.e., 4 to 6 months after planting. The tubers are taken out by using spade. Manual harvesting of the above mentioned crops is very tedious and time consuming which also requires proper handling, and avoid of cuts, breakage, bruises and injuries. To overcome these problems and to decrease the cost of harvesting operation, mechanical coleus harvester is to be developed.

The harvesters have to ensure the quality of tubers during operation. The difficulty in developing suitable mechanical harvesters for root crops arises due to irregular geometry of tubers and soil conditions. Hence for the successful development of root crop harvesters, research is to be focused on digging out the tubers with minimum damage.

Harvesting technique and design considerations

In developing countries, most of the produce is harvested by hand for internal rural and urban markets. Larger commercial producers may find a degree of mechanization an advantage, but the use of sophisticated harvesting machinery will be mainly limited to agro-industrial production of cash crops for processing or export or both.

Manual harvesting is usually preferred in crops were multiple harvesting is required. Machine harvesting is usually viable when an entire crop is harvested at one time. Most of the roots and tubers are likely to suffer mechanical injury at harvest caused by digging tools, which may be wooden sticks, machetes (or cutlasses, pangas or bolos), hoes or forks. Harvesting of these crops is easier if they are grown on raised beds or or "earthed up" as is common in potato-growing. This enables the digging tool to be pushed into the soil under the roots or tubers, which can be levered upwards, loosening the soil and decreasing the possibility of damage to the crop.

A coleus harvester developed at the KCAET was taken as base for the research work. It consisted of flat tyne digger with rotary mechanism. There were several problems associated with its construction specially with respect to the harvesting of coleus planted in raised bed in farmer's field. An attempt was made to resolve the above said problems in this study and the said harvester was modified.

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.

- Is to 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.

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 coleus relevant to machine harvesting.
2. To study the different methods of machine harvesting and design of major components.
3. To modify the developed prototype and testing.
4. To compare its performance with the commercially available harvester.

REVIEW OF LITERATURE

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}.

Mechanical harvesting had been affected by constraints such as soil characteristics, nature and size of tubers, depth and width of cluster, and bond between tubers and the soil, which lead to high tuber damage. Damaged tubers deteriorated rapidly after three days of harvesting. Matured roots were spread over 1 m and penetrated to a depth of 50-60 cm, this made it difficult to readily mechanize harvesting due to the way the tubers grow (Bobobee *et al.*, 1994).

Gupta *et al.* (1994) developed a powered disc potato digger cum soil clod separator. The single row spacing, spring oscillated, perforated disc rotary type potato digger was developed for small farmers and tested for its performance. The machine was powered by a two wheel single axle 9.0 Kw walking tractor. The power to the 600 mm disc rotating at 160 rpm was transmitted from the gear box through a pair of 450 bevel gear and a sprocket and a chain drive. The harvesting efficiency of the machine was 100 percent and the field capacity was about 0.19 hah^{-1}.

Petrov *et a.l* (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 operated width were compared.

Thakur *et al.* (1994) conducted studies on evaluating of soil bin and performance evaluation of lifting shares used on potato harvesters. The four different shapes of potato lifting share *viz.* rectangular, convex, V-scoop, triangular fork types

CHAPTER II

REVIEW OF LITERATURE

The past research works relating to the relevant aspects of root crop harvesters were reviewed in this chapter. Many types of root crop harvesters were developed and tested in different countries. To comprehend the research towards the development of root crop harvesters, literature reviews were done and are grouped under the following headings.

2.1 Root crop harvesting

Muhammed Yasein, *et al.* (1986) designed and manufactured a rotary potato digger. The field capacity of the machine was 0.2 ha h^{-1} at an operating speed of 6 kmph. The digger saved Rs 264 $ha^{-1}$when compared to manual harvesting of potatoes. The potatoes harvested with the rotary digger were free of cut damage and bruises.

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 digged 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 ,left a well pulverized row with good tilth. The harvester operates at a forward speed of about 2.5 kmph to 4 kmph and harvesting rate was 0.25 to 0.4 ha h^{-1}.

Jadhav *et al.* (1992) designed and evaluated the performance of onion digger. A simple low cost self propelled onion digger windrower was designed and developed. It was powered by a 5 hp diesel engine mounted on the frame along with the main gear box . Handle was provided for steering the entire unit. The digging unit consisted of sweeps fitted to the front of frame. For controlling the depth of operation, a caster wheel was provided in front of the digging unit.

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}.

Mechanical harvesting had been affected by constraints such as soil characteristics, nature and size of tubers, depth and width of cluster, and bond between tubers and the soil, which lead to high tuber damage. Damaged tubers deteriorated rapidly after three days of harvesting. Matured roots were spread over 1 m and penetrated to a depth of 50-60 cm, this made it difficult to readily mechanize harvesting due to the way the tubers grow (Bobobee *et al.*, 1994).

Gupta *et al.* (1994) developed a powered disc potato digger cum soil clod separator. The single row spacing, spring oscillated, perforated disc rotary type potato digger was developed for small farmers and tested for its performance. The machine was powered by a two wheel single axle 9.0 Kw walking tractor. The power to the 600 mm disc rotating at 160 rpm was transmitted from the gear box through a pair of 450 bevel gear and a sprocket and a chain drive. The harvesting efficiency of the machine was 100 percent and the field capacity was about 0.19 hah^{-1}.

Petrov *et a.l* (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 operated width were compared.

Thakur *et al.* (1994) conducted studies on evaluating of soil bin and performance evaluation of lifting shares used on potato harvesters. The four different shapes of potato lifting share *viz.* rectangular, convex, V-scoop, triangular fork types were carried out under controlled soil bin condition for the measurement of draft while harvesting potatoes. The draft of shares of 500 mm width, was found maximum with rectangular shaped one followed by convex, triangular fork and V-scoop share when operating in silt clay loam soil at 16 percent (db) moisture content and 1.51 g cm^{-3}dry bulk density. Maximum recovery of potatoes at velocity ratio of 1.38 was found to be 99.23, 89.80, 88.01and 82.48 percent with V-scoop, triangular fork, rectangular and convex shapes, respectively.

Tiwari (1994) conducted studies to evaluate the performance of three types of tractor drawn potato diggers *viz.* oscillatory sieve potato digger windrower, elevator convey digger and two mechanical digger. The diggers were operated at different forward speed ranging from 0.29 ms^{-1} to 1.2 ms^{-1}. Their performance in terms of recovery, cut, bruise, damage and labour requirement for picking were evaluated. The maximum potato recovery of 98.77 percent and 85.07 percent was obtained with oscillatory sieve and elevator convey diggers with minimum forward speed of about 0.29 ms^{-1}. In case of mechanical digger, recovery was about 69.24 percent at a speed of 1.2 ms^{-1}. The labour requirement for picking and collection of tubers was found minimum with oscillatory sieve digger and maximum with mechanical digger.

Berbekov, *et al.* (1995) designed a bulb and potato digger with actively working walking tractor. The digger was operated by means of two counter vibrating undercutting arms, belt driven from the tractor. The working width of digger was 0.6 to 0.7 m with an undercutting depth of 22 cm, working speed of 0.7 to 0.1 ha h^{-1}.The results indicated satisfactory performance.

Bulgakov *et al.* (1995) designed a MKP-4 harvesting machine with vibratory working parts for harvesting four rows of beet. The harvested beet was fed to a trailer traveled along side. Speed of the harvester was about 1.3- 2.55 ms^{-1} .The rate of harvesting was 3 ha per shift.

Peters (1995) designed windrowers for potatoes. An account was given for windrowers available in Germany for two stage potato harvesting. Potatoes were lifted from two or four rows and deposited in a single windrow which was then picked by a harvester. This machine was either rear mounted, semi mounted or trailed. The operations of ridge lifting, screening, haulm removal and windrow deposition were discussed.

Kathiravel *et al.* (2002) conducted studies to analyse the effect of tool geometry on the harvesting efficiency of turmeric harvester. The various design parameters namely blade shapes (crescent, straight, inverted-V), rake angle (10°,15°,20°) and lift rod length (450,500,550 mm) were investigated to satisfy the basic requirements.

Mozaffary, *et al.* (2002) designed and developed three onion toppers to overcome laborious and time consuming harvesting operation of onion. Factors were topper prototypes and rotational speed of mechanisms. Some parameters such as acceptable top percent and damaged bulb percent were determined and analyzed. The results showed that flail topper was most suitable for onion topping.

Manual harvesting was slow and associated with drudgery and high level of root damage in potato, requiring approximately 53 man days per hectare (Nweke *et al.*, 2002). This tended to increase the total cost of production because more farm hands are required to harvest in order to meet industrial demands.

Yasin *et.al* (2003) conducted a field test with a rotary potato digger at Research Center of Agricultural Engineering in Faisalabad, Pakistan. Intact harvested, cut and bruised potatoes were respectively as 99.0, 4.0 and 1.0 %, at moisture content of 10.3% and at a speed of 6 kmph.

Singh (2006) developed and tested a tractor mounted, 2 - row multipurpose potato digger. Maximum exposure percentage of tubers was 84.5% when operated at 4.5 kmph. The percentage of damage observed was 1.48.

Harvesting of coleus and ginger had been identified as a highly labour intensive and difficult task to be performed in the fields. As a solution of these problems, the development and testing of coleus and ginger harvester was undertaken at KCAET, Tavanur (Ajoy *et al.*, 2009). They reported that, there were a lot of difficulties while uprooting the tubers especially to operate in wide range of size of the beds and a large portion of th tuber remain in the soil itself.

2.2 Soil mechanical properties

Brandelik and Hiibner (1996) developed electromagnetic measurement techniques of soil moisture. Three new sensors were used, which improved the accuracy of exiting measurement device and extend the range applications. The first one was in-situ sensor, which evaluated soil moisture profile down to 2.5 m with a vertical resolution of 3 cm 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 a moisture sensitive cable. It used the technique of time domain reflectometry and frequency domain reflectometry.

According to Jahn and Hamburg (2002), many research applications within agriculture require some measure of soil strength as a part of a thorough study. Plant and soil scientists frequently use a cone penetrometer and the Cone Index (CI) to characterize soil strength in agronomic studies. Traction models had been developed that utilize CI as the measure of surface soil strength. The use of cone penetrometers had been simplified by the development of hand-operated recording devices, and tractor mounted versions that reduce manual labour requirements. General use of Cone Index was enhanced by the existence of a standard (ASAE S313.2) addressing the physical and operational aspects of cone penetrometers and the calculation of the CI, making comparisons from different studies reasonable. Cone penetrometers alone had limitations as a means of characterizing soil strength. The easily measured parameter (cone index), represented by the force to push a cone into the soil divided by the cross sectional area of the cone, was complex but ill-defined measure of soil strength and compressibility.

The cone index of a soil which was the degree of its strength had been shown to be affected by its water content and bulk density (Agodzo and Adama, 2003; Vaz *et al.,* 2001) and was usually measured in kilo-Pascal (kPa). According to USDA (1999), penetration resistance (Cone Index) depends strongly on the soil water content: the drier the soil, the greater the resistance to penetration. Therefore, the water content of the soil should be noted when taking a measurement of cone index.

The water content of the soil is an important property that controls its behaviour. 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 (Agodzo and Adama (2003).

Morris (2006) surveyed some low-cost soil moisture monitoring tools and methods, including new generation of sophisticated and user-friendly electronic device and explained the process of water detention by soil.

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. Indices were calculated for 0-20 and 20-40 cm soil depth in four drying cycles applied to melon and to autumn and spring tomato crops. In each cycle, there were well watered and un watered irrigation treatments.

2.3 Field testing

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 tonnes 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 covered per hour of operation (Hanna, 2001).

Macmillan (2002) defined wheel-slip as the proportional measure by which the actual travel speed of the wheel falls short of (or exceeds) the "theoretical" speed and in terms of measurement, prediction and presentation of tractor performance, slip is the single most important, dependent parameter.

According to Grisso *et al.* (2010), farmers might consider numerous ways to estimate and reduce fuel consumption but the first step is to determine how much fuel is being used for a particular field operation and compare it to average usage. This measurement can be completed by filling the fuel tank of the tractor before and after a field operation, noting the number of hectares covered.

Depending on the type of fuel and the amount of time a tractor or machine was used, fuel and lubricant costs will usually represent at least 16 percent to over 45 percent of the total machine costs (Siemens, Bowers, 1999). With reference to the above statement, Grisso (2010) emphasized on the fact that fuel consumption plays a significant role in the selection and management of tractors and equipment.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

In this study, a self-propelled coleus harvester for harvesting coleus planted on raised beds in uplands was modified and field tested. In upland coleus cultivation, the practice was the preparation of raised beds/ridges. In traditional method beds are prepared by skilled labour using spades (Plate 3.1). The beds/ridges were made at height 30 cm to 45 cm in garden cultivation and in wet lands it will be higher.

This method was highly laborious, time consuming and a costly farm operation. In KAU as well as State Seed Farms, beds were raised as per the Package of Practices of KAU. The harvesting of coleus, in both cases was done by means of spade with much care and proper handling. To overcome the problems of breakage, bruises and injuries that happen during harvesting and to decrease the cost of harvesting operation, a self-propelled coleus harvester was modified and field tested.

In this chapter, the site selection, lay out and seed bed preparation were briefly explained. Methods followed to determine the physical and mechanical properties of soil and coleus affecting the design parameters of cutting blades (tynes) of the harvester were detailed. Design of machine parameters such as speed of rotation of rotary tiller, size and shape of blade, diameter of the drive wheels and number of blades, spacing, time to harvest were explained.

Two sets of digger tynes were developed as per the optimized values of machine parameters. The procedure for conducting field trials with the developed digger and the statistical analysis of the result to sort out the effect of implement on yield and the procedure for accounting the costs involved are also explained.

Plate 3.1 Manual harvesting of coleus

3.1 Description of study area

3.1.1 Site selection

The field was selected in such a way that there was good drainage and sunlight without any shade. The soil of the selected field was sandy loam with moisture content 30 per cent. A total area of 32 cents (0.128 ha) in 8^{th}-Block of RARS Pattambi was chosen, which is situated at 10.8200° N latitude and 76.2000° E longitude.

3.1.2 Field preparation

Coleus was grown in sandy loam and was planted at a depth of 10 cm. The field was ploughed two times with a tractor drawn disc plough followed by two passes of spring tyne cultivator. Later on, the field was again ploughed with a tractor drawn rotavator to make the soil in good tilth.

3.1.3 Field layout

The field was divided into two equal plots of 0.063 ha. In each plot, beds of sizes 10 m x 0.5 m and 10 m x 0.7 m respectively as length x breadth were prepared. Trials were conducted with different bed heights of 20, 30 and 40 cm. The treatments were replicated three times in these beds having width x height as 50 cm x 20 cm, 50 cm x 30 cm, 50 cm x 40 cm, 70 cm x 20 cm, 70 cm x 30 cm and 70 cm x 40 cm for each bed length of 10 m. The layouts of experimental plots are shown in Fig. 3.1. In each bed, performance evaluation of the harvester with 6 and 10 number of flat and angular tyne diggers was carried out for each of the treatment combinations. Channels of 0.3 m x 0.3 m were made around each plot to provide proper drainage.

