DEVELOPMENT OF HARVESTING EQUIPMENT FOR TREE FRUITS

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TAVANUR -679 573, MALAPPURAM

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PROJECT REPORT

Submitted on partial fulfillment of the requirement for the degree of

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In
Agricultural Engineering

Faculty of Agricultural Engineering and Technology

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ABSTRACT

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DECLARATION

We hereby declare that this project report entitled **''DEVELOPMENT OF HARVESTING EQUIPMENT FOR TREE FRUITS''** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title of another University or Society.

GAYATHRI T.P (2013-02-020)

LIVINA V.K (2013-02-031)

RAHUL P.K (2013-02-033)

Place: Tavanur
Date: 07.02.2017

CERTIFICATE

Certified that this project work entitled **"DEVELOPMENT OF HARVESTING EQUIPMENT FOR TREE FRUITS"** is a record of project work done jointly by Ms. Gayathri T.P, Ms. Livina V.K. and Mr. Rahul P.K. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

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GAYATHRI T.P.

LIVINA V.K.

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DEDICATED TO
PROFESSION OF FARMING

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SYMBOLS AND ABBREVATIONS

Al	Aluminum
cm	Centimeter
Et.al	And others
etc	Etcetera
Fig	Figure
g	Gram
h	Hour
ie	That is
IR	Infra Red
KCAET	Kelappaji College of Agricultural Engineering and Technology
kg	Kilogram
Kg/h	Kilogram per hour

Kg/cm	Kilogram per cm
m	Meter
No.	Number
rpm	Revaluations per second
Sl No	Serial number
v	Voltage
%	Percentage
Ø	Diameter

CHAPTER - 1
INTRODUCTION

India is a major producer of fruits, vegetables, cereals, pulses, tuber crops and spices in the world. India produces around 40 million tons of fruits per year. World production of tree fruits is increasing rapidly leading to more competition on export market. Adoption of more efficient fruit production and harvesting system is one way for the industry to remain competitive and increase market share on the world stage.

Production of fruit crop is expensive and labor intensive. Harvesting is the most labor intensive operation in the fruit production accounting for up to 60% of total labor requirement. Timely harvesting of fruits is important for maintaining quality and shelf life. Harvesting of fruits is a cumbersome and time-consuming process. Different methods are being practiced for harvesting fruits from trees. Mango is being harvested by shaking the tree manually or by plucking the fruits manually by climbing over the fruit tree. In conventional harvesting, the laborers climb over the trees to harvest the fruits and then they throw the fruits on a gunny bag held by another person on the ground to reduce the injury to the fruit. A lot of fruits may fall on the ground and this may cause internal injury to the fruits and subsequent spoilage during ripening. The popular mango harvester, *THOTTI*, generally consists of a bamboo pole fixed with a small wooden piece at an angle to make '**v**' shape at the end. The fruits are harvested by this device by breaking the pedicel and allowing the fruits to drop on the ground. This is a time consuming process and sometimes can be dangerous to the labors as mishaps often take place during harvesting fruits from trees.

Table.1.1.Analysis of different method of harvesters

Method of harvesting	**Fruit harvested per hour (No)**	**Damaged fruits per hour (No)**
Manual plucking	375	38
Tree shaking	318	55
Local harvester	417	27

The availability of sufficient labors for manual harvesting is a major concern to many growers. Fruit harvesting is a very seasonal activity. The shortage and high cost of labor for manual harvesting, declining fruit prices and increased competition for reducing the cost of production are the driving forces behind the development in mechanical harvesting devices.

Conventional harvesting method is highly labor intensive and inefficient in terms of both economy and time. Machine harvesting systems are a partial solution to overcome these issues by removing fruits from the trees efficiently thus reducing the harvesting cost to about 35-45% of total production cost. Major breakthroughs in mechanical harvesting technology involving computers, image technology and a new generation of robotic harvesters are more suitable for most advanced countries. These intelligent systems have been designed to selectively pick the individual fruit based on skin color thereby improving the uniformity of maturity of harvested crops. While mechanization is recognized as the major vehicle for reducing the cost and the only mean to stay competitive, it is important to note that in addition:

- ✓ Mechanization reduces the farmer's drudgery and improves his ability to perform operations in a timely matter.
- ✓ Reduces the risks associated with need for large amounts of seasonal labor for short periods of time
- ✓ Lessens the social problems which accompany excessive influx of low-wage workers.
- ✓ Has the ability to potentially reduce human contact with food (food safety). In spite of the complexity of the problem there are, nevertheless quite some cases of success that are already in commercial use.

Farmers in developed countries can't ignore any more technological improvements and the need for investments. Competing on low labor costs is infeasible. To stay in business means reducing costs and the only viable way to do that is through mechanization. The developed countries have advanced technologies in many areas, but fruits, for the most part, are still being picked by hands, worldwide.

Hence this project work has been taken up to develop a low cost, electronically operated harvesting system for tree fruit crops, suitable for our Indian conditions, with the following objectives

1.3 OBJECTIVES

1. To develop a suitable harvesting equipment for tree fruit crops.
2. To evaluate the performance of the developed equipment

CHAPTER - 2
REVIEW OF LITERATURE

2.1 HARVESTING

Harvesting is often considered as the last operation in agricultural production and as the first step in post-production system. Harvesting detaches the seed or fruit from the plant or tree and mainly it is the operation of cutting for removing the crop from under the ground or above the ground or useful part or fruit from plants. Harvesting action can be achieved by four different actions as given below:

- Slicing action with a sharp tool.
- Shearing action by two opposite shearing elements.
- Tearing action with a rough serrated edge.
- High velocity single element impact with sharp or dull edge.

2.2 TYPES OF HARVESTING

- Manual Harvesting
- Mechanical Harvesting
- Robotic Harvesting

2.2.1 MANUAL HARVESTING

Manpower is used for manual harvesting. Plucking of fruits by hand is generally followed by Indian farmers. The tree branches are shaken to speed up the harvesting, which results in post-harvest losses due to physical damage, stem end rot due to the excessive sap bleeding in mangoes due to the breakage of pedicel. The local mango harvester generally consists of a bamboo pole fixed with a small wooden piece at an angle to make ‘v’ shape at the end. The fruits are harvested by breaking the pedicel and dropping the fruits on the ground. In conventional harvesting the laborers climb on the trees to harvest and they throw the harvested fruits on a gunny bag held by another person on the ground to reduce the physical injuries to the fruit. This is a time consuming process and sometimes can be dangerous to the labor.

Plate 1.1 Sap ooze out problem in harvesting of mango.

2.2.2 MECHANICAL HARVESTING

Mechanical harvesting methods have been investigated and practiced since early. Fruit can be harvested by mechanical means after proving that a tree could be mechanically shaken to remove the fruit from the branches without destroying the whole tree. To reduce the physical damage to the tree, a pre-harvest abscission spray was also proposed to loosen the fruits on the tree. In order to improve the design of mechanical harvester the biological and physical properties of the fruit were also studied. This section will review those mechanical harvesting methods and others very briefly. The mechanical harvesting methods reviewed here are limb shaking, air blasting, canopy shaking, trunk shaking, and the use of an abscission chemical agent to loosen the fruits.

2.2.2.1 Limb Shaker

There is a mechanism to produce the shacking action after the shaker was attached to the tree limb. Notably some damage was made to the bark of the tree by the clamping mechanism. An alternative tree shaker was represented using fixed stoke, inertia, and direct impact on trees limbs. The issues from this practice included such as fruit damage due to fall of foliage, lower removal rate in earlier and mid of harvesting season, and large or small immature fruit removal. Still, immature fruits were removed with damages to the fruits. A self-propelling full powered positioning limb shaker was also evaluated with abscission aid.

2.2.2.2 Air Blast

The application of force generated by air blast to remove the fruit was started in 1961. Nowadays oscillating air blast machine was tested. Fruit removal was maximized by the oscillation rate. The air blast model and all the subsequence models were made and named after FMC (Food Machinery Corporation). The performance of FMC series was dependent on factors such as structure of tree, size and weight of fruits. Later, an air shaker was designed and constructed to alleviate issues such as the high power requirement. However still damages to the fruits and leaves are the major issues to be addressed.

2.2.2.3 Canopy Shaker

A canopy shaker was designed to clamp secondary limbs to shake vertically. The shaker was extended into tree with a pantograph lift unit and shake always vertically. Two continuing canopy shakers were reported, one was self-propelled unit and another was tractor-drawn unit. These two units were used for juice processing plants. Manual workers were needed to collect the fruits after the harvest. Shaking frequency and stroke are important factors in the performance in this type of harvester and it requires more tests to determine the optimal values.

2.2.2.4 Trunk Shaker

Trunk shaker was used to remove deciduous fruits and nuts. The linear low frequency shaker with a larger displacement performed better than the canopy shaker machine. The bark was more or less damaged during the experiment. The efficiency or removal was from 67% on large trees to 98% on small trees. More recently, a tractor mounted trunk shaker was tested. Overall the tractor mounted shaker was more effective with 72% detachment than the hand-held shaker with 57% detachment rate.

2.2.2.5 Chemical Abscission

Abscission chemical agent was designed to loosen the mature fruit and improve the rate of removal of fruit during the harvesting season. There are many kinds of abscission agents such as Ethephon and 2-chloroethyl phosphoric acid. The use of abscission agent was applied as pre-harvest process and constituted part of harvesting such as air shaker.

2.2.3 ROBOTIC HARVESTING

The mechanical harvesting system cannot maintain the quality and size selection that the human vision can do. The automatic individual harvester was considered as an alternative method to the mechanical harvester by Schertz and Brown. The two detachment devices, a vacuum twisting device and a rotating cutoff device, were used in the research. The photometric comparisons showed the potential use of the light reflectance for the fruit detection. The concepts were further developed by Parrish and Goskel from University of Virgia in 1976. More serious research works began at around 1983 at Kyoto University at Japan, and at University of Florida. Then CEMAGREF Montpellier France extended it on the subsequent projects.

The state of arts of individual robotic harvesting systems has been reviewed in this section. The study focused on the sensors and the vision system in mechanical manipulator. Even though the review is majorly focused on the citrus fruit harvester, some other significant robotic harvesting systems for different kinds of fruits harvesting are selected and reviewed as a complementary reference.