Plate 3.2 Field preparation

Plate 3.3 layout preparation

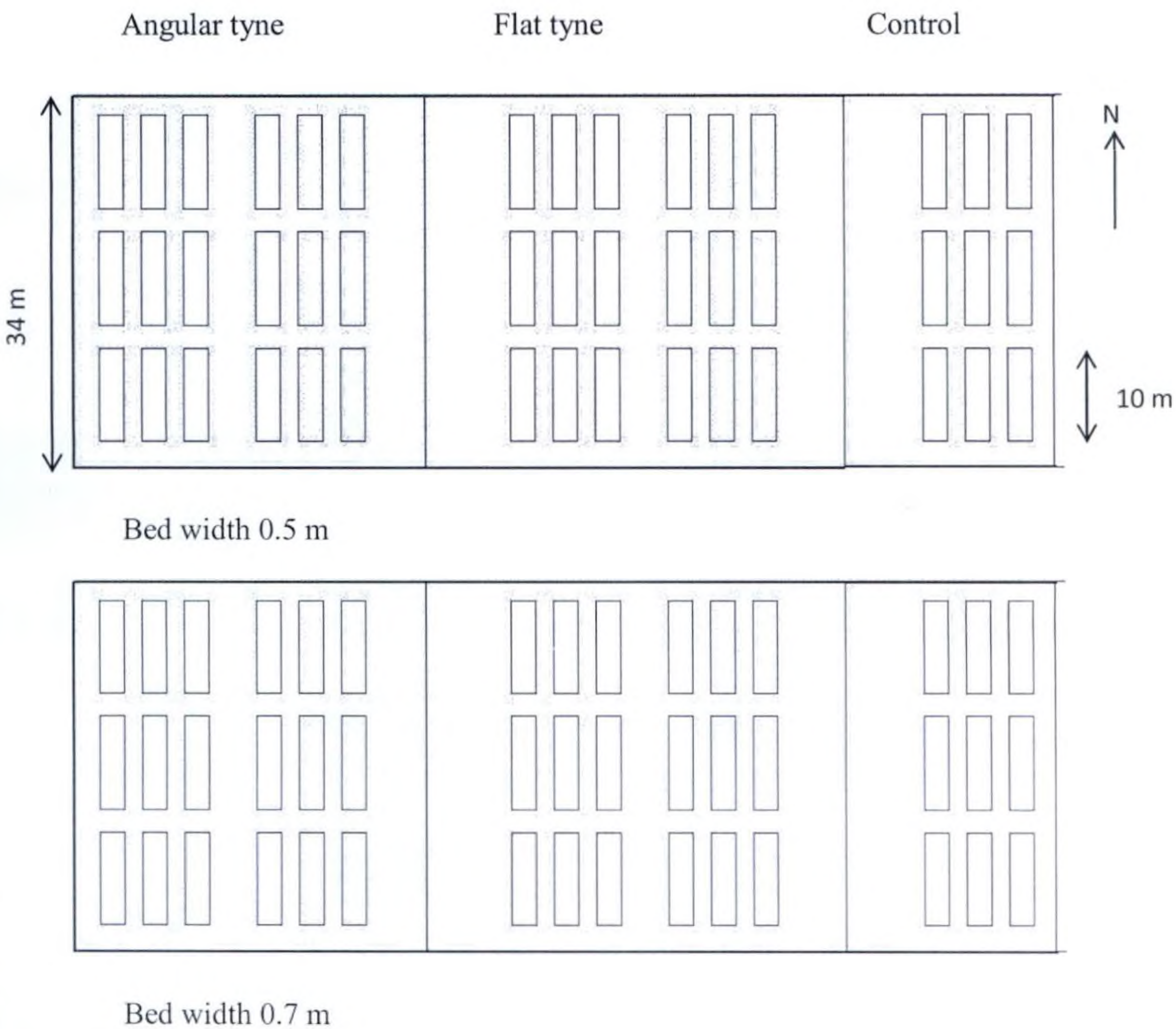

Fig. 3.1 Field lay out

3.1.4 Planting

Good quality cuttings of 'Nidhi' variety of coleus were selected for planting. It was planted at a depth of 10.0 cm with spacing of 15 cm x 15 cm in each bed. Hence the total number of cuttings per bed were 189. Planting was done during first week of July 2014, *i.e*, after getting enough rainfall during South West monsoon.

Plate 3.4 Planting of coleus

3.1.5 Intercultural operations

In each bed, manures and fertilizers were applied as per KAU PoP.

3.1.6 Field management

Wire fencing was made to protect from wild pigs, as there were several incidents of attacks noticed in the area adjacent to the selected location. The fencing comprised of wires 16 gauge tied in two rows 0.2 m and 0.5 m from the ground. GI poles of height 0.8 m were properly fixed at 3 m intervals.

3.2 Physical and Mechanical Properties of Soils

The physical properties of the soil directly or indirectly affect the soil-tool interface as well as the growth of the crop. The three properties, *viz*, moisture content, bulk density and penetration resistance of the soil were determined. Soil samples from different parts of the experimental plot were collected in clean and closed containers to determine the present status of the soil. The tests were conducted in the Soil and Water Laboratory at K.C.A.E.T, Tavanur and Soil Science laboratory at Regional Agricultural Research Station, Pattambi.

Soil samples were collected from all study sites after ploughing and at the time of harvest. Six samples were taken from each of the study area for soil moisture determination at depths of 0-5 cm, 5-10 cm, 10-15 cm, 15-20 cm, 20-25 cm and 25-30 cm; but bulk density was determined at depths of 0-20, 20-30 and 20-40 cm after ploughing. A soil core cutter of size 6.5 cm and 10 cm in diameter and a rammer was used to take soil samples for bulk density determination. A soil auger was used to take soil samples for moisture content determination.

Field tests were carried out at depths of 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm for each study area at harvest to determine the soil penetration resistance using a soil cone penetrometer.

Plate 3.5 Soil sampling

3.2.1 Moisture content

It is the percentage of water in a given soil sample. It is found out by standard test procedures and using the equation,

$$\text{Soil moisture content (wb)} = \frac{W_i - W_f}{W_i} \times 100$$

where,

W_i = initial weight of the soil, gm

W_f = final weight of the soil, gm

Oven drying method was used to determine the moisture content of the soil sample. In this study, a soil sample of 50 g was collected in a clean container and placed in an oven under controlled temperature between 105°C to 110°C for a time period of 24 hours. The experiment was replicated for six samples from different parts of the field and the mean value was calculated.

3.2.2 Bulk density

The bulk density was found out by using the formula,

$$\rho = \left(\frac{M}{V}\right)$$

where,

ρ – Bulk density, g cm^{-3}

M – Mass of the soil, g

V – Volume of the soil, cm^3

3.2.3 Penetration resistance

Soil cone penetrometer was used to measure the penetration resistance of the soil. Penetrometer was positioned in the field and slightly pressed on the handle. A uniform force was placed on the handle and the deflection of dial gauge was noted for 1 cm in depth. The solid stem penetrated in to the soil and force was measured from the deflection of the needle of proving ring corresponding to the insertion of 30^0 cone. The penetrometer resistance was measured for each increment of one cm and recorded manually. The same procedure was repeated to measure penetration resistances at various location of the study area.

3.3 Physical and mechanical properties of coleus

The physical and mechanical properties of the coleus *viz.*, size, shape, sphericity and firmness were found out using standard test procedures. The firmness and toughness of the coleus were determined using texture analyzer. The observations were recorded from six samples taken at random.

3.3.1 Size and shape

The following parameters were measured for describing the size and shape of the coleus. The size of the coleus was determined by using Vernier callipers and the shape by graphical method.

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.

3.3.3 Weight

Weight of coleus was determined by an electronic balance having sensitivity of 0.01 g. The weight of a tuber is an important parameter in designing the digger tyne and its scattering while harvesting.

3.3.4 Firmness and toughness

Important quality parameters which affect the consumer acceptability of coleus are firmness and toughness, which were determined using Texture Analyzer (Plate 3.6). The instrument has a microprocessor regulated texture analysis system interfaced to a personal computer. The instrument consists of two separate modules; the test-bed and the control console (keyboard). Both are linked by a cable which route low voltage signal and power through it. The texture analyzer measures force, distance and time and hence provide a three-dimensional product analysis. Forces may be measured to achieve set distances and distances may be measured to achieve set forces. The sample was kept on the flat platform of the instrument and was subjected to double compression by a cylindrical probe with 5 mm diameter. The test was conducted at a speed of 10 mm/s using 50 N load cells. The sample was allowed for a double compression of 40 per cent with trigger force of 0.5 kg during which various textural parameters were determined. From the force deformation curve, the firmness or hardness (peak force), and toughness (area under the curve) were determined.

Plate 3.6 Texture analyzer

3.4 Study of the KCAET coleus harvester

A coleus harvester (plate 3.7) developed at the KCAET was taken as base for the research work. It consisted of flat tyne digger with rotary mechanism. There were several problems associated with its construction specially with respect to the harvesting of coleus planted in raised beds in farmer's field, mainly height of bed and width of bed. An attempt was made to resolve the above said problems in this study and the said harvester was modified as follows.

Plate 3.7 KCAET coleus harvester

3.5 Modification of coleus harvester

The harvester was made with an attachment to a 3.5 hp mini tiller (Plate 3.8). The harvester (Fig. 3.2) consisted of a prime mover, a digger, rotary blade, and driven wheels. The prime mover was a 3.5 hp 2- stroke diesel engine. The use of such a tiller proved to be advantageous for wide variety of reasons like the compactness, small size, easy movement on narrow terrains, smooth mobility and also a 360^{o} turning facility of handle. A set of wheels were specially made for easy operation. The harvester was also provided with a supporting wheel at rear side. The specification of the harvester is presented in Appendix VIII.

3.5.1 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 coleus from the soil. The use of 3.5 hp mini tiller satisfied the maneuverability and provided enough torque to uproot the underground rhizomes. A 3.5 hp mini tiller was used to overcome a load of about 300 kg . The details of the specification of mini tiller is shown in Appendix VIII.

3.5.2 Main Frame

Main frame accommodated all the attachments and accessories of the harvester. It was made up of mild steel angles 7 mm x 40 mm. The main frame held the digger assembly and was bolted to chassis of mini tiller (Fig.3.2).

Plate 3.8 Testing of modified coleus harvester

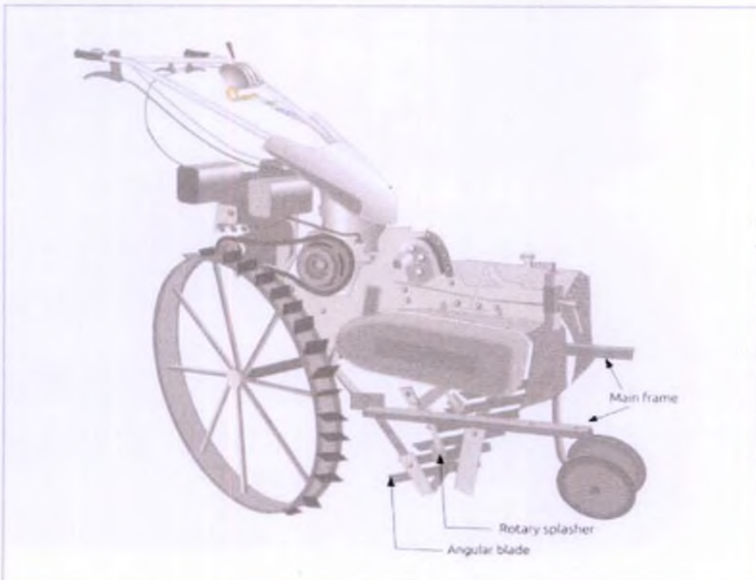

Fig 3.2 Modified coleus harvester

3.5.3 Digger

The digger was a unit having a number of tynes welded on a flat bar. The tynes of the digger were attached to the soil penetrating parts of the equipment. It takes most of the soil resistance during operation. The two sets of digger with flat (Fig.3.3) and angular (Fig.3.4) tynes were made for comparing the performance of the harvester. The flat tynes were made of MS square pipe of 20 mm size and 300 mm length angular tynes were made of MS angle 25 mmx 5 mm and length 300 mm. The ends of square pipes were provided with a slight bending for better penetration and taking up of coleus from soil. The tynes were positioned in such a way that they made an angle of 40° with the vertical. This facilitated easy operation.

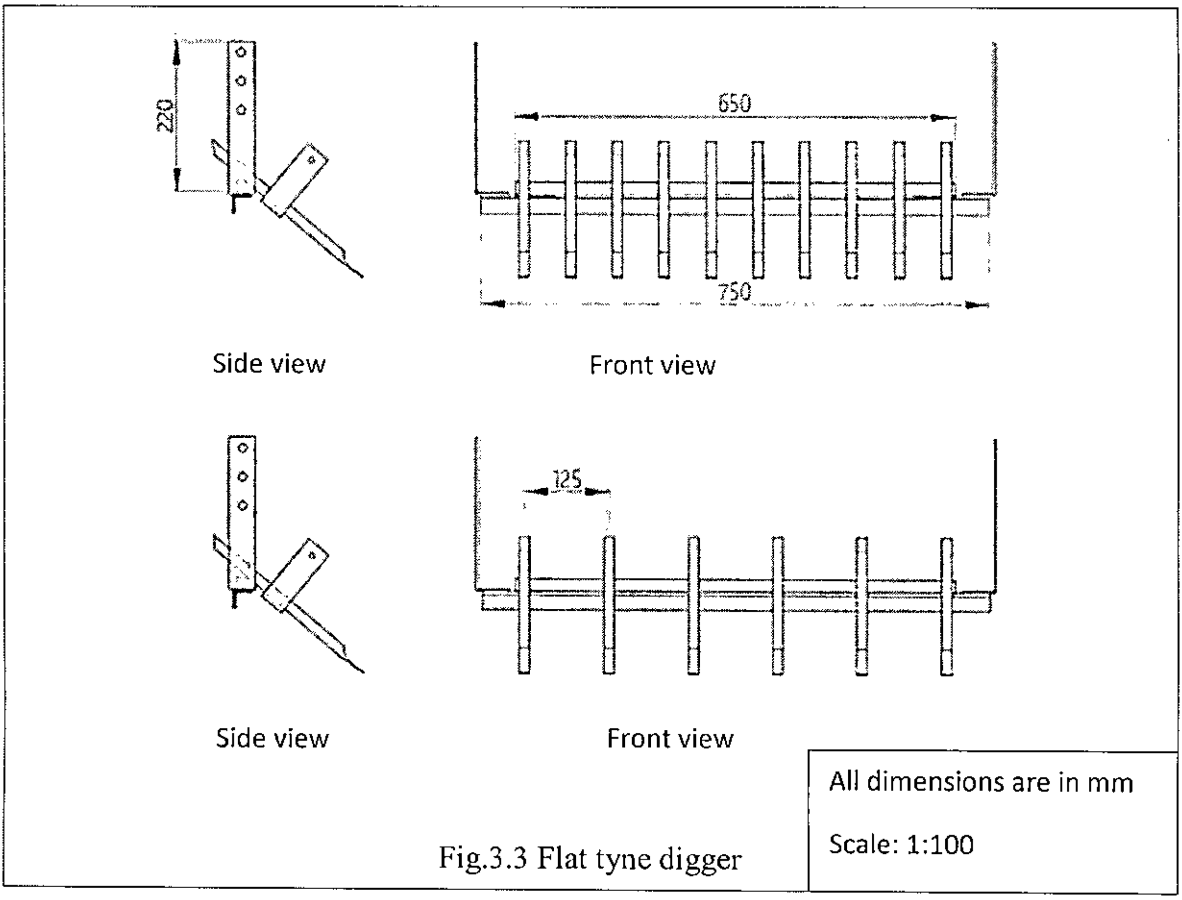

Fig.3.3 Flat tyne digger

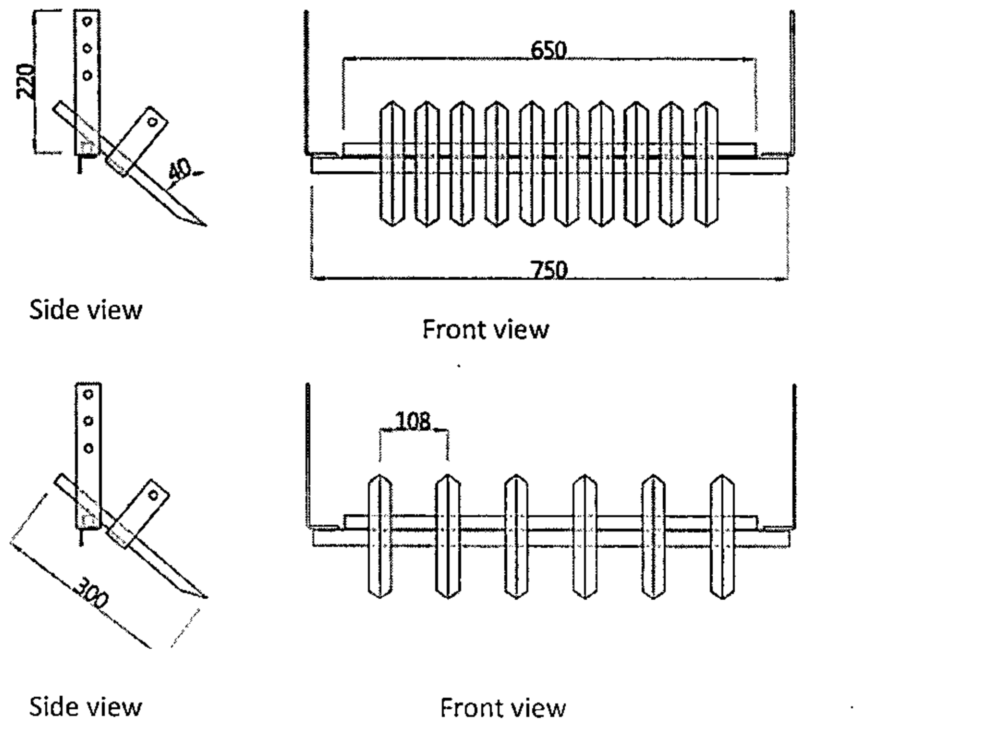

Fig.3.4 Angular tyne digger

3.5.4 Rotary slasher

In all types of power tillers rotary blades are the integral part attached to the rear side of the tiller. The drive to this is transmitted through a chain and sprocket assembly from the engine. In order to modify the harvesting unit, the rotary blades (L-shaped tynes) were removed and rubber flaps of 75 mm x 75 mm x 0.3 mm were fastened to the shank of the rotary blade. These rubber flaps fastened tynes (rotary splasher), splashed or pushed away the dugout coleus outward.