Agribot project from Spain developed a semi-automatic harvester by combining both human and machine functions. Two jointed harvesting arms were built and were mounted on the human guided vehicle. The manipulator was three degree of freedom (DOF) design with one vertical rotation axes and two horizontal rotation axes and the rotation on the end effecter with gripper. The gripper was specially designed with the pneumatic suction cup and proximity IR sensor to sense the attached fruit followed by the saw cutter to cut the stem. Detection was done by the human operator when the vehicle was placed opposite the fruit tree using a joystick to control the pan and tilt mechanism pointing to the target. Fruits were localized in spherical coordinates with distance detected by laser telemetry and the angular position by two rotational axes. The laser ranger finder was sensitive to the outdoor lighting conditions. Hence the special goggles were used to block and enhance the red laser spot. The harvesting cycle time for this machine was 2 seconds.

The vision system used in the automatic harvester aims to detect the fruits and provides the information of the location and the distance to the fruits to the robotic controller. In vision recognition system, vision cameras are mainly the solution to communicate with the environment.

This chapter includes previous works on harvesters carried out by various investigators and institutes.

Colorio,G et al., (1987) developed strawberries harvesting machine by bilateral combing. Development of a harvester for straw berries for processing is outlined. It is designed to select and harvest large strawberries without damage to plants, uses cylindrical brushes rotating in opposite directions to lift the plants and harvests by a comb on a belt rotating perpendicularly to the fruit rows. Good results were obtained in trials.

Thuesen, A et al., (1988) developed a mechanical harvester for strawberry. In a breeding program in Denmark, cultivars have been developed with vigorous, erect fruit stalks and fruits which readily separate from the calyx. Mechanical harvests have been designed. The harvester has rotary comb fingers that extend under the fruit clusters, a conveyor belt with a fan that blows of the leaf debris and a size graders for the fruits. The harvester, which can collect the fruit has a capacity of 1500-2000kg/h and is designed to pick from each field only once, so that cultivars where fruits ripen over a short period are preferable. Plants grown in a solid bed , with all runners retained, are easier to harvest mechanically then plants grown in row with exposed soil between them.

Bychkov et al., (1989) developed a mechanized fruit harvester. This machine is designed to harvest fruits or nuts from trees with up to 5m crown diameter and 230mm trunk diameter. A hydraulic mechanism shakes the trunk of the tree for 1-3sec; the fruits fall on to the wide soft sloping catchment area and are gathered by a central conveyor belt which transport it to one side. Another conveyor transfers the produced in to crates. Two operators are needed for the operations and trees up to 80m height can be harvested.

James Thompson et al., (2000) reviewed that California farmers have remained competitive in the global market place by using technology to reduce their costs and to expand production. Case studies elaborate how that harvest mechanization has reduced labor use by 92% to 97% and has also reduced labor costs, down from half to two- thirds of total costs to less than 20%. Mechanization is at least partly responsible for the steady increase in production of these two crops. Although mechanization has reduced the number of labor hours for harvesting, over-all employment has risen due to increased production, and so have harvester operator wages. Further advances in tomato harvest technology will continue to reduce labor needs, while the rice industry will experience moderate changes.

Muhammad et al., (2000) conducted studies on improved fruit plucker. The improved fruit plucker is an improved hook type plucker for plucking fruits like Mangoes, Sapota etc. After detachment the fruits are conveyed downwards at a safe velocity, and stored at the bottom of the chute. The advantage is more quality can be plucked in a batch since the fruits are stored in the net at the bottom of the pole there by giving a better balance than the conventional top loading type.

B,Sivaraman et al., (2005) summarized that automated solutions for fresh market fruit and vegetable harvesting have been studied by numerous researchers around the world during the past several decades. However, very few developments have been adopted and put into practice. The reasons for this lack of success are due to technical, economic, horticultural, and producer acceptance issues. The solution to agricultural robotic mechanization problems is multidisciplinary in nature. Although there have been significant technology advances during the past decade, many scientific challenges remain. Viable solutions will require engineers and horticultural scientists, who understand crop specific biological systems and production practices, as well as the machinery, robotics, and controls issues associated with the automated production systems. Focused multidisciplinary teams are needed to address the full range of commodity specific technical issues involved. Although there will be common technology components, such as machine vision, robotic manipulation, vehicle guidance, and so on,each application will be specialized, due to the unique nature of the biological system. Collaboration and technology sharing between commodity groups offers the benefit of leveraged research and development dollars and reduced overall development time for multiple commodities. This paper presents an overview of the major horticultural and engineering aspects of robotic mechanization for horticultural crop harvesting systems.

Krishanunni et al., (2009) developed a manually operated pepper harvester which was handy and simple tool which can ensure safe handling of pepper. The special feature of the tool was that a person standing on the ground can harvest pepper and lower it safely to the ground. The harvester consisted of a long telescopic pole with a hook knife at the top.

Plate 2.1 Pepper harvester-1 Plate 2.2 Pepper harvester-2

It consisted of a basket to collect the cut pepper after harvest. For collecting the panicles a basket was set, just below the blade with a required angle for proper conveyance through it. A four-mm metal wire was bent in the form of a circular ring of diameter 13.5 cm over which nylon net were stitched to form a basket. When the basket is filled, it can be easily be disposed to the required destination and again the process could be continued.