3.5.5 Wheels

The wheels of tillers acts as vehicle traction elements to generate enough tractive force to overcome soil resistance and to ensure resistive forced motion. The wheel provided by the manufacturer was lesser in diameter and with low maneuverability, especially when operating on the raised seed beds in coleus cultivation. Hence a set of larger wheels (Fig.3.5) were fabricated separately with diameter of 80 cm, using MS flat of 50 mm x 3 mm and square rod of 10 mm x 10 mm.

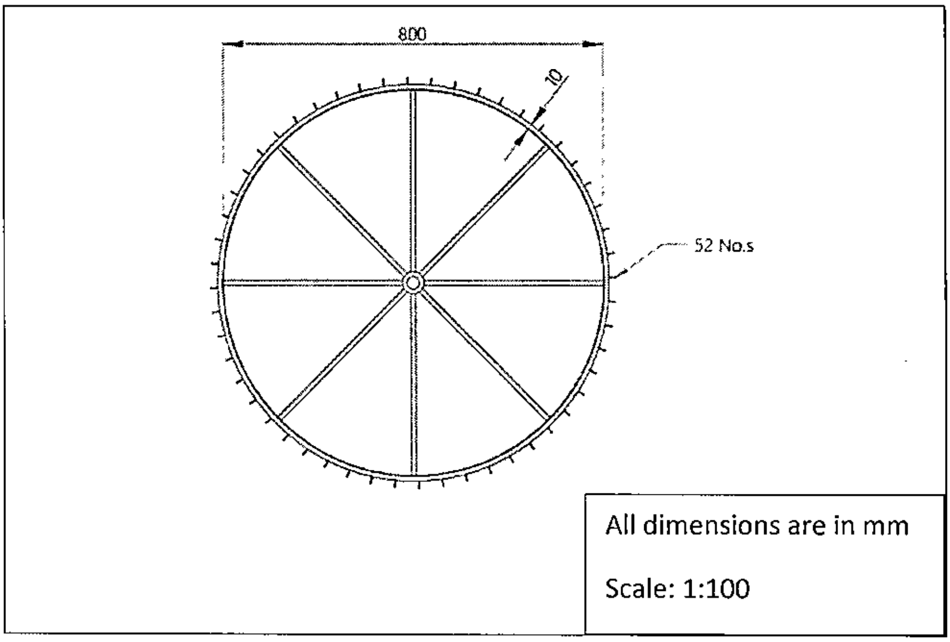

Fig.3.5 Modified wheel

3.5.6 Working

During operation, the digger pierced into the soil at a depth of 10 -15 cm and at an angle of 40°, to dig out the tubers lying inside the soil. The uprooted coleus coming over the inclined tynes of digger were then pushed out by means of the rotary splasher rotating just above the digger. The scattered coleus lying in the seed bed can be collected easily by manual method and hence the harvesting became easier and faster. Rubber mudguard was provided to protect the operator from scattered stones or debris which may be thrown away as projectile along with coleus.

3.6 Selection of variables

The machine parameters such as size and shape of blade, spacing of tynes and speed of operation influence the harvesting of underground coleus tubers. These parameters were optimized to achieve the most suitable size and shape and angle of cutting blades for complete uprooting. The other individual parameters selected for the study were wheel track and ground clearance.

3.6.1 Size and shape of blade

The size and shape of blade affect, the draft of the implement. The independent parameter selected for the study includes two types of shapes namely flat and angular with spacing between blades as 10 cm and 5 cm respectively. Size of all types of tynes selected for the study was 300 mm x 20 mm x 20 mm for flat tyne and 300 mm x 25 mm x 5 mm for angular tyne.

3.6.2 Number of tynes

The number of tynes on the digger depended upon spacing. It offers the load on engine. The two sets of tynes for the study selected were 10 and 6 for the two shapes of tynes.

3.6.3 Height of bed

The ground clearance is an important parameter affecting the movement of tiller on the raised beds. The height of bed decides the level of ground clearance. Three level of height of beds were selected for this study, *viz.* 20 cm, 30 cm and 40 cm.

3.6.4 Width of bed

The width of bed decided the width of operation of digger. The width of digger was decided according to the wheel track. It is an important parameter to permit free movement of the machine over the beds during operation. The width of beds was found to increase due to various agronomic parameters. Hence two levels of widths were selected *viz.* 50 cm and 70 cm.

3.6.6 Depth of operation

Depth of operation affected the draft of implement, size and performance of machine. The level of depth of operation was selected as 10 cm, 12 cm and 15 cm respectively for the study.

3.7 Level of variables and statistical analysis

The levels of independent parameters affecting the uprooting of rhizomes were selected by considering the operational constraints in the field. The four parameters are shape, number of tynes, height of bed and width of bed. Each beds were replicated three times. The size of tyne was separately fixed as 300 mm x 20 mm x 20 mm for flat type and 300 mm x 25 mm x 5 mm for angular tyne. The angle of cutting blade was 40 degrees and speed of operation was selected as 1.5 to 2.0 kmh^{-1} respectively. Depth of operation was selected as 10 cm to 15 cm. The number of cutting tynes *viz.* 6 and 10 numbers were selected for each shape of digger. Two widths of bed selected for the study were 50 and 70 cm and three height of bed were selected as 20, 30 and 40 cm and three replication were carried out for each trials.

The observations were statistically analyzed using three factor ANOVA using MSTAT. The experiments were laid out according to Factorial Randomized Block Design (FRBD). The various factors and its levels are furnished in the Table 3.1.

Table 3.1 Factors selected for FRBD experiment

Variety	Shape	Number of blades	Height of beds (cm)	Width of beds(cm)
Nidhi	Flat	10	20	50
	Angular	6	30	70
			40	
Replication – 3 bed length – 10 m				

Total number of treatments = 1 x 2 x 2 x 3 x 2 = 24

3.8 Performance evaluation of coleus harvester

The performance of the coleus harvester was tested for time taken, fuel consumption, harvesting capacity and percent of damage with respect to various independent parameters. The independent parameters include shape of tyne (flat and angular), number of tynes (6 and 10), and size of bed (50 cm x 20 cm, 50 cm x 30 cm, 50 cm x 40 cm, 70 cm x 20 cm, 70 cm x 30 cm and 70 cm x 40 cm).

3.8.1 Time of operation

The time taken to dig out the coleus with respect to bed width, number of tynes and height of bed was observed by using a stop watch. The results were statistically analysed using MSTAT software.

3.8.2 Fuel consumption

The harvester with the implement was placed on a level ground on the field and the fuel tank filled to the brim. After the harvester has worked within a known area, it was brought to the same level ground and then with the help of a 1000 ml graduated measuring cylinder, the fuel used was determined by filling the measuring cylinder to a known level and pouring into the fuel tank of harvester until it is full to the brim. The quantity of fuel used to top-up the fuel tank was then recorded as the fuel consumed by the harvester to work that known area (litres.ha^{-1}). The results were statistically analysed using MSTAT software.

3.8.3 Harvesting capacity

The harvesting capacity of coleus harvester was determined by measuring the weight of the uprooted coleus with respect to the time taken for each bed sizes (width x height) of 50 x 20 cm, 50 x 30 cm , 50 x 40 cm, 70 x 20 cm, 70 x 30 cm and 70 x 40 cm and flat and angular digger tynes . The results were statistically analysed using MSTAT software.

3.8.4 Percentage of damage

Coleus tuber damage, attributed to cutting by the harvester blade or bruising during harvesting was due to either shallow harvesting depths or speed of operation. According to farmers and processors, coleus damage occurred when the whole roots did not come out after harvesting, but with cuts and bruises, that would render them unsuitable for storage and sale. After harvesting damaged root tubers were separated and then weighed using a electronic balance to determine their mass in kilograms.. The total coleus yield (kg) were also determined. The percentage of coleus tuber damage for each harvester and harvesting method was calculated using equation.

$$\text{Damage (\%)} = \frac{\text{Mass of damaged coleus (kg)}}{\text{Total yield (kg)}} \times 100$$

The results were statistically analysed using MSTAT software.

3.9 Comparison of performance with commercial harvester (TNAU ginger harvester)

TNAU ginger harvester was used to uproot coleus as it is the only one commercial harvester available in the college. It was operated for uprooting coleus planted in the same bed sizes (width x height) of 50 x 20 cm, 50 x 30 cm , 50 x 40 cm, 70 x 20 cm, 70 x 30 cm and 70 x 40 cm. The digger of TNAU model ginger harvester was a sweep type shovel having vibrating mechanism. The harvester vibrations were provided from the drive taken from its prime mover (4-S diesel engine, 9 hp) *via* an eccentric shaft welded at its flywheel. The specification of the harvester is given in the Appendix IX.

3.10 Field efficiency

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

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

S = Average speed of machine, $m.h^{-1}$

W = Rated width of machine, m

3.11 Cost economics

The field capacity of the implement and the cost of operation were calculated. The saving in cost in the field operation with coleus harvester was worked out in comparison with the conventional method of harvesting and also with a commercial harvester (TNAU ginger harvester).

Manual harvesting was carried out using tools like the spade. The capacity of the manual labourers for the harvesting (man-hours/ha) was determined by recording total time (seconds) taken to harvest the bed.

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

This chapter deals with the details of the field experiments done to evaluate the performance and economics of the newly modified coleus harvester. The relevant physical properties of soil are determined and summarized. The field performance of the coleus harvester along with cost economics is also presented.

4.1 Physical and mechanical properties of soil

Physical properties such as the moisture content, soil texture, bulk density and penetration resistance of the soil, which influence the performance of the coleus harvester were determined.

4.1.1 Moisture content

Moisture content was determined as percentage by weight, by oven drying method. Soil samples from six different locations in the study area at specified intervals were determined using the equation as explained in sec. 3.2.1. The average moisture content found out was 21.63 percent. The recorded values and its calculations are given in Appendix I.

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 1.95 g cm^{-3}. The recorded values and its calculations are given in Appendix II.

4.1.3 Penetration resistance

The cone penetrometer test was conducted to find the cone index. Appendix III shows the soil penetration resistance with respect to depth and soil moisture at the selected sites. It was observed that the penetration resistance increased with increasing depth and moisture content for all trial sites. Ploughing the soil generally reduced penetration resistance. At the time of harvest, penetration resistance in the range from 0.061 - 2.450 MPa.

4.2 Physical and mechanical properties of coleus

The physical and mechanical properties of the coleus *viz.*, size, shape, sphericity and firmness were found out using standard test procedures. These properties are important in designing the coleus harvester and determining the behavior of the machine for handling.

4.2.1 Size of coleus

The size of coleus was determined using Vernier calipers. The maximum and minimum length measured are given in Appendix IV. The average maximum length of a tuber is 6.5 cm and the average maximum width is about 3.4 cm.

4.2.2 Shape of coleus

Shape of a coleus is an important parameter which affected the conveying characteristics of solid materials. The shape of coleus was determined by graph paper using tracing method. The shape of coleus variety 'Nidhi' was almost oblong.

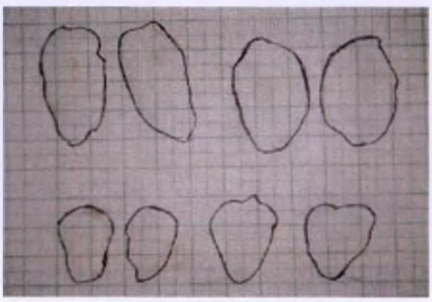

Fig. 3.6 Shape of coleus

4.2.3 Sphericity

This parameter showed the shape character of the particle relative to the sphere having same volume. The average maximum and minimum sphericity recorded were respectively as 4.30 and 1.29. The calculations are given in the Appendix V.

4.2.3 Weight of coleus

The weight of coleus was determined by an electronic balance. The weight of a tuber is important in designing a particular digger and determing scattering of tubers during harvesting. The weights of separated tubers are given in the Appendix VI. The average weight of a tuber obtained was 22.60 gm.

4.2.4 Firmness and toughness

Firmness is the characteristic of a material expressing its resistance to permanent deformation. Toughness of a material is its resistance to fracture when stressed or the amount of energy that a material can absorb before rupturing and was found out by calculating the area underneath the stress strain curve. Firmness and toughness of coleus is an indicator of good edible quality of the roots with more consumer appeal. The maximum and minimum firmness found out were 5.54 kg and 4.539 kg respectively whereas the maximum and minimum toughness values were respectively 9.121 and 5.361 kg.s. The results are given in Appendix VII.

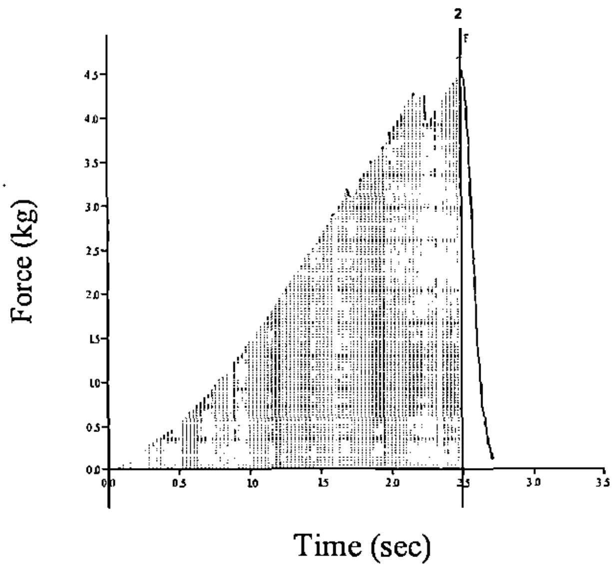

Fig. 3.7 Texture profile of the coleus

4.3 Field testing

The field performance of coleus harvester was evaluated at RARS Pattambi during December 2014. The experiment was conducted in the pre designed layout as explained in section 3.1.3. The field testing of the harvester was conducted for time of operation, fuel consumption, weight and percentage of damage with respect to bed size, number and type of tyne attached with digger. The results obtained under various level of parameters were statistically analysed. The results are explained separately for flat and angular tyne diggers.

4.3.1 Field testing of the coleus harvester with flat tyne digger

4.3.1.1 Time taken to dig out coleus

The analysis of variance for the time taken to dig out coleus with respect to bed width, number of tynes and height of bed is given in Table 4.1. From the results it was inferred that the interaction effect due to number of tynes and height of bed and is significant, and also the effect due to bed width is significant.

It was also observed that the effect of interaction of factor means of bed width and height of bed was highly significant, but the interaction of factor means of number of tynes and bed width and bed height and number of tynes were not significant. The three factor interaction, namely the influence due to bed width, number of tynes and height of bed were not significant. It was inferred that there were differential effect due to bed width, number of tynes and height of bed at 5 percent level of significance. The effect due to the treatment combinations of bed width and height of bed was high differential response. The three factor interaction was not significant, showing that there was no differential response among the three selected variables namely number of tynes, bed width and bed height.

Table 4.1 Analysis of variance of time taken to dig out coleus using with flat tyne digger

Source	DF	SS	MS	F	
Bed width (A)	1	2288.02	2288.02	167.41	*
No. of Tynes (B)	1	84.02	84.02	0.14	*
Bed width x No. of Tynes (A x B)	1	8.02	8.02	0.58	NS
Height of bed (C)	2	137.16	68.08	4.98	*
Bed width x Height of bed (A x C)	2	215.05	107.52	7.86	**
No. of Tynes x Height of bed (B x C)	2	20.72	10.36	0.75	NS
A x B x C	2	8.72	4.36	0.319	NS
Error	24	328.00	13.66		

CV= 10.90%

* Significant at 5% level ** Highly significant at 1% level NS - Not significant

4.3.1.2 Interaction of factor means for time to dig out coleus

The interaction of factor means of bed width and number of tynes, bed height and number of tynes and bed width and height of bed on minimum time to dig out coleus is shown in Table 4.2. It is observed that the minimum time taken to dig out the coleus from bed width of 50.0 cm with 6 tynes digger is 21.6 s. But for same bed width, the time taken to dig out coleus is 25.00 s, planted in a bed height of 20.0 cm and harvested using 6 tynes fitted on digger.

Table 4.2 Interaction of bed width, number of tynes and height of bed on time taken (mean values)

Width of bed, cm	Number of tynes					
	6			10		
	Height of bed, cm					
	20	30	40	20	30	40
50	25.0^{ab}	21.6^{a}	28.0^{ab}	24.3^{a}	23.6^{a}	33.0^{bc}
70	44.0^{de}	38.3^{cd}	37.3^{cd}	48.0^{c}	41.0^{d}	42.6^{de}

SED = 3.018 CD = 6.036

The maximum time taken to harvest was 48.00 s with respect to the bed width of 70 cm and at a bed height of 20 cm when harvested using 10 tynes. The time taken for digging coleus was found to be less when using both 6 tynes and 10 tynes in bed height of 20 cm and 30 cm and the width of 50 cm. If bed height was raised to 40 cm, 6 tynes are found to be better for digging out coleus rather than 10 tynes. If bed width is increased to 70.0 cm only 6 tynes are necessary to dig coleus out. A bed width of 50 cm is found to be optimal, for both 6 and 10 tyne diggers. The least time taken was observed for harvesting of coleus. If the number of tynes was increased to 10, bed height of 30 cm was found to be optimal. This might be due to effect of load on tynes with respect to height and width of bed. This might be due to the fact that as the height and width of bed was increased, the load on tyne will be increased and ultimately the speed of operation is decreased and hence more time is taken to cover the selected field plots.

4.3.1.3 Fuel consumption

The analysis of variance for the fuel consumption required to dig out coleus, with respect to bed width, number of tynes and height of bed is given in Table 4.3 The results show that only the effect of bed width was highly significant. The other treatments and their combinations *viz.*, bed width and number of tynes, bed width and bed height and number of tynes and height of bed were not significant. Hence it is inferred that there was no differential effects on fuel consumption during the treatment combinations.

It was therefore inferred that the number of tynes and height of bed is not a factor affecting the fuel consumption when using the harvester to dig out the coleus with respect to the width of bed of 50 cm and 70 cm. Also the fuel consumption was on par at various heights of bed at 20 cm, 30 cm, and 40 cm.

Table 4.3 Analysis of variance of fuel consumption (ml) to dig out coleus using flat tyne digger

Source	DF	SS	MS	F	
Bed width (A)	1	34.0	34.0	9.8	**
No. of Tynes (B)	1	3.3	3.3	0.9	NS
Bed width x No. of Tynes (A x B)	1	4.6	4.6	1.3	NS
Height of bed (C)	2	1.5	0.7	0.2	NS
Bed width x Height of bed (A x C)	2	9.5	4.7	1.3	NS
No. of Tynes x Height of bed (B x C)	2	8.2	4.1	1.1	NS
A x B x C	2	16.8	8.4	2.4	NS
Error	24	82.6	3.4		

CV= 8.06 % ** Highly significant at 1% level NS - Not significant

4.3.1.4 Interaction of factor means on fuel consumption

The effect of factor means of bed width, bed height and number of tynes on fuel consumption while digging out of coleus is shown in Table 4.4. It is observed that a minimum fuel consumption of 20.00 ml was used to dig out of coleus with 6 tyne digger, when harvested from beds of 50.0 cm width and 20.0 cm height. But for the same bed width and bed height the fuel consumed was 23.00 ml, which were on par, when operated with 10 tynes, which was on par. The maximum fuel consumption was observed with 10 tynes when harvesting beds of 70 cm width and 20 cm height. On critical observation, it is noted that when the height of bed was increased to 40 cm, the fuel consumption was found to be minimum in 6 number of tynes, at 50 cm bed width.

Table 4.4 Interaction of bed width, number of tynes and height of bed on fuel consumption (mean values)

Width of bed , cm	Number of Tynes					
	6			10		
	Height of bed , cm					
	·20	30	40	20	30	40
50	20.0^{bc}	23.0^{bc}	20.3^{a}	21.0^{bc}	22.0^{bc}	23.0^{bc}
70	23.0^{bc}	23.0^{bc}	24.0^{b}	26.0^{e}	23.0^{bc}	25.0^{de}

SED = 0.8748   CD = 1.7496

Hence it is concluded that the two factor interactions did not have a significant influence on fuel consumption. This may be due to fact that there was reduction in fuel consumption when operating at a minimum length of bed of 10m, for which the time taken is only 21.6 s. The observations were taken on the basis of small experimental plot design.

4.3.1.5 Capacity

The analysis of variance for the harvesting capacity of coleus harvester with flat tyne digger is shown in Table 4.5. From the table, it is noted that all the treatment and their combinations are not significant, except the effect due to bed width. The F-value for the bed width treatment was 24.7. This indicated that the capacity of the machine due to agronomic parameters *viz.*, bed width and height, and the machine parameters viz., the number of tynes on the digger were on par. This may be due to the fact that the coleus uprooted purely depended on how the machine could expose the underground tubers irrespective of the width and depth of beds made for planting. Hence it is concluded the weight of coleus dig out with respect to various parameters and its treatment combinations were all on par.

Table 4.5 Analysis of variance of capacity of coleus harvester with flat tyne digger

Source	DF	SS	MS	F	
Bed width (A)	1	284	284	24.7	*
No. of Tynes (B)	1	10.0	10.0	0.8	NS
Bed width x No. of Tynes (A x B)	1	9.6	9.6	0.8	NS
Height of bed (C)	2	12.4	6.2	0.5	NS
Bed width x Height of bed (A x C)	2	14.5	7.2	0.6	NS
No. of Tynes x Height of bed (B x C)	2	4.3	2.1	0.1	NS
A x B x C	2	27.4	13.7	1.1	NS
Error	24	275.3	11.4		

CV= 37.37 % *- significant at 5%level NS- Not significant

Table 4.6 Interaction of bed width, number of tynes and height of bed for capacity (kg h^{-1})of harvester (mean values)

Width of bed , cm	Number of tynes					
	6			10		
	Height of bed , cm					
	20	30	40	20	30	40
50	1166[a]	1233[a]	1002[a]	1229[a]	1113[a]	767[a]
70	849[a]	789[a]	1224[a]	772[a]	1677[a]	929[a]

SED = 1.884 CD = 3.768

4.3.1.6 Percentage of damage

The analysis of variance of percentage of damage that occurred while uprooting the coleus using a digger fitted with flat tynes is shown in Table 4.7. The results revealed that the effects due to number of tynes and height of bed were not significant. The effects due to bed width and number of tynes were not significant. While the response due to bed width was highly significant. The other effect due to treatment combinations of bed width and number of tynes, bed width and height of bed and number of tynes and height of bed were significant of 5% level. The three factor interaction of the above said parameters are significant. Hence it was inferred that there were differential effects in the percentage of the damage with respect to the selected variables and its interactions.

Table 4.7 Analysis of variance of percentage of damage occurred while uprooting the coleus using flat tyne digger.

Source	DF	SS	MS	F	
Bed width (A)	1	0.015	0.015	24.0175	**
No. of Tynes (B)	1	0.000	0.000	0.2807	NS
Bed width x No. of Tynes (A x B)	1	0.0005	0.005	7.7368	*
Height of bed (C)	2	0.002	0.001	1.6316	NS
Bed width x Height of bed (A x C)	2	0.005	.002	3.6491	*
No. of Tynes x Height of bed (B x C)	2	0.006	0.002	4.7018	*
A x B x C	2	0.006	0.003	5.1053	*
Error	24	0.0015	0.001		

CV= 26.03 %

* Significant at 5% level   NS- Not significant   ** Significant at 1% level

4.3.1.7 Interaction of factor means on percentage of damage

Interaction of factor means for percentage of damage that occurred during harvesting of coleus at the bed heights of 20 cm, 30 cm and 40cm and at bed widths of 50 cm and 70 cm using a digger with flat tynes is depicted in Table 4.8. From the table values, it was observed that the minimum damage of 5.0 per cent occurred while harvesting the coleus using a digger fitted with 6 flat tynes when operated in a bed of 40 cm height and 70 cm width, closely followed by the bed having same dimensions and in 30 cm bed height with 6 tynes. The maximum damage of 16.0 per cent noticed in beds of 50 x 40 cm, when harvested using 6 tynes. From the results it is concluded that the minimum percentage of damage occurred was 5.0 percent in a bed of size 70 x 40 cm while maximum damage of 16.0 percent occurred when the machine was operated in a bed of 50 x 40 cm. This might be due to fact that as the height of bed increases the impact of cutting tynes was higher at lower bed heights. It is *vice versa* at higher bed height. The percent of damage was on par when operated with 10 tynes in bed of 50 x 40 cm size. It was also noted that when operated 6 tynes in beds of 50 x 30 and 70 x 40 cm were on par.

Table 4.8 Interaction of bed width, number of tynes and height of bed on percentage of damage (mean values)

Width of bed , cm	Number of Tynes					
	6			10		
	Height of bed , cm					
	20	**30**	**40**	**20**	**30**	**40**
50	0.14^{cd}	0.08^{bc}	0.16^{e}	0.13^{cd}	0.10^{b}	$0.08b^{c}$
70	0.08^{bc}	0.05^{a}	0.05^{a}	0.07^{bc}	0.11^{b}	0.09^{bc}

SED = 0.0146 CD = 0.0292

4.3.2 Field testing of coleus harvester with angular tyne digger

4.3.2.1 Time taken to dig out coleus

The analysis of variance for the time taken to dig out coleus with respect to bed width, number of tynes and height of bed is given in Table 4.9. From the table it is inferred that the effect of treatment combinations of bed width and number of tynes is highly significant. But the interaction between bed width and height of bed was significant at 5 % level. Hence, it was inferred that there was differential effect in time with respect to bed width, bed height and number of tynes.

Table 4.9 Analysis of variance of time required to dig out coleus using angular tyne digger

Source	DF	SS	MS	F	
Bed width (A)	1	1653.7	1653.7	212.6	**
No. of Tynes (B)	1	44.4	44.4	5.71	*
Bed width x No. of Tynes (A x B)	1	169.0	169.0	21.7	**
Height of bed (C)	2	130.7	65.3	8.4	**
Bed width x Height of bed (A x C)	2	70.0	35.0	4.5	*
No. of Tynes x Height of bed (B x C)	2	9.7	4.8	0.6	NS
A x B x C	2	73.5	36.7	4.7	*
Error	24	186.6	7.7		

CV= 8.44%

* Significant at 5% level ** Highly significant at 1% level NS- Not significant

There is also a differential response of height of bed with respect to bed width. As regards to the number of tynes in relation to height of bed, no differential response was noticed. It can be therefore , inferred that the number of tynes is not a factor for the time taken to dig out the coleus with respect to height of bed, for 20 cm, 30 cm and 40 cm. In general the three factor interaction was significant, indicating that there is differential response of number of tyne with respect to time taken to dig out coleus.

4.3.2.2 Interaction of factor means for time to dig out coleus

The interaction of factor means of bed width and number of tynes, bed height and number of tynes and bed width and height of bed on minimum time to dig out coleus is shown in Table 4.10. It is observed that the minimum time taken to dig out the coleus from beds of width 50.0 cm and with 10 tynes is 22.667 s. But for same bed width, the time taken at a height of 30.0 cm for both 10 tynes and 6 tynes were on par. The maximum time taken was 46.0 s with respect to the bed width of 70 cm and at a bed height of 40 cm with 10 tynes.

Table 4.10 Interaction of bed width, number of tynes and height of bed on time taken (mean values)

Width of bed , cm	Number of Tynes					
	6			10		
	Height of bed , cm					
	20	**30**	**40**	**20**	**30**	**40**
50	23.6^{a}	25.0^{ab}	33.3^{c}	20.6^{a}	25.0^{ab}	28.0^{b}
70	36.3^{cd}	37.6^{cd}	35.6^{cd}	44.0^{e}	39.3^{d}	46.0^{e}

SED = 2.275 CD = 4.55

The time taken for digging coleus was found to be reduced under 6 tynes and 10 tynes in both bed height of 20 cm and 30 cm, under the width of 50 cm. when the bed height was raised to 40 cm, 10 tynes are found to be better for digging rather than 6 tynes. When bed width was increased to 70 cm, only 6 tynes were necessary to dig out whatever be the height of bed, as no significant difference was observed. If the number of tynes was increased to 10, bed height of 30 cm was found optimal. This might be due to the effect of load on tynes with respect to height and width of bed.

4.3.2.3 Fuel consumption

The analysis of variance for the fuel consumed to dig out coleus with respect to bed width, number of tynes and height of bed is shown in Table 4.11. The results indicated in the table reveal that the effect of treatment combinations of bed width and height of bed were significant. The other treatment combinations, *viz.*, bed width and number of tynes and three factor interactions were not significant. Hence it is inferred that there are differential effects on fuel consumption during the treatment combinations of bed width and height and also with varying number of tynes and height of bed. But it was observed that the three factor combination has no differential effect on fuel consumption.

Table 4.11 Analysis of variance of fuel consumed to dig out coleus using angular tyne digger

Source	DF	SS	MS	F	
Bed width (A)	1	17.3	17.3	5.7	NS
No. of Tynes (B)	1	0.6	0.6	0.2	NS
Bed width x No. of Tynes (A x B)	1	0.0	0.0	0.0	NS
Height of bed (C)	2	18.7	9.3	3.0	NS
Bed width x Height of bed (A x C)	2	31.7	15.2	5.2	*
No. of Tynes x Height of bed (B x C)	2	9.3	4.6	1.5	*
A x B x C	2	5.0	2.5	0.8	NS
Error	24	72.6	3.0		

CV= 7.98%   * Significant at 5% level   NS- Not significant

It is hereby inferred that the number of tynes is not a significant factor for the fuel consumed to dig out the coleus, for width of bed of 50 cm and 70 cm. Also, the fuel consumption were on par at various heights of bed is 20 cm, 30 cm, and 40 cm. In general, the three factor interaction was not significant, which showed that there is no differential response to fuel consumption with respect to width and height of bed and number of tynes on digger.