Savita et al., (2010) concluded that manual plucking of fruits is generally followed by Indian farmers. The tree branches are shaken to speed up the harvesting, which results in post harvest losses due to physical damage, stem end rot due to sap bleeding in mangoes due to absence of pedicel. Mango harvester is one which has conical shaped frame for easy pushing in to canopy, blade for shearing the pedicel, collecting net and a pole to avoid damage due to dropping of fruits on the ground. The mango is held within the frame and the fruit is harvested by shearing action of blade. Harvesting efficiency of different harvesters were studied in comparison to hand plucking & tree shaking to reduce the drudgery due to fatigue on labour, to save time. University of Agricultural Sciences, Bangalore (UAS) model was compared with that of Indian Institute of Horticultural Research, Bangalore (IIHR) model. IIHR model is found to have higher efficiency as compared to the other models.

Bulanon et al., (2010) reviewed that the challenges in developing a fruit harvesting robot are recognizing the fruit in the foliage and detaching the fruit from the tree without damaging either the fruit or the tree. The objectives of this study were to develop a real-time fruit detection system using machine vision and a laser ranging sensor and to develop an end effector capable of detaching the fruit in a way similar to manual pick. The Fuji apple variety was used in this study. In the detection of the fruit, machine vision was combined with a laser ranging sensor. The machine vision recognized the fruit and the laser ranging sensor determined the distance. The system detected a single fruit with 100% accuracy in both front and back lighted scenes with 3 mm accuracy in distance measurement. To detach the fruit from the tree, an end effector was developed with a peduncle holder and a wrist; the peduncle holder pinches the peduncle of the fruit and the wrist rotates the peduncle holder to detach the fruit. Field test results of the end effectors showed more than 90% success rate in detaching the fruit with average time use of 7.1 seconds.

Peilin Li et al., (2011) have been reviewed about the different mechanical harvesting systems in this paper. It is well known that harvesting fruits in a large scale is still inefficient and not cost effective. To solve this challenging task, mechanical harvesting systems have been investigated and practiced to enhance profitability and efficiency of horticultural businesses. However they often damage fruits in the harvesting process. Development of efficient fruit removal methods are required to maintain the fruits quality. This paper reviews fruit harvesting systems from purely mechanical based systems in which operator involvement is still required, to automatic robotic harvesting systems which require minimal or no human intervention in their operation. The researches on machine vision system methodologies used in the automatic detection, inspection and the location of fruits for harvesting are also included. The review is focused on the citrus fruits due to the fact that the research on citrus fruit harvesting mechanism is a bit more advanced than others. Major issues are addressed in the camera sensor and filter designs and image segmentation methods used to identify the fruits within the image.

Rahul,M et al., (2012) developed pepper plucking equipment to facilitate the pepper harvesting in agriculture sector. In order to avoid the climbing and to solve the problems related in the field. It is essential to have a pepper plucking equipment. The inspiration for designing a pepper harvesting equipment originated from the fact that the pepper cultivating field does not have any equipment for plucking pepper.

Aneeshya et al., (2012) developed three models of pepper harvesters and they were fabricated and evaluated on the basis of efficiency. Three models of pepper harvester were fabricated and evaluated on the basis of efficiency in the cutting action and easiness in operation. All the three models basically consisted of a mild steel cutting unit, aluminum conveying pipe and a collecting basket. The main concepts adopted for the fabrication were impact, shear and pulling action for the proper insertion and cutting of the spikes and collection. The test was conducted for Panniyur variety out of which, the most efficient and user friendly was the second model due to its light weight, easiness in operation and minimum loss. The main advantages accounted for this model were simultaneous cutting and collection of spikes without heavy loss.

Davinia Font et al., (2014) reported the development of an automatic fruit harvesting system by combining a low cost stereovision camera and a robotic arm placed in the gripper tool. The stereovision camera is used to estimate the size, distance and position of the fruits whereas the robotic arm is used to mechanically pickup the fruits. The low cost stereovision system has been tested in laboratory conditions with a reference small object, an apple and a pear at 10 different intermediate distances from the camera. The average distance error was from 4% to 5%, and the average diameter error was up to 30% in the case of a small object and in a range from 2% to 6% in the case of a pear and an apple. The stereovision system has been attached to the gripper tool in order to obtain relative distance, orientation and size of the fruit. The harvesting stage requires the initial fruit location, the computation of the inverse kinematics of the robotic arm in order to place the gripper tool in front of the fruit, and a final pickup approach by iteratively adjusting the vertical and horizontal position of the gripper tool in a closed visual loop. The complete system has been tested in controlled laboratory conditions with uniform illumination applied to the fruits. As a future work, this system will be tested and improved in conventional outdoor farming conditions.