4.3.2.4 Interaction of factor means on fuel consumption

Interaction of factor means of bed width and height and number of tynes and height of bed on fuel consumed while digging out of coleus is shown in Table 4.12. It is observed that a minimum fuel of 19.0 ml was used for digging out of coleus with 10 tynes digger, in beds of 50.0 cm width. But for the same bed width the fuel consumed was 22.00 ml, which was on par at the bed height of 20 cm and 30 cm, for 10 tynes. The same results were obtained during harvesting of coleus, irrespective of varying heights of bed such as 20 cm, 30 cm and 40 cm and also at bed widths of 50 cm and 70 cm and, with 6 tynes. The maximum fuel consumption was observed with 10 tynes when harvested in beds of 70 cm width and 40 cm height. It is specifically noted that when the height of bed was raised to 40 cm the fuel consumption was found to be minimum in both 10 and 6 number of tynes, at 50 cm bed width.

Table 4.12 Interaction of bed width, number of tynes and height of bed on fuel consumption (mean values)

Width of bed, cm	Number of Tynes					
	6			10		
	Height of bed, cm					
	20	30	40	20	30	40
50	21.6^{ab}	23.0^{b}	19.0^{a}	22.0^{ab}	22.0^{ab}	19.0^{a}
70	22.0^{ab}	24.0^{b}	22.0^{ab}	21.0^{ab}	22.0^{ab}	24.0^{b}

SED = 0.0820   CD = 1.640

Hence, it is concluded that the two factor interactions did not have much influence on fuel consumption. This may be due to fact that the rate of fuel consumption was recorded for a small length of bed of 10m, for which the time taken is only 22.6 s, as the observations were taken on the basis of small experimental plot design.

4.3.2.5 Capacity of the harvester

The analysis of variance for harvesting capacity of the harvester with angular tyne digger is shown in Table 4.13. From the results, it is obvious that all the treatment combinations are not significant, except the effect of bed width on yield. The F value for the bed width is 26.6, which indicated that as width of bed increased, the yield obtained was also increased. This may be due to the fact that as the bed width increased, the crop has established in much wider area and hence this increased the yield. It is concluded that the yield obtained due to various treatments and combinations were all on par.

Table 13. Analysis of variance of capacity of the harvester with angular tyne digger

Source	DF	SS	MS	F	
Bed width (A)	1	358	358	26.6	*
No. of Tynes (B)	1	4.2	4.2	0.31	NS
Bed width x No. of Tynes (A x B)	1	0.3	0.3	0.02	NS
Height of bed (C)	2	1.9	0.9	0.07	NS
Bed width x Height of bed (A x C)	2	5.1	2.5	0.19	NS
No. of Tynes x Height of bed (B x C)	2	17.6	8.8	0.65	NS
A x B x C	2	2.6	1.3	0.09	NS
Error	24	322.8	13.4		

CV= 27.85% *- significant at 5% level NS- Not significant

Table 4.14 Interaction of bed width, number of tynes and height of bed on capacity of the harvester (mean values)

Width of bed , cm	Number of Tynes					
	6			10		
	Height of bed , cm					
	20	**30**	**40**	**20**	**30**	**40**
50	1464[a]	1281[a]	929[a]	1345[a]	1209[a]	1105[a]
70	773[a]	1148[a]	1011[a]	900[a]	970[a]	7826[a]

SED = 1.2525 CD = 2.564

4.3.2.6 Percentage of damage

The analysis of variance of percentage of damage that occurred while uprooting the coleus using a digger fitted with angular tynes is shown in Table 4.15. The results revealed that only the effect due to height of bed was significant at 5 % level. The other individual effect due to bed width and number of tynes were not significant. It was also seen that the effect due to treatment combinations *viz.*, number of tynes, and height of bed are significant at 5% level, while the response due to bed width and height of bed was highly significant. The three factor interaction of the above said parameters were not significant. Hence it was inferred that there was differential effect in the percentage of the damage with respect to height of bed and at the treatment combinations of 6 and 10 number of tynes with varying bed width of 50 cm and 70 cm and bed heights of 20 cm, 30 cm and 40 cm. As regards to the separate response due to bed width and number of tynes, no differential response was observed.

Table 4.15 Analysis of variance of percentage of damage while uprooting the coleus using angular tyne digger

Source	DF	SS	MS	F	
Bed width (A)	1	0.001	0.001	2.1235	NS
No. of Tynes (B)	1	0.000	0.000	0.1471	NS
Bed width x No. of Tynes (A x B)	1	0.0002	0.002	4.288	*
Height of bed (C)	2	0.005	0.002	5.1235	*
Bed width x Height of bed (A x C)	2	0.009	0.005	9.718	**
No. of Tynes x Height of bed (B x C)	2	0.004	0.002	4.4176	*
A x B x C	2	0.001	0.000	1.0059	NS
Error	24	0.0011	0.000		

CV= 20.32%

* Significant at 5% level ** Highly significant at 1% level NS- Not significant

4.3.2.7 Interaction of factor means on percentage of damage

Interaction of factor means for percentage of damage occurred during harvesting of coleus at the bed heights of 20 cm, 30 cm and 40 cm and at bed widths of 50 cm and 70 am using a digger with angular tynes is depicted in Table 4.16. From the results, it is observed that the minimum damage of 7.67 per cent occurred while harvesting coleus using a digger fitted with 6 tynes in a bed of 40 cm height and 70 cm width, closely followed by another bed having same dimensions but with 10 tynes. The damage of 11.00 per cent was observed in beds in 50 cm x 20 cm and 50 cm x 30 cm when operating with both 6 and 10 tynes. The maximum damage of 15.70 per cent occur in beds of 70 x 30 beds, when harvested using 6 tynes. From the results it is concluded that the minimum percentage of damage was 7.67 in the bed of size 70 cm x 40 cm while maximum damage of 15.70 per cent occurred in a bed of 70 x 30 cm, both at 6 tynes. This may be due to fact that as the height of bed increases the impact of cutting tynes as higher at lower height beds, it is in *vice versa* at higher bed length.

Table 4.16 Interaction of bed width, number of tynes and height of bed on percentage of damage (mean values)

Width of bed, cm	Number of tynes					
	6			10		
	Height of bed, cm					
	20	30	40	20	30	40
50	0.11^{abc}	0.11^{abc}	0.09^{ab}	0.11^{abc}	0.13^{ab}	0.15^{c}
70	0.09^{ab}	0.15^{b}	0.076^{a}	0.08^{ab}	0.12^{bc}	0.08^{a}

SED = 0.178 CD = 0.356

4.4 Comparison of performance of the coleus harvester with flat and angular tyne diggers

The coleus harvester was compared with respect to time, fuel consumption, weight and percentage of damage of coleus separately with flat and angular tynes. The observations were separately recorded for various width of bed 50 x 20 cm, 50 x 30 cm, 50 x 40 cm, 70 x 20 cm, 70 x 30 cm, and 70 x 40 cm respectively. The results are illustrated with respect to time, fuel consumption, weight and percentage of damage.

4.4.1 Time taken to dig out coleus

The performance on time taken (s) to dig out coleus with 6 - tyne and 10 - tyne flat and angular digger fitted with harvester is shown in Fig 4.1 and Fig 4.2 It is obvious that the time taken was the highest in beds of 70 x 30 cm, whereas minimum time taken was in the bed size of 50 x 30 cm.

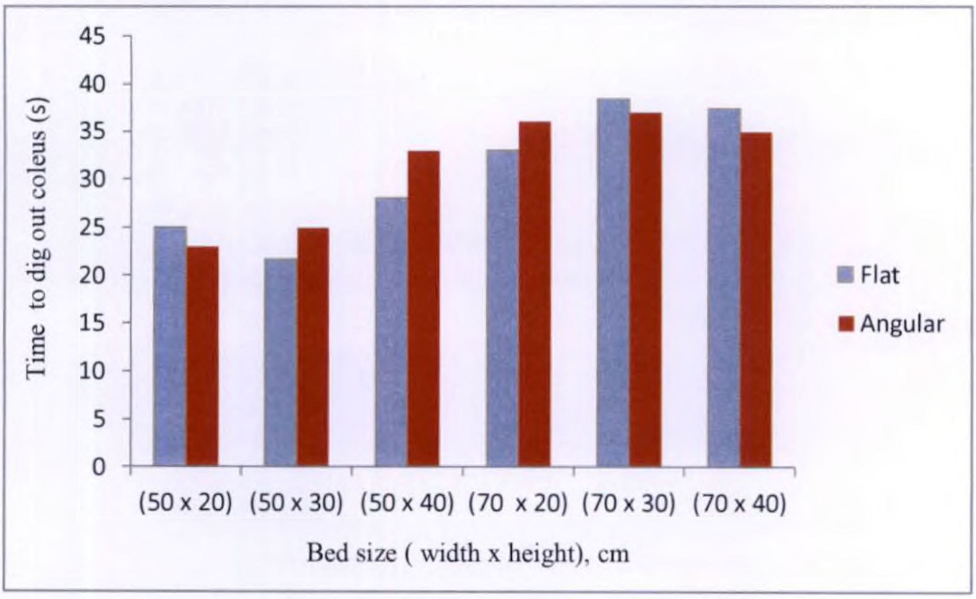

Fig. 4.1 Performance on time taken (s) to dig out coleus with 6 - tyne of flat and angular digger

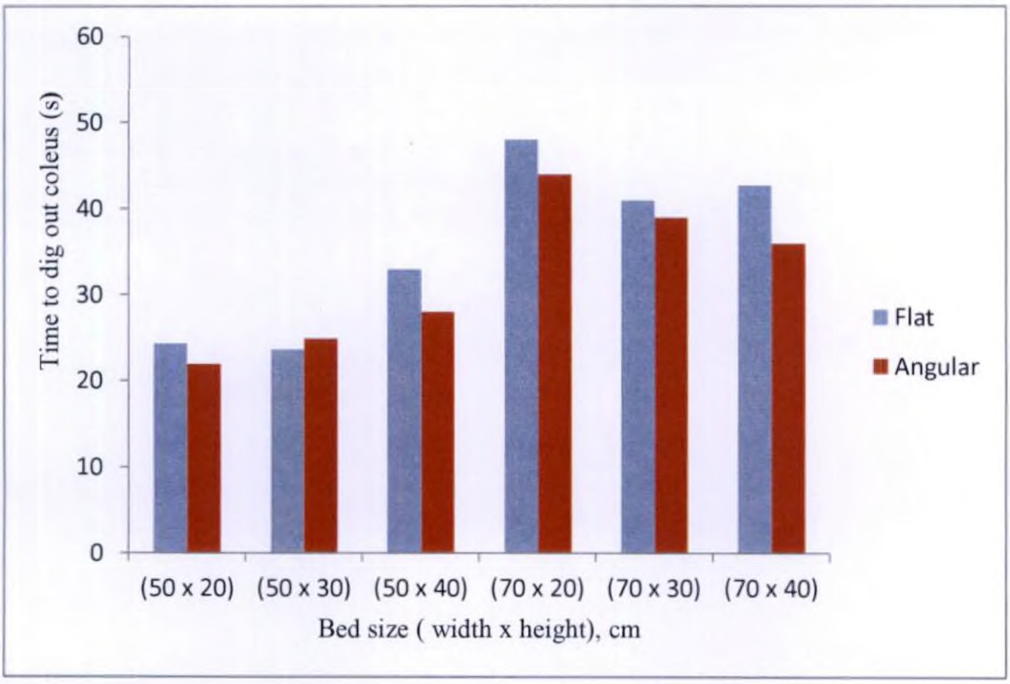

Fig. 4.2 Performance on time taken (s) to dig out coleus with 10 - tyne flat and angular tyne digger.

4.4.2 Fuel consumption

The performance with respect to fuel consumption (ml) to dig out coleus with 6 - tyne and 10 - tyne flat and angular diggers fitted to harvester is shown in Fig. 4.3 and Fig.4.4. It is obvious that the fuel consumption was the highest in harvesting of coleus in bed size of 70 x 20 cm, whereas minimum fuel consumption was seen in the bed size of 50 x 40 cm while using 6 tynes. If 10 tynes are used it is noted that the fuel consumed was the highest in beds of 70 x 20 cm, whereas minimum fuel consumption was in the bed size of 50 x 20 cm.

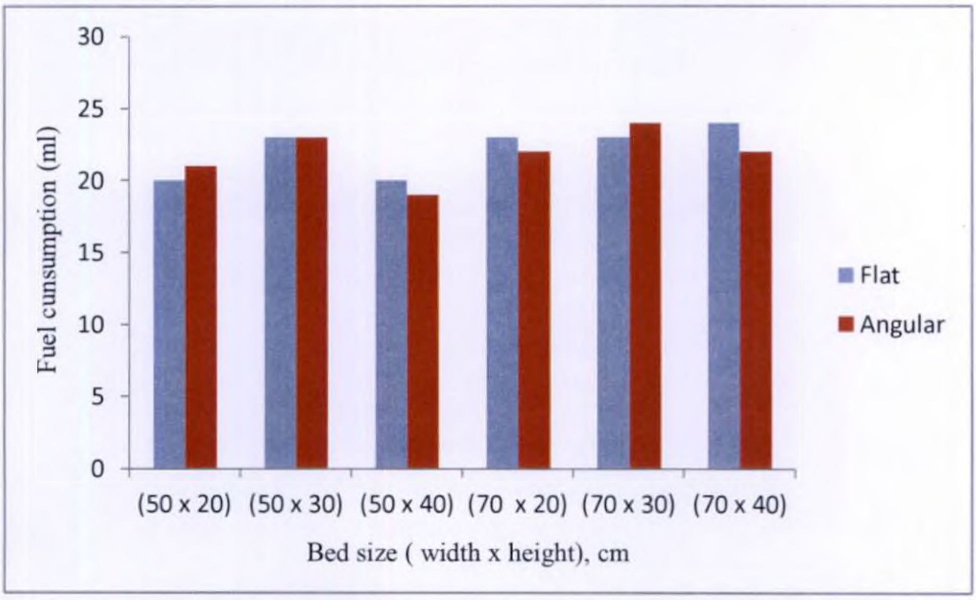

Fig. 4.3 Performance with respect to fuel consumption to dig out coleus with 6 - tyne of flat and angular digger

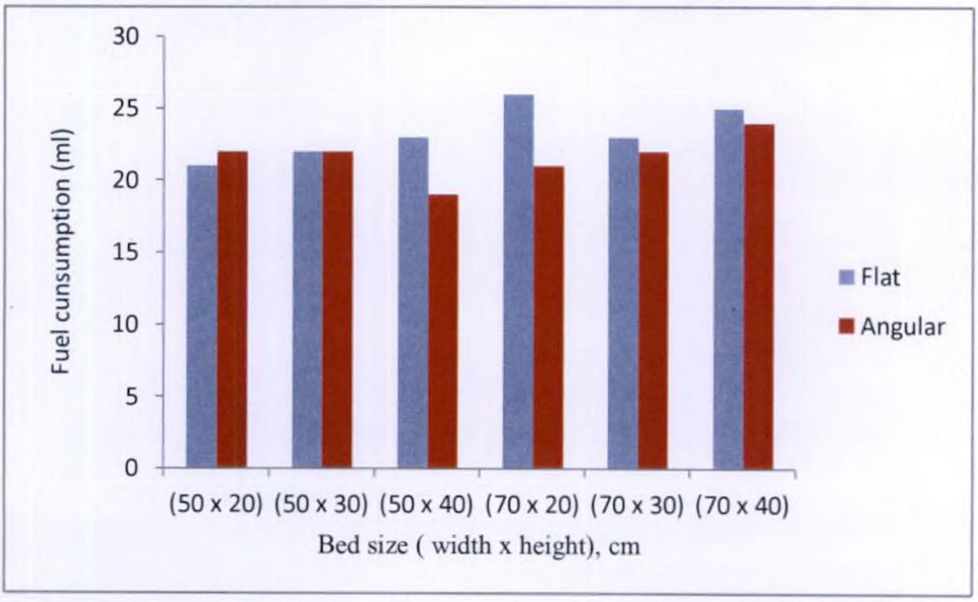

Fig. 4.4 Performance with respect to fuel consumption to dig out coleus with 10 - tyne of flat and angular digger

4.4.3 Capacity

The harvesting capacity of coleus harvester with 6 - tyne and 10 - tyne flat and angular diggers is shown in Fig.4.5 and Fig. 4.6. It is noted that the uprooted was the highest in beds of 50 x 20 cm, whereas minimum weight uprooted was in the bed size of 50 x 40 cm when operated with 6 flat tynes. When 10 angular tynes were used, it is noted that the weight (kg) of coleus uprooted was the highest in beds of 70 x 30 cm and minimum weight uprooted was in the bed size of 50 x 20 cm. Thus the average capacity of the harvester was observed as 1069 $kg.h^{-1}$.