Kusuma Guturu et al., (2015) reviewed that oil palm (Elaeis guineensis Jacq) is a tree without branches but with many wide leaves at its top. One of the important and cumbersome activities in palm fruit cultivation is harvesting. Harvesting of oil palm is difficult due to its thorns like cut stems. Harvesting is being carried out manually by using sickle and pole arrangement. But the process is cumbersome and needs lot of effort. To banish the difficulty of harvesting and to achieve good productivity of the crop an optimum machine has to be developed. Much research was done in this sector, but still the industry is in the need of an optimum machine. Hydraulic lifting platforms, motorized (cantas) cutters, pneumatically operated cutters, were developed but these have their own setbacks. Recently, focus was drawn towards the robotics. The paper explains all the available and developing technologies in the area of harvesting of oil palm. Oil palm is a very good plantation crop which contributes much to the global economy, and which plays very important role to achieve food security. The manual harvesting of oil palm has its own difficulties even though energy requirement for harvesting is reduced by ergonomic refinement of the machines. The other harvesting equipment like cantas tool, pneumatic cutter, lifting platform perform better than the manual harvesting, but they have drawbacks of less reach of height, high initial investment, inquisitive in operation. The harvesting robot is good substitute for all these machines and to achieve all the above discussed objectives.

CHAPTER - 3
MATERIALS AND METHODS

An attempt was made to development of harvesting equipment for fruits like mango with suitable collecting and conveying mechanical aids. It can also be used for all the fruits which are hanging from branch with a stalk. The materials and methodology adopted for the development of the mechanism is briefly discussed in this chapter. The methodology adopted for the study is

- Identification of commonly used manual fruit harvesters
- Study of its operations and drawbacks
- Identification of functional mechanism for appropriate battery operated fruit harvester
- Design of the functional mechanism and components
- Conceptual design of the harvester
- Development of designed model
- Performance evaluation of the developed model

3.1 CONCEPTUALIZATION OF EQUIPMENT

Major considerations taken in developing the conceptual model was simplicity in fabrication, operation and handling. Conceptual design of the model includes the following advantages over a manual fruit harvesting.

1. Cutting of the fruit stalk should be smooth to retain its pedicel to prevent sap ooze out.
2. The operator could harvest the fruit without much physical efforts.

3. The entire unit needs not to be down for collecting harvested fruits, ie the harvested fruit should be safely conveyed down.
4. Cutting of fruit stalk could be controlled by standing on ground.
5. Entire equipment should be easy to handle and transport.
6. Equipment should be light weight.
7. Time taken for harvesting should be minimized.

3.2 DEVELOPMENT OF FRUIT HARVESTER

A model is developed for harvesting the tree fruits like mango, sapota etc and is tested in KCAET farm. It was developed based on the merits and drawbacks of the manual fruit harvesters studied. The basic concept was to develop a simple equipment which is easy to handle and with minimum damage to fruits. In identifying components of the mechanism, due consideration was given to select standard components or readily available tool or gadgets as far as possible.

Fruit harvester model consists of the following parts

(i) Power source- battery
(ii) Main Frame
(iii) Cutting unit
(iv) Collecting cum conveying bag
(v) Telescopic pole
(vi) Remote controls

3.2.1 Power source

Four batteries of 1.5V each placed in a battery box made up of PVC pipe as shown in plate: 3.1 was used as the power source. Batteries are arranged in series manner. The battery provides power to the motor for harvesting the fruit stalk. The power supply was controlled by a main switch provided on the controller board box. The specification of the battery is given in the Table 3.1.

Plate 3.1 Power source

Table 3.1 Specifications of Power Source

Particulars	Value
Voltage	6V
Discharge rate	2.5 A-hr per cel
Weight	90.6g
Dimensions	210 mm length 10 mm diameter

3.2.2 Main frame

A rhombus shaped frame was made up of 6mm mild steel iron rod and is welded over a hollow pipe at one corner as shown in plate: 3.2. A small box for fixing ‘servo motor cutting assembly’ is also provided on the opposite corner. Cutting cum collecting net is hanging from the main frame. Frame is fixed on a telescopic aluminum pole by using nut and screw fasteners. Frame is painted properly to avoid corrosion. Weight of the frame is 0.5kg.

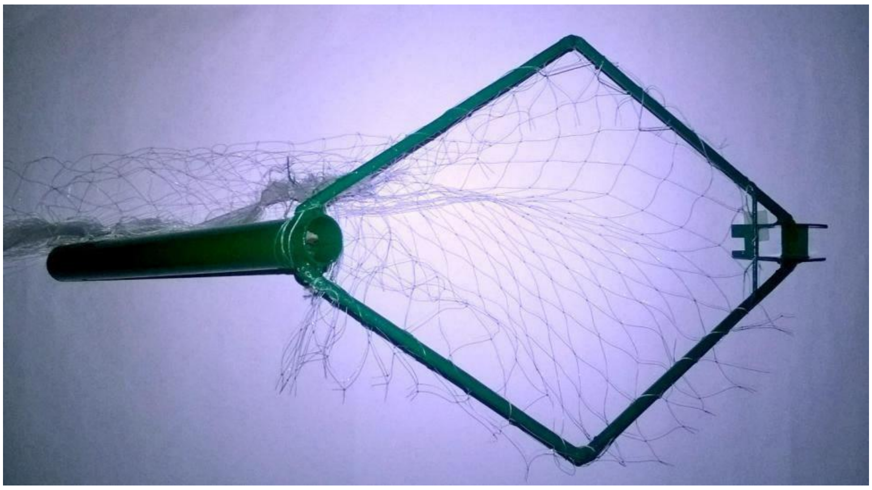

Plate 3.2 Main frame

3.2.3 Cutting unit

It consists of two stainless steel blades and a battery operated servo motor. One of the blades is stationary and attached on the main frame and another is attached on the servo motor (Plate: 3.3). Servo motor rotates by utilizing the power from batteries. It provides high torque to the rotating blade. Shearing action between the stationary blade and rotating blade results in the cutting of fruit stalk. Thermocol cutting blades are used. If its sharpness reduces due to continuous working, it is possible to replace the older blade with sharp new blade inside the blade frame.