4.4.4 Percentage of damage

Performance of the harvester on percentage of damage with 6 - tyne and 10 - tyne flat and angular digger is shown in Fig.4.7 and Fig. 4.8. It is obvious that the percentage of damage of coleus was the highest in beds of 70 x 30 cm, whereas minimum damage occurred in the bed size of 70 x 40 cm while using 6 tynes . If 10 tynes are used, it is noted that the damage of coleus was the highest in beds of 70 x 20 cm, whereas minimum damage was in the bed size of 50 x 20 cm.

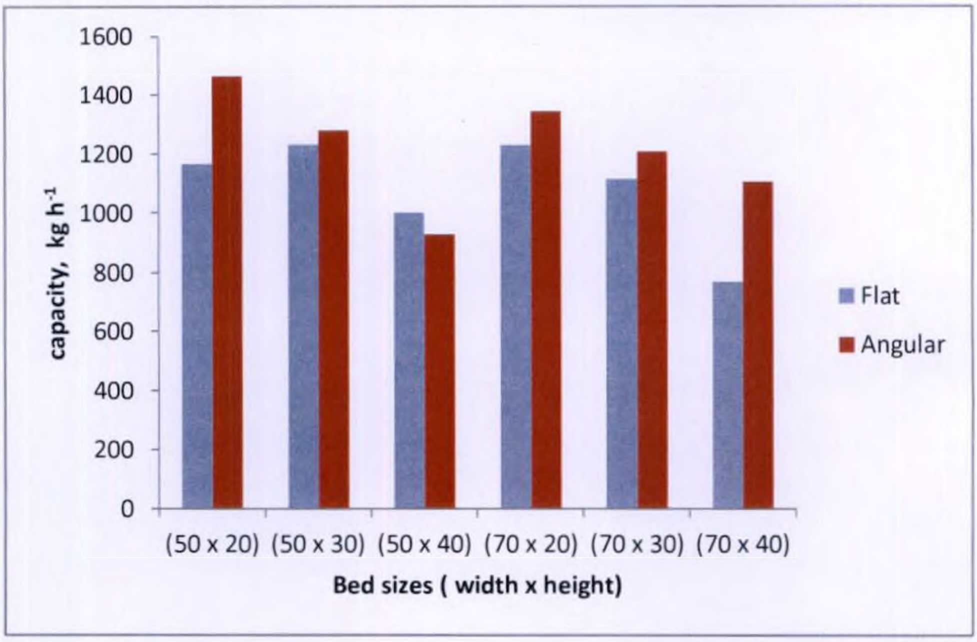

Fig. 4.5 The capacity of the harvester with 6 - tyne flat and angular digger

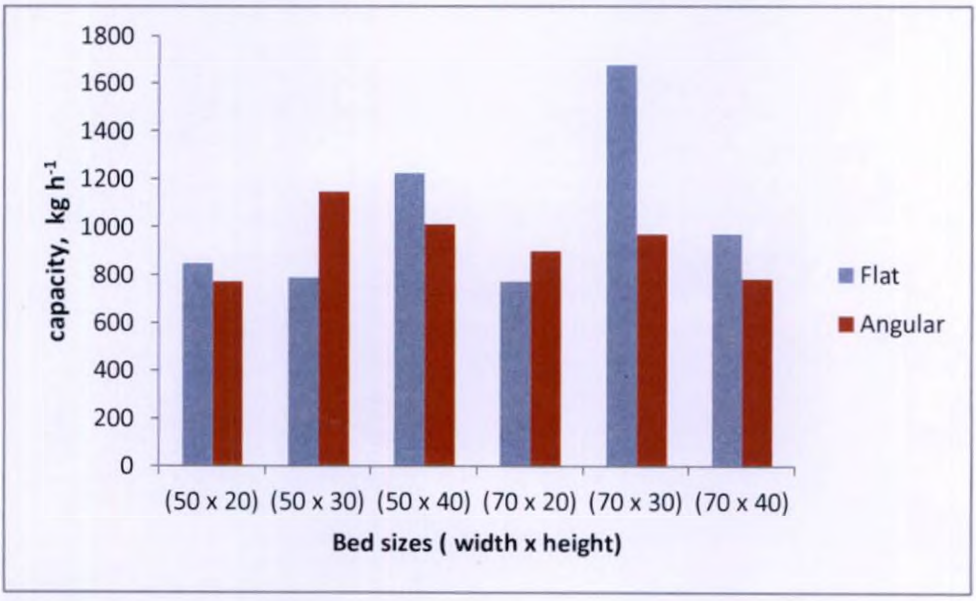

Fig. 4.6 The capacity of the harvester with with 10 - tyne flat and angular digger

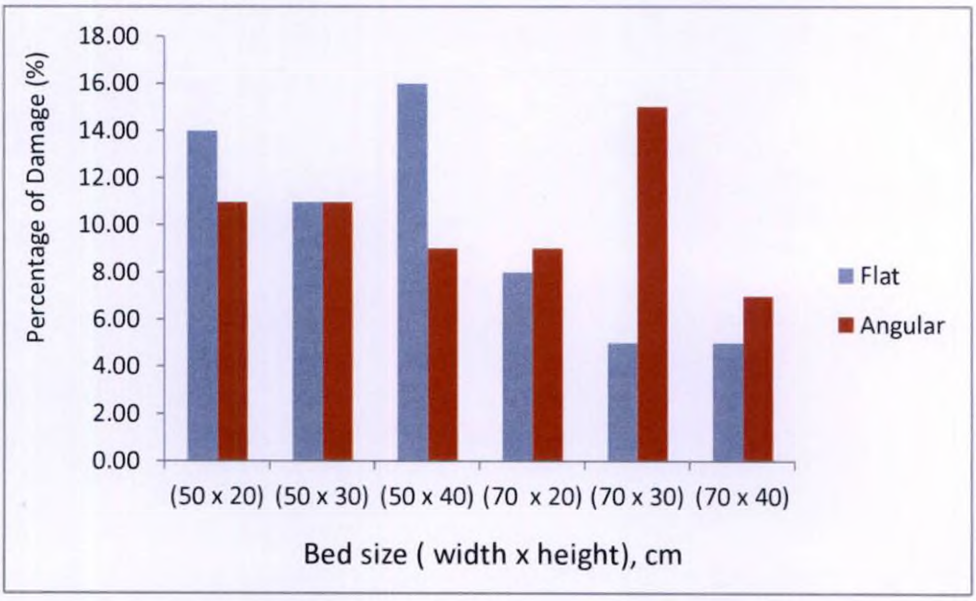

Fig .4.7 Performance on damage of coleus when harvested with 6 - tyne flat and angular digger

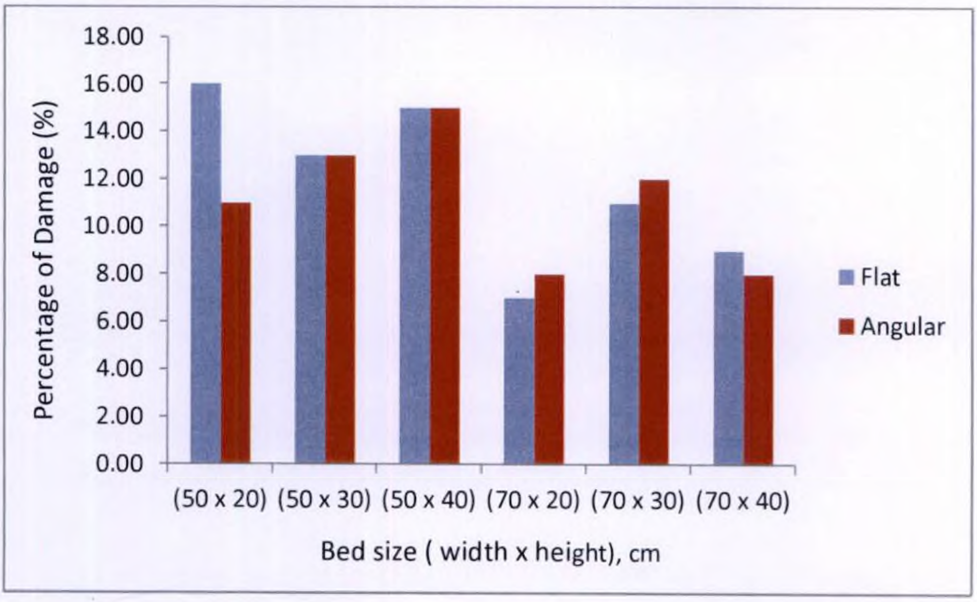

Fig 4.8 Performance on damage of coleus when harvested with 10 - tyne flat and angular digger

4.5 Comparison with a commercial harvester (TNAU ginger harvester)

It was observed that the vibrating mechanism provided was useful to obtain the coleus in clumps after harvest. In field operation it was not possible for uprooting coleus in the bed sizes of 50 x 40 cm and 70 x 40 cm. The observations were recorded and are shown in the Appendix XI. The major draw backs observed with this harvester were its low ground clearance and non detachment of the clumps hence it cannot be used for beds having height more than 30 cm. The separation of coleus after harvest is yet another difficulty in operating with such commercial model. Hence the harvester is to be further modified to suit the bed sizes having more than 30 cm height. This modified harvester can be used even in a bed height of 40 cm of bed usually with high in wet land where it is largely cultivating.

4.6 Field efficiency

Field efficiency of modified harvester is the ratio of actual field capacity to the theoretical field capacity. It was observed that the total time taken to harvest of an area 0.0632 ha was 1.13 h. Hence the actual field capacity was 5.7×10^{-2} ha.h^{-1}. The theoretical field capacity was 6×10^{-2} ha h^{-1} calculated as explained in section 3.10. The calculation of field efficiency is given in Appendix XII. The field efficiency of the harvester was calculated as 95 %.

4.7. Cost economics

The field capacity of the modified coleus harvester is 0.057 ha h^{-1}. Manual harvesting of coleus requires 6.2 x 10^{-5} ha h^{-1}. At the present wage rate of Rs 500 per day, the total cost of operation by manual method is about Rs 31,250 per hectare. By mechanical harvesting the total cost of operation is Rs 7680 per hectare. Hence the savings over conventional method is Rs 24,470 per hectare. The details of the cost analysis and the field coverage by manual method are given in Appendix X.

SUMMARY AND CONCLUSIONS

CHAPTER V

SUMMARY AND CONCLUSIONS

Coleus (*Solenostemon rotundifolius*) commonly known as Chinese potato, is a major tuber crop of our State. It is grown in most of the homestead gardens of Thrissur, Palakkad and Malappuram districts. It grows well in warm humid climate and in drained medium fertile soils. It is raised purely as a rain fed crop in the State from June to December. The first step in coleus cultivation is preparation of nursery, which is usually done during May-June every year. Herbaceous cuttings of coleus from nursery are Planted on raised beds at a spacing 15 cm at a depth of 5 to 10 cm. Harvesting is done when haulms dry up, i.e., 4 to 6 months after planting. Using spade, the tubers are taken out from the soil. Manual harvesting of coleus is very tedious and time consuming operation which requires proper handling, to avoid cuts, breakage, bruises and injuries. To overcome these problems and decrease the cost of harvesting operation, a self propelled coleus harvester was developed earlier. The irregular geometry of tubers, different maturity stages and soil conditions were the major constraints in its modification. Hence a research work was carried out to modify the developed harvester to dig out the coleus with specific objectives of minimizing time, fuel consumption and damage.

An area of 0.128 ha in 8th Block of Regional Agricultural Research Station (RARS), Pattambi was selected as study area, which is situated at a 10.8200° N latitude and 76.2000° E longitude. The site has good drainage and sunlight without any shade. The soil of the selected field was sandy loam with moisture content 30 per cent. The physical properties of the soil have an effect directly or indirectly at the soil-tool interface as well as the growth of the crop. The major three properties, *viz*, moisture content, bulk density and penetration resistance of the soil were determined. Soil samples were taken from each of the study area for soil moisture content determination, at depths of 0-5 cm, 5-10 cm, 10-15 cm, 15-20 cm, 20-25 cm and

25-30 cm, but bulk density were determined at depths of 0-20 cm, 20-30 cm and 20-40 cm after ploughing. A soil auger was used to take soil samples for moisture content determination, whereas a soil core cutter of size 6.5 cm and 10 cm in diameter and a rammer was used to take soil sample for bulk density determination. Soil samples were oven dried at a temperature of 105°C for 24 hours in accordance with the gravimetric soil moisture determination method. *In situ* tests were carried out at depths of 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm for each study area at harvest to determine the soil penetration resistance at known soil depths and using soil cone penetrometer.

The field lay out was made in such a way that it was divided into two equal plots of 0.06 ha. In each plot, beds of sizes 10 m x 0.5 m and 10 m x 0.7 m respectively as length x breadth were prepared. Good quality cuttings of 'Nidhi' variety of coleus were selected for planting. It was planted at a depth of 10 cm with spacing of 15 cm x 15 cm in each bed; hence the total number of cuttings per bed was 189. Channels of 0.3 m x 0.3 m were made around each lot to provide proper drainage. The planting was done during first week of July 2014, *i.e*, after getting enough rainfall during south west monsoon.

The physical and mechanical properties of the coleus *viz*., size, shape, sphericity, weight and toughness and firmness were found out using standard test procedures. The size of the coleus was determined by using Vernier calipers and the shape by graphical method. The firmness and toughness of the coleus were determined using texture analyzer.

The coleus harvester was developed as an attachment to a mini tiller. It consisted of a prime mover, a digger, rotary blade, and driven wheels. The prime mover was a 3.5 hp 2- stroke diesel engine. The use of such a tiller proved to be advantageous for wide variety of reasons like the compactness, small size, easy movement on narrow terrains, and ease of operation for women, smooth mobility and also a 360° turning facility of handle. Its main frame accommodates all the attachments and accessories of the harvester. It holds the digger assembly and is bolted to chassis of mini tiller. The tynes fitted to the digger was the penetrating part of the equipment. It takes most of the soil resistance during operation. The two sets of digger with flat and angular tynes were made for comparing the performance of the harvester. The flat tynes were made of MS square 300 mm x 20 mm x 20 mm and angular tynes were made of MS angle 300 mm x 5 mm x 25 mm. The ends of square pipes were provided with a slight bending for better penetration and earthing up of coleus from soil. The tynes are positioned in such a way that they make an angle of 40° with the vertical. This helps in easy penetration into the soil with respect to various tyne, provisions were made to adjust the penetrating angles for better performance.