Plate 3.3 Blade with frame

3.2.3.1 Servo Motor

Servo motor (Plate 3.4) is a rotary actuator that allows for precise control of angular position. It consists of a motor coupled to a sensor for position feedback. It also requires a servo drive to complete the system. The drive use the feedback sensor to precisely control the rotary position of the motor. Servo is controlled by sending an electrical pulse of variable width, or pulse width modulation (PWM), through the control wire. There is a minimum pulse, maximum pulse and a repetition can usually turn 90° in either direction for total of 180° movement.

It rotates the cutting blade with a high torque. Rotation of the motor is controlled by remote controls. Clockwise and anti clockwise rotation of blades are possible with a programmed chip associated with the controlling board .The operating torque of the motor is 13.5 kg/cm with 60rpm. Motor is 62.6g in weight and is placed on the front corner of frame provided at the top of the pole.

Plate 3.4 Servo motor

3.2.4 Collecting cum conveying unit

Collecting and conveying of harvested fruit is done simultaneously by the help of a bag made up of nylon net. It is extended from main frame up to the ground. The bag does not obstruct the vision of operator standing below the ground. An offset angle was provided between main frame and telescopic pole hence the bag provides a slight slanting surface for harvested fruit to travel down. It prevents free fall of fruit through bag which cause drudgery to the fruit.

3.2.5 Telescopic pole

A length adjustable telescopic aluminum pole is used. Maximum height up to 6m can be attained. By folding, it can be reduced up to 2m. Three pieces of 3cm, 2.5cm and 2cm inner diameter aluminum hollow pipes are concentrically arranged. Main frame is mounted on the pole by means of nut and bolt fasteners. Total weight of telescopic pole is 1.55kg. It is readily available in markets.

Plate 3.5 Telescopic pole

3.2.6 Remote control

Remote control is used to start rotational movement of cutting blades and the direction of rotation. It rotates the blade in clockwise as well as in anticlockwise direction. In accordance to the need the angle of rotation also can be adjusted by changing the programme decoded. It can sent a signal up to a height of 10m. C programme is used for the working of remote.