The rotary slasher are the rotating blades attached to the rear side of the tiller. The drive is transmitted through chain sprocket assembly from the engine. In order to modify the harvesting unit, the rotary blades (L-shaped tynes) were removed and rubber flaps of 75 x 75 x 0.3 mm were fastened to the shank of the rotary blade. Thus the rubber flaps fastened tynes (rotary splasher) on rotation will splashes or pushes away the dugout coleus outward simultaneously. The wheels of tillers act as vehicle traction elements to generate enough tractive force to overcome soil resistance and to ensure resistive forced motion. The wheel provided by the manufacturer was lesser in diameter and with low maneuverability. Hence a set of larger wheels were fabricated separately with diameter of 80 cm using in MS flat of 50 mm x 3 mm and square rod of 10 mm x 10 mm to operate the harvester at various heights of seed beds. As and when tiller moved, the digger pierced into the soil at a depth of 10 cm -15 cm and at an angle of 40° to dig out the rhizomes that lie inside the soil. The uprooted coleus coming over the inclined tynes of digger were then pushed out by means of the rotary splasher rotating just above the digger. The scattered coleus lying in the seedbed could be collected easily and hence the harvesting becomes easier and faster. Rubber mudguard was provided to protect the operator from scattered stones or debris which may be thrown away as projectile along with coleus.

Trials were conducted in beds having width x height as 50 x 20, 50 x 30, 50 x 40, 70 x 20, 70 x 30 and 70 x 40 cm for each bed length of 10 m. In each bed, performance evaluation of the harvester with 6 and 10 number of flat and angular tyne diggers was carried out for each of the treatment combinations. Three replications were carried out, to each trial. The total number of treatments was 72. Observations were statistically analyzed using three factor ANOVA using MSTAT. The experiments were laid out according to Factorial Randomized Block Design (FRBD).

Performance analysis of the modified coleus harvester was compared with respect to time, fuel consumption, harvesting capacity and percentage of damage of coleus separately with flat and angular tynes. The observations were separately recorded for various width of bed 50 x 20 cm, 50 x 30 cm, 50 x 40 cm, 70 x 20 cm, 70 x 30 cm, and 70 x 40 cm respectively. The results were compared with respect to time, fuel consumption, weight and percentage of damage.

The performance on time taken (s) to dig out coleus with 6- tyne and 10 - tyne flat and angular digger fitted with the harvester revealed that the time taken was the highest in beds of 70 x 30 cm, whereas minimum time taken was in the bed size of 50 x 30 cm.

The fuel consumption (ml) for harvesting was the highest in the bed size of 70 x 30 cm and minimum in the bed size of 50 x 40 cm, while using 6 tynes. When operated with 10 tynes, it is noted that the fuel consumed was the highest in beds of 70 x 20 cm, whereas minimum fuel consumption was in the bed size of 50 x 20 cm. The capacity of coleus harvester with 6 - tyne and 10 - tyne flat and angular diggers were determined. It is noted that the uprooted was the highest in beds of 50 x 20 cm, whereas minimum weight uprooted was in the bed size of 50 x 40 cm when operated with 6 flat tynes. When 10 angular tynes were used, it is noted that the weight (kg) of coleus uprooted was the highest in beds of 70 x 30 cm and minimum weight uprooted was in the bed size of 50 x 20 cm. Thus the average capacity of the harvester was observed as 1069 $kg.h^{-1}$.

It was also observed that the percentage of damage of coleus was the highest in beds of 70 x 30 cm, whereas minimum damage was occured in the bed size of 70 x 40 cm while using 6 - tyne digger. If 10 - tyne diggers are used it is noted that the damage of coleus was the highest in beds of 70 x 20 cm, whereas minimum damage was in the bed size of 50 x 20 cm.

Performance analysis of a commercial harvester (TNAU ginger harvester) indicated that the vibrating mechanism provided was useful to obtain the coleus in clumps after harvest. In field operation it was not possible for uprooting coleus in the bed sizes of 50 x 40 cm and 70 x 40cm. The major draw backs observed with this harvester were its low ground clearance and non detachment of the clumps hence it cannot be used for beds having height more than 30 cm which is the common practice among coleus farmers of the State. The separation of coleus after harvest is yet another difficulty in operating with such commercial model. Hence the harvester is to be further modified to suit the bed sizes having more than 30 cm height.

Thus it is concluded that the minimum time taken and fuel consumed were respectively as 20.66 s and 19.0ml, when operated with 10- tyne angular digger. Though the percetge of damage (8%) was a little higher than that of 6- tyne flat digger (5%), the weight of coleus harvested was also better when operated with 10-tyne angular digger. Hence it is suggested that the best digger is with 10 angular tynes. The optimum size of bed was found to be 50 x 40 cm. The harvester can be further modified by suitably designing a vibrating mechanism along with the digger tyne for minimum damage.

The field capacity of the modified coleus harvester is 0.057 $ha.h^{-1}$. Coleus harvesting by manual method requires 6.2×10^{-5} ha h^{-1}. At the present wage rate of Rs 500 per day, the total cost of operation by manual method is about Rs 31,250 per ha. By mechanical harvesting the total cost of operation is Rs 7680 per ha. Hence the savings over conventional method is Rs 24,470 per ha. The field efficiency of the harvester was calculated as 95%.

REFERENCE

REFERENCES

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.

Ajoykumar Das., DhanyaAugustin, and NadiyaNesthad. (2009). Development and testing of coleus and ginger harvester. B. Tech project report submitted to the Kelappaji College of Agricultural Engineering and Technology, Tavanur.

Arshad, M.A., Lowery, B., and Grossman, B. 1996. Physical tests for monitoring soil quality. p.123-142. *In*:. Doran, J.W and Jones, A.J. (eds.) Methods for assessing soil quality. *Soil Sci. Soc. Am. Spec.* Publ. 49. SSSA, Madison, WI.

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

Bentini, M. and Biavati, E. 1995. Mechanical harvesting of sugarbeet. MachinieeMotori. Agrico Li 53(7/8).pp: 17-33.

Berbekov, Y.T., Sysokoev, K., and Afonski, A.S. 1995. A bulb and potato digger with active working organ for use with the MB-1 walking tractor. Traktory Mushing no.7, Russia. pp: 25-29.

Bulgakov, V.M., Finko,S.V., Glukhosov,V.S and Mazurenko, A.M. 1995. The MKP-4 root harvesting machine with vibratory working parts. Sakharrya Svelta no.8,Russia.pp: 9-11.

Bobobee, E.Y.H., Okyere, J. B., and Asare, E. 1994. Mechanical Cassava HarvestingTechnique: Final Report. National Agricultural Research Project (NARP)- Council for Industrial and Scientific Research (CSIR).

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

Grisso, R., Perumpral, J. V., Vaughan, D., Roberson, G. T., and Pitman, R. 2010. Predicting Tractor Diesel Fuel Consumption. Communications and Marketing, College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University, Publication 442-073, pp 1-10.

Harmenn, K. and Schuh, J.P. 1994. Lifting equipment for the sugarbeet harvest. *Neise Landwirtschaft*, no. 8:(72-76).

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.

Jahn, B. R., and Hamburg, D. S. (2002). A Tractor-Mounted Device for Measurement of In-situ Soil Strength Properties. *An ASAE/CSAE Meeting Presentation*, Paper No: MBSK 02-308, Niles Road, St. Joseph, MI 49085-9659 USA

Kathirvel, K. and Manian, R. 2002. Effect of tool geometry on harvesting efficiency of turmeric harvester. AMA 33(1).39-42.

Macmillan, R. H., 2002. The Mechanics of Tractor - Implement Performance: Theory and Worked Examples. Agricultural Engineering International Development Technologies Centre, University of Melbourne.

Morris, M.2006. Soil moisture monitoring: low-cost tools and methods. A publication of ATTRA- National Sustainable Agriculture Information service.1-800-346-9140.

Mozaffary, M., Kazmeinkhan, K., Mousavizadeh, S.A. and Abdi, S. 2002. Design and development of three onion toppers and selecting the best for an onion harvester. The joint agricultural and national resources symposium, TahsizGanya, May14-16.

Nweke, F. I., Dunstan S. C. S. and Lynam J. K. 2002. The Cassava Transformation: Africa"s Best Kept Secret. *Lansing, Mich., USA: Michigan State University Press.*

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

Peters, R. 1995. Windrowers for potatoes, a list of makes. *Kartoffelbau* 46(6): 232-235.

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

Pillai, K.S., Steemulanathan, H., and Chettiar, A.P. 1970. Studies on the preservation of cassava (tapioca) tuber. *Agric. Res. J. Kerala* .8: 82-85.

Ricca, A. 1995.Technical chokes for competitive sugar beet production. Mondo Machinia no.2, Italy. pp: 54-56.

Siemens, J. C., and W. W. Bowers. (1999). Machinery Management: How to Select Machinery to Fit the Real Needs of Farm Managers. *Farm Business Management Series.* Davenport, Iowa: John Deere Publishing.

Singh S., 2006 - Design, development and field testing of a multipurpose potato digger. Potato Journal, 33 (34): 134-138.

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

Tiwari, P.S. 1994.Soil Bin Investigation into the performance of tractor drawn potato diggers. Jl. Of Agric. Engg. 31(44):57-60

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.

Yasin M., Ahmed , M.M, and Rehman, R 2003 Design, development and performance evaluation of rotary rotato digger. AMA, 34(2): 43-46.

APPENDICES

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 $(m_2-m_3)/(m_3-m_1)$	Moisture content in percent
22.0	54.50	48.0	0.25	25.00
36.5	65.30	60.5	0.20	20.00
39.0	86.80	79.5	0.18	18.02
23.0	71.10	62.0	0.23	23.33
32.0	75.97	68.5	0.20	20.46
22.5	78.65	68.0	0.23	23.40

Sample calculations :

Mass of container, m_1 (g) = 22.00

Mass of container + wet soil, m_2 (g) = 54.50

Mass of container + dry soil, m_3 (g) = 48.0

Moisture content, % $= [(m_2-m_3)/(m_3-m_1)] \times 100$

$= (54.5- 48.8)/(48.0-22.00)$

$=6.5/26$

$=0.25 \times 100$

Moisture content (%) = 25.00

Appendix II

Determination of bulk density

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	2750	1750	13	10	1020.5	1.714	16.822
900	2650	1750	12.6	10	989.10	1.769	17.356
900	2600	1700	12.6	9.5	892.66	1.904	18.6823
750	1500	750	11	6.5	364.82	2.055	20.166
550	1400	850	11	6.5	364.82	2.329	22.855
550	1300	750	11	6.7	387.62	1.934	18.980

Sample calculations:

Mass of core cutter, gm = 1000

Mass of core cutter + wet soil, gm = 2750

Mass of wet soil, gm) = 1750

Height of core cutter, cm = 13

Internal diameter, cm = 10

Volume, cm^3 = 1020.5

Bulk density, g/cm^3 = Mass/ volume

= 1.714

Appendix III

Determination of penetration resistance

Depth (cm)	Force (Kg)	Force (N)	Cone area (m^2)	CI (N/m^2)	CI (MPa) ($N/m^2 X10^{-6}$)
0	0	0	0.00032	0	0
1	2	19.62	0.00032	61312.50	0.061
2	2	19.62	0.00032	61312.50	0.061
3	5	49.05	0.00032	153281.25	0.153
4	25	245.25	0.00032	766406.25	0.766
5	42	412.02	0.00032	1287562.50	1.287
6	48	470.88	0.00032	1471500.00	1.471
7	54	529.74	0.00032	1655437.50	1.655

Sample calculations:

Depth of penetration, cm = 2

Force applied, kg = 2

= 19.6 N

Cone area ,m^2 = 0.00032

Cone index = Force/ Cone area

= 19.6/0.00032

= 61312.5 Nm^{-2}

= 0.061 x 10^{-6} Nm^{-2}

Appendix IV

Size of coleus

Number	length (cm)	width (cm)
Sample 1	6.5	3.4
Sample 2	5.7	2.8
Sample 3	3.5	2.7
Sample 4	4.5	1.6
Sample 5	4.3	2.1
Sample 6	4.3	1.0
Sample 7	4.4	1.3

Appendix V

Determination of sphericity

Sl. No	Diameter of largest circumscribing circle(cm)	Diameter of smallest circumscribing circle(cm)	Sphericity
Sample 1	6.5	3.4	1.91
Sample 2	5.7	2.8	2.03
Sample 3	3.5	2.7	1.29
Sample 4	4.5	1.6	2.81
Sample 5	4.3	2.1	2.04
Sample 6	4.3	1.0	4.30

Appendix VI

Average weight of coleus

Sl. No	Weight (gm)
Sample 1	64.50
Sample 2	39.10
Sample 3	20.10
Sample 4	17.50
Sample 5	24.30
Sample 6	2.200
Sample 7	1.800

Appendix VII

Determination of firmness and toughness

Sl.No	Firmness, kg	Toughness, kg.s
1	5.203	9.121
	4.606	7.028
	4.864	7.73
2	4.784	8.507
	4.796	5.512
	4.603	7.463
3	4.935	6.861
	4.601	7.129
	5.54	7.155
4	4.539	5.361
	4.948	7.587
	4.977	7.801

APPENDIX VIII

Specifications of Asia cultivator (Mini tiller)

Model			ASC-610
Body	Overall length (mm)		1530
	Overall height (mm)		1030
	Overall width (mm)		620
	Weight(kg)		89kg
Engine	Model		G-160T1
	Type		Air Cooled 4Cycle ,
	HP		3.5
	Cont. output (ps/rpm)		4.5/1800
	Max. output (ps/rpm)		5.5/1800
	Displacement (cc)		163
	Fuel tank capacity(L)		3.6
	Starting System		Recoil Starting
	Tyre		Φ330 mm
	Main clutch system		Belt Tension Type
	Main transmission		Forward : 2, Reverse : 2
	Rotary clutch system		dog-type
	The range of adjusting the handle	Up & Down	4STAGE
		Left & Right	360°
	P.T.O Rotation(rpm)		Low : 333, High : 709
Rotary	Transmission		Forward rotation 2, Reverse rotation 2
	Driving system		Center Driving Type
	Max. rotor diameter (mm)		290
	Rotary width (mm)		250

APPENDIX IX

Specifications of commercial harvester (TNAU ginger harvester)

Model	Engine :ER90
	Tiller KMB200
Type	Rotary, diesel-powered, water cooled with radiator
HP	Continuous : 9
	Maximum : 12
RPM	2000
Fuel consumption	1.5 lph
Fuel tank capacity	10.7 l
No. of speeds	Forward :6
	Reverse :2
	Tilling :4
Wheel track	Maximum : 930 mm
	Minimum 690 mm
Tyre size	6.00 x 12
Ground clearance	203 mm
Traveling speed	15 kmph (max)
Tilling width	600 mm
Tilling depth	190 mm
No. of blades	20
Overall dimensions	L : 2250 x W :820 x H :1030 mm
Weight	485 kg

APPENDIX X

Cost analysis of the modified coleus harvester.

1. Mini tiller (Asia cultivator)

A. Basic information

(i) Cost of the mini tiller, Rs	: 1,50,000
(ii) Useful life, year	: 10
(iii) Hours of use per year	: 350
(iv) No. of skilled labours required	: 2
(v) Rate of interest	: 10 %
(vi) Salvage value (10 % of investment cost)	: 15,000
(vii) Field capacity of coleus harvester, ha h^{-1}	: 0.057
(viii) Fuel requirement, $l\ h^{-1}$	: 2

B. various costs

I Fixed cost

(i) Depreciation cost per year, Rs : $\frac{\text{Initial cost} - \text{Salvage value}}{\text{Useful life}}$

: $\frac{1,50,000 - 15,000}{10}$

: 13,500

(ii) Interest on investment per year, Rs : $\frac{(\text{cost of mini tiller} + \text{Salvage value})}{2}$ x Intrest rate

: $\frac{1,50,000 + 15,000}{2}$ x 0.10

: 8250

(iii) Taxes, insurance and shelter per year, Rs : cost of mini tiller x 0. 02

: 3000

(iv) Total fixed cost per year, Rs : 13,500 + 8,250 + 3,000 = 24,750

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

: 82.5

II Variable cost

(i) Repair and maintenance per hour, Rs : $\frac{\text{Cost of mini tiller x 0.05}}{1000}$

: 9.3

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

: 110

(iii) Cost of lubricant per hour, Rs : Fuel cost x 0.20

22

(iv) Labour cost per hour, Rs : 200

(v) Total variable cost per hour, Rs : 9.3 + 110+ 22 + 200 = 341.3

: 341

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

: 83 + 341= 423

2. Digger

Basic information

(i) Cost of the digger, Rs	:	15,000
(ii) Useful life, year	:	10
(iii) Hours of use per year	:	200
(iv) Rate of interest	:	7 %
(v) Salvage value (10 % of investment cost)	:	1,500
(vii) Field capacity of digger, ha h^{-1}		0.057

B Cost calculation.
I Fixed cost

(i) Depreciation cost per year, Rs : $\frac{\text{Initial cost} - \text{Salvage value}}{\text{Useful life}}$

: $\frac{15{,}000 - 1{,}500}{10}$

: 1350

(ii) Interest on investment per year, Rs : $\frac{(\text{cost of digger} + \text{Salvage value})}{2}$ x Intrest rate

: $\frac{15{,}000 + 1{,}500}{2}$ X 0.07

: 577.5

(iii) Taxes, insurance and shelter per year, Rs : cost of digger x 0.02

15,000 x 0.02

:300

(iv) Total fixed cost per year, Rs : 1350+ 578+ 300 = 2228

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

: $\frac{2228}{200}$

:11.14

II Variable cost

(i) Repair and maintenance per hour, Rs : $\frac{\text{Cost of digger}}{200}$ x 0.05

:3.75

III Total cost per hour, Rs : Fixed cost + variable cost
: 11.14+ 3.75 = 14.89

Total cost per hectare, Rs : $\frac{\text{Total cost per hour for digger + Mini tiller}}{\text{Field capacity}}$

= 7682.2

Round to the value, Rs : 7680

Cost for manual harvesting is Rs 12,500 per acre
Total manual cost per hectare = Rs 31,250

Appendix XI

Field coverage by manual method

Bed height(cm)	Bed Width(cm)	Time to harvest(min)	Time to collect(min	Total time (h)	Bed length (cm)	Area ha	Field coverage ($ha.h^{-1}$)
20	0.7	50	90	2.34	10	0.00007	0.000084
30	0.7	90	90	3.00	10	0.00007	0.000046
40	0.7	60	90	2.50	10	0.00007	0.000070
20	0.5	50	90	2.34	10	0.00005	0.000060
30	0.5	45	55	1.67	10	0.00005	0.000066
40	0.5	60	90	2.50	10	0.00005	0.000050

Appendix XII

Field efficiency of modified coleus harvester

Total area covered	=	0.063 ha
Total time taken to harvest	=	1.1 hr
Field capacity	=	$\frac{0.063}{1.1}$
	=	5.7×10^{-2} ha h^{-1}
Theoretical Field capacity	=	$\frac{W x S}{10}$
	=	$\frac{0.05 * 1.2}{10}$
	=	6.02×10^{-2} ha h^{-1}
Efficiency	=	95 %

ABSTRACT

MODIFICATION AND TESTING OF A COLEUS HARVESTER

By

YOUNUS. A
(2013 - 18 - 111)

ABSTRACT

Submitted in partial fulfillment of the requirement for the degree of

MASTER 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 - 679 573
KERALA
2015

ABSTRACT

Coleus (*Solenostemon rotundifolius*) commonly known as Chinese potato, is a major tuber crop of Kerala used for vegetable purpuse, raised purely as a rain fed crop from June to December. Manual harvesting of coleus is done by using spade, which is very tedious and time consuming, bruises and injuries. To overcome these problems and decreasing the cost of harvesting operation, a self propelled coleus harvester was modified and field tested. The developed coleus harvester was an attachment to a mini tiller, which consists of a prime mover, a digger, rotary blade, and driven wheels. As and when the tiller moves, digger pierced into the soil at a depth of 10-15 cm to digout the rhizomes that lie inside the soil. The uprooted coleus were then pushed out by means of the rotary splasher. The scattered coleus lying in the raised bed were collected easily and hence the harvesting becomes easier and faster. The rotary slasher are the rotating blades attached to the rear side of the tiller which was modified in such a way that they were removed and rubber flaps of 75 x 75 x 0.3 mm were fastened to the shank of the rotary blade. A set of larger wheels were designed and fabricated separately with diameter of 80 cm.

The performance of the modified coleus harvester was compared with respect to time, fuel consumption, capacity and percentage of damage of coleus separately with flat and angular tynes. The performance on time taken (s) to dig out coleus with 6- tyne and 10 - tyne flat and angular digger revealed that while using 6 - tynes, the time taken and fuel consumption (ml) were highest in beds of 70 x 30 cm, whereas minimum were in the bed size of 50 x 30 cm The capacity of coleus harvester with 6 - tyne and 10 - tyne flat and angular diggers were determined. It is noted that the uprooted was the highest in beds of 50 x 20 cm, whereas minimum weight uprooted was in the bed size of 50 x 40 cm when operated with 6 flat tynes. When 10 angular tynes were used, it is noted that the weight (kg) of coleus uprooted was the highest in beds of 70 x 30 cm and minimum weight uprooted was in the bed size of 50 x 20 cm. Thus the average capacity of the harvester was observed as 1069 $kg.h^{-1}$.The

percentage of damage of coleus observed was the highest in beds of 70 x 30 cm, whereas minimum was in the bed size of 70 x 40 cm while using 6 - tynes.

Performance analysis of a commercial harvester (TNAU ginger harvester) indicated that the vibrating mechanism provided was useful to obtain the coleus in clumps after harvest. In field operation it was not possible for uprooting coleus in the beds having more than 30 cm height.

The field capacity of the modified coleus harvester is 0.057 $ha.h^{-1}$. At the present wage rate of Rs 500 per day, the total cost of operation by manual method is about Rs 31,250 per ha. Whereas harvesting by the harvester, the total cost of operation is Rs 7680 per ha. Hence the savings over conventional method is Rs 24,470 per ha. The field efficiency of the harvester was calculated as 95 %.

The performance of the machine was tested with two types of tynes - flat and angular with 6 - tyne and 10 - tynes. Time to harvest one bed of crop, fuel consumed for harvesting one bed, capacity of the harvester and percentage of damaged tubers were calculated. Among two types of flat tynes, the minimum time for harvesting one bed was achieved using 6 - tynes (21.66 min) and its fuel consumption was also less compared with 10 - of tynes. The average capacity of the machine was obtained as 1061 kg h^{-1}.Percentage of damaged tubers was 5% corresponding to 6 - tynes. In the case of angular tynes, the shortest time for harvesting was achieved with 10 - tynes and the corresponding fuel consumption was 19 ml. The percentage of damaged tubers was 8% with 10 - tynes and was little high compared with 6 - tynes.

സംഗ്രഹം

ഒരു സമ്പൂർണ്ണ മഴക്കാല വിളയായ കൂർക്ക മധ്യകേരളത്തിൽ ജൂൺ മുതൽ ഡിസംബർ വരെയുള്ള മാസങ്ങളിൽ കൃഷിചെയ്യുന്നു. ഈ വിള സാധാരണയായി 90 സെ.മി വീതിയും, 50 സെ.മി ഉയരവുമുള്ള തടങ്ങളെടുത്ത് 15 സെ.മീ അകലത്തിലും 10സെ.മി താഴ്ച്ചയിലുമാണ് നട്ടു വളർത്തുന്നത്. തൂമ്പ ഉപയോഗിച്ചുള്ള വിളവെടുപ്പ് വളരെയധികം ദുഷ്ക്കരവും സമയനഷ്ട്ടമുണ്ടാക്കുന്നതുമാണ്.മാത്രവുമല്ല, കൂർക്കക്ക് കേടുപാടുണ്ടാകാനും ഇതു കാരണമാകുന്നു. ഇതിനു പരിഹാരമായാണ്, ടില്ലറിൽ ഘടിപ്പിക്കാവുന്ന കൂർക്ക പറിക്കുന്ന യന്ത്രം നിർമ്മിച്ച് പരീക്ഷിച്ചത്. ഇത് മുൻ ഗവേഷണ പദ്ധതികളിലായി നിർമ്മിച്ച യന്ത്രത്തിന്റെ വിവിധങ്ങളായ ന്യൂനതകൾ പരിഹരിച്ചാണ് നിർമ്മിച്ചിട്ടുള്ളത്. ഈ യന്ത്രത്തിന്റെ പ്രധാന ഭാഗങ്ങൾ 3.5 കുതിരശക്തിയുള്ള ഡീസൽ എഞ്ചിൻ, കൂർക്ക പിഴുതെടുക്കാനുള്ള ഡിഗ്ഗർ, കിഴങ്ങ്തള്ളി നീക്കാനുള്ള റോട്ടറിസ്ലാഷർ എന്നിവയാണ്. ടില്ലർ മുന്നോട്ടു നീങ്ങുമ്പോൾ ഡിഗ്ഗറിൽ ഘടിപ്പിച്ച കൊഴുകൾ 10-15 സെ.മീ ആഴത്തിലും 45 ഡിഗ്രി ചെരിവിലും ആഴ്ന്നിറങ്ങുന്നു. തന്മൂലം മണ്ണിനടിയിൽ നിന്നും കിഴങ്ങ് അനായാസമായി പുറത്തെടുക്കുന്നു, അതേസമയം ഡിഗ്ഗറിനു മുകളിൽ ഘടിപ്പിച്ചിട്ടുള്ള റോട്ടറിസ്ലാഷർ കറങ്ങുന്നതിനാൽ കൂർക്ക യഥേഷ്ടം പുറന്തള്ളപ്പെടുന്നു. മണ്ണിനു മുകളിൽ ചിതറിക്കിടക്കുന്ന കൂർക്ക വളരെയെളുപ്പത്തിൽ ശേഖരിക്കാം. ഇപ്രകാരം വിളവെടുപ്പ് എളുപ്പത്തിൽ ചെയ്തു തീർക്കാൻ സാധിക്കുന്നു. പരീക്ഷണത്തിനായി 2014 ജൂൺ മാസത്തിൽ പട്ടാമ്പിയിലുള്ള പ്രാദേഷിക കാർഷിക ഗവേഷണ കേന്ദ്രത്തിൽ 0.063 ഹെക്ടർ സ്ഥലത്ത് രണ്ടു പ്ലോട്ടുകളിലായി നിലമൊരുക്കി. പരന്നതും കോണിക്കലുമായ 6,10 എണ്ണം വീതമുള്ള രണ്ട് തരം ഡിഗ്ഗർ കൊഴുകളാണ് ഈ പഠനത്തിന് ഉപയോഗിച്ചത്. വിളവെടുക്കുന്നതിനുള്ള സമയം, ഇന്ധന ക്ഷമത, യന്ത്രത്തിന്റെ പ്രവർത്തന ക്ഷമത, വിളവെടുത്ത കൂർക്കയുടെ ക്ഷതം എന്നിവ പ്രധാനമായും ഗവേഷണ വിഷയമാക്കി. ഇതിൽ നിന്നുംലഭിച്ച ഫലങ്ങൾ 'എം-സ്റ്റാറ്റ്' എന്ന സോഫ്റ്റ്‌വെയർ ഉപയോഗിച്ച് സ്ഥിതിവിവരണ കണക്കുകൾ അവലോകനം ചെയ്തു. 10 മീറ്റർ നീളത്തിൽ 50X 20, 50 X 30, 50 X 40,70 X 20, 70 X 30, 70 X 40 സെമീ വീതിയിലും ഉയരത്തിലുമുള്ള 90 തടങ്ങളിലായി കൂർക്ക കൊളുന്തുകൾ നട്ട് വിളവെടുപ്പിന് പാകമാക്കിയിരുന്നു. ഇന്ധനക്ഷമതയുടെ കാര്യത്തിൽ പരന്ന 6 കൊഴുവെച്ച് നടത്തിയ പരിക്ഷണത്തിൽ ഏറ്റവും കുറവ്സമയം 50 X 40 സെ മി തടത്തിലും കൂടുതൽ സമയം 70 X 30 സെമീ തടത്തിലുമാണ് ഉണ്ടായത്. അതേസമയം, 10 കൊഴുവെച്ച് പരീക്ഷണം ആവർത്തിച്ചപ്പോൾ ഇന്ധനക്ഷമത ഏറ്റവും കൂടുതൽ 70 X 20സെ മി തടത്തിനും കുറവ് 50 X 20 സെ മി തടത്തിനുമാണെന്നും കണ്ടെത്തി. പ്രവർത്തന ക്ഷമതയെ അടിസ്ഥാനമാക്കി നടത്തിയ പരീക്ഷണത്തിൽ പരന്ന 6 കൊഴു 50 X 20 സെ മി തടത്തിൽ കൂടുതൽ പ്രവർത്തനക്ഷമമാണെന്നും 50 X 40 സെ മി തടത്തിൽ കുറഞ്ഞ പ്രവർത്തന ക്ഷമമാണെന്നും കണ്ടെത്തി. കോണിക്കൽ ആകൃതിയിലുള്ള 10 കൊഴു ഉപയോഗിച്ച പരീക്ഷണത്തിൽ 70 X 30 സെ മി തടത്തിൽ കൂടുതൽ പ്രവർത്തന ക്ഷമതയും 50 X 20 സെ മി തടത്തിൽ കുറഞ്ഞ പ്രവർത്തന ക്ഷമതയും കണ്ടെത്തി. 6 കൊഴു ഉപയോഗിച്ചുള്ള വിളവെടുപ്പിൽ ഏറ്റവും കൂടുതൽ ക്ഷതം സംഭവിച്ചത് 70 X 30 സെ മി തടത്തിലും കുറവ് 70 X 40 സെ മി തടത്തിലുമാണ്. തമിഴ്നാട് കാർഷിക സർവ്വകലാശാല നിർമ്മിച്ച ഇഞ്ചിവിളവെടുപ്പ് യന്ത്രവുമായി പ്രവർത്തികൾ താരതമ്യപ്പെടുത്തിയപ്പോൾ അത് കിഴങ്ങുകൾ കൂട്ടമായി പിഴുതെടുക്കാൻ സഹായകരമാണെന്ന് മനസ്സിലാക്കി. എന്നാൽ 30 സെ മീ ഉയരം കൂടുതലുള്ള തടങ്ങളിൽ ഇവ പ്രവർത്തിക്കുവാൻ ഉപയോഗ സാധ്യമല്ലെന്നും തിരിച്ചറിഞ്ഞു. തൊഴിലാളികൾ പണിയെടുക്കുമ്പോൾ ഇപ്പോഴുള്ള ദിവസവേതനം 500 രൂപ പ്രകാരം ഒരു ഹെക്ടറിന് ഏകദേശം 31250 രുപ ചിലവുവരും. എന്നാൽ ഈ ഗവേഷണത്തിൽ നിർമ്മിച്ച യന്ത്രം ഉപയോഗിക്കുമ്പോൾ 7680 രൂപ മാത്രമാണ് ചിലവ് വരുന്നത്. അതിനാൽ 24470 രൂപ ഇതിലൂടെ ലാഭിക്കാൻ സാധിക്കുന്നു. മണിക്കൂറിൽ 1069 കി ഗ്രാം കൂർക്ക ഈ യന്ത്രം ഉപയോഗിച്ച് പറിച്ചെടുക്കാൻ സാധിക്കുന്നു. ഇപ്രകാരം മണിക്കൂറിൽ 0.057 ഹെക്ടർസ്ഥലത്തെ വിളവെടുക്കാവുന്ന ഈ യന്ത്രത്തിന്റെ പ്രവർത്തനക്ഷമത 95 ശതമാനമാണ്.