Plate 3.6 Remote control

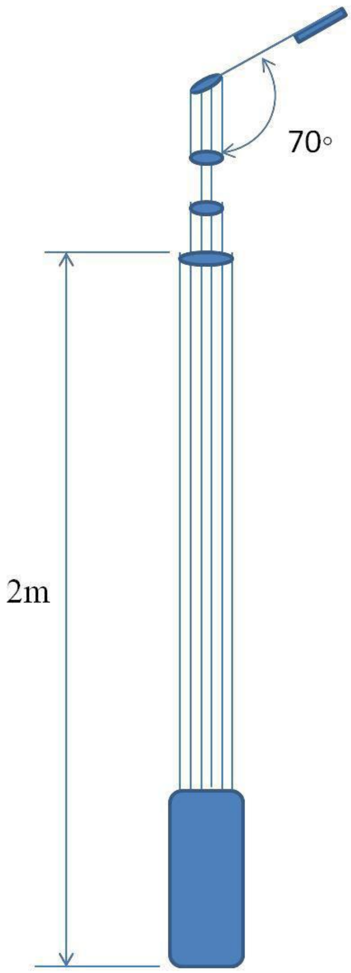

Figure 3.1 Diagrammatic view of entire equipment without conveying bag

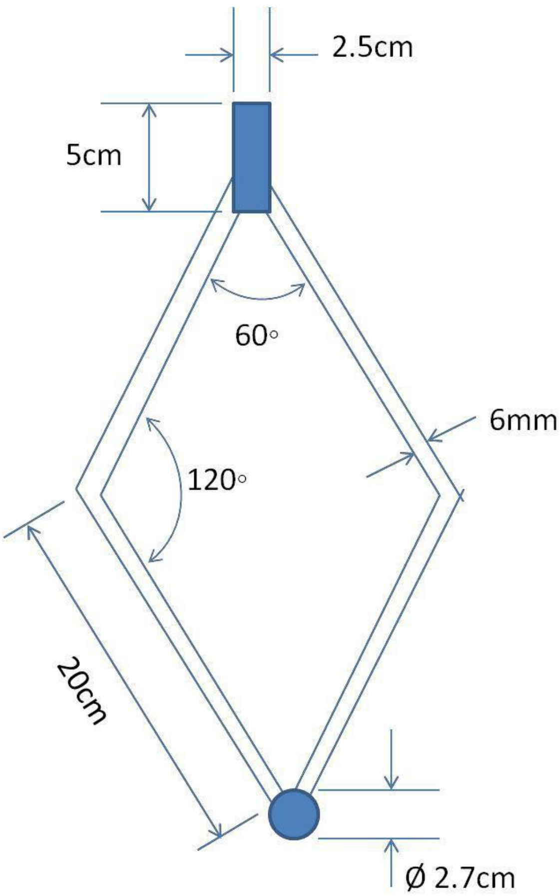

Figure 3.2 Top view of Main frame

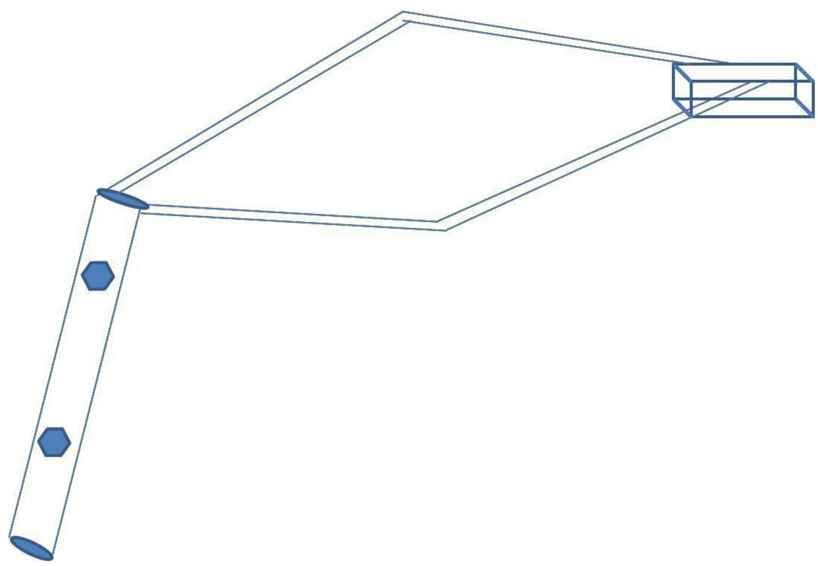

Figure 3.3 Isometric view of main frame

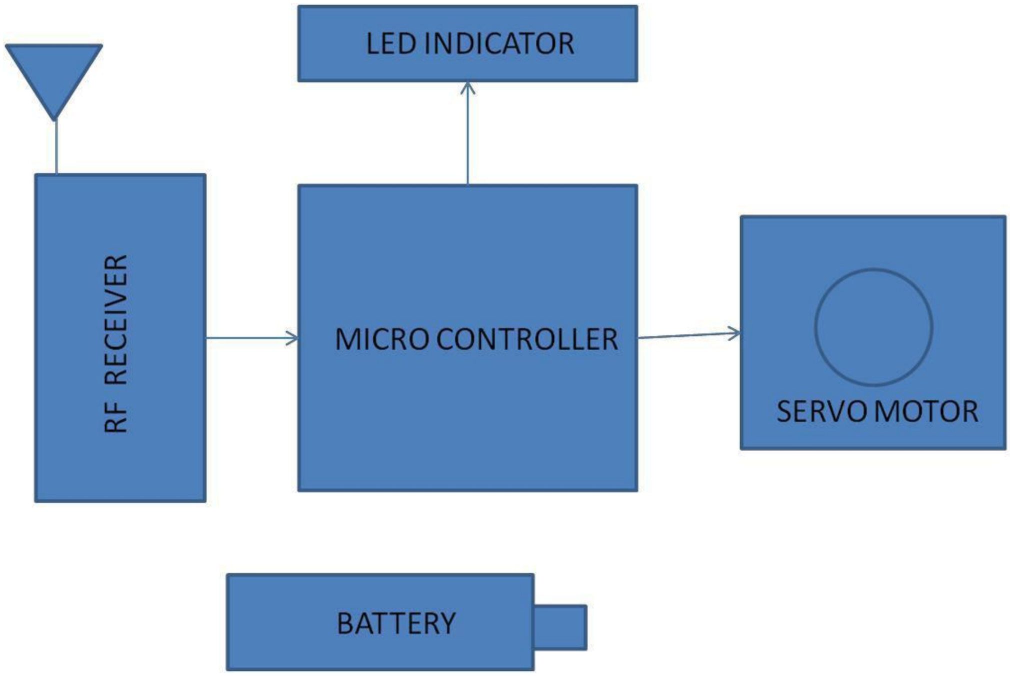

Figure 3.4 Block diagram of Receiver

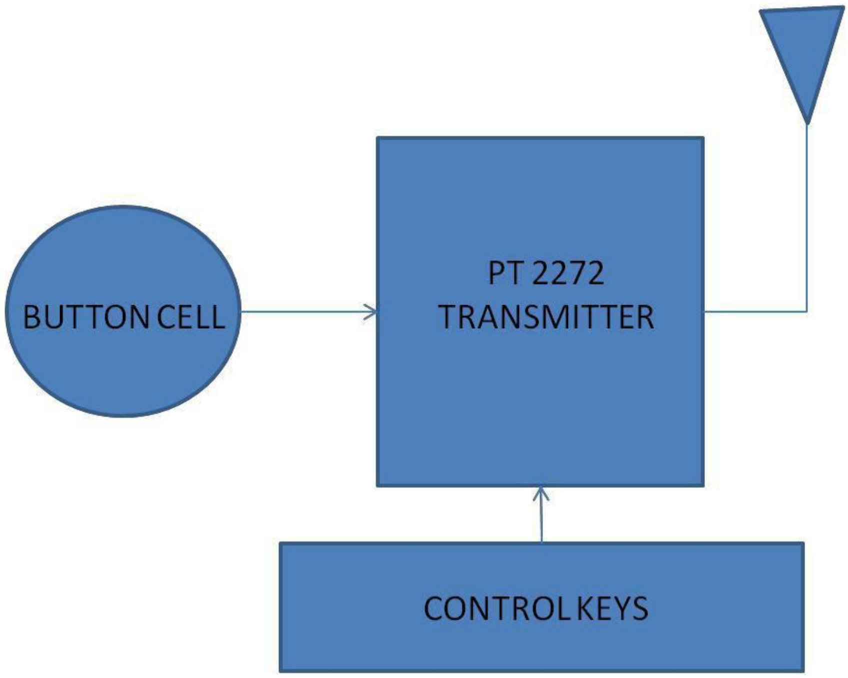

Figure 3.5 Block diagram of Transmitter

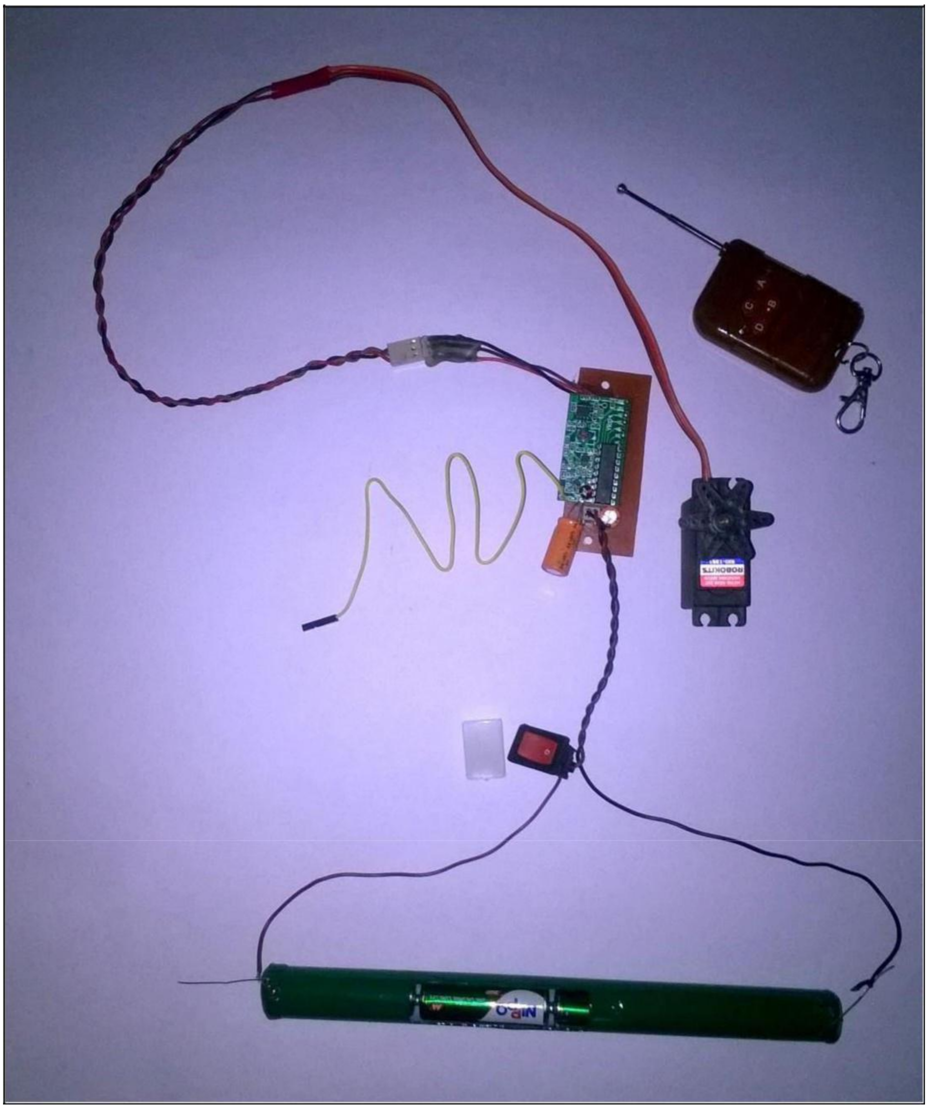

Plate 3.7 Entire Circuit

Table 3.2 Details of the components of Equipment

Sl No.	Items	Material	No. of Items
1	Main frame	Mild steel	1
2	Telescopic pole	Aluminum	1
3	Remote control	Fiber	1
4	Motor	Motor	1
5	Blade	Stainless steel	2
6	Collecting bag	Nylon net	1

CHAPTER - 4
RESULT AND DISCUSSION

This chapter deals with the results obtained from experiments conducted with the developed model based on the number of fruits harvested per unit time and the easiness in operation.

4.1 Testing of the developed model.

The developed model is tested for harvesting mango and sapota tree fruits and the results are discussed in terms of easiness in operation, amount of harvesting, energy utilized by the motor etc. Due to lack of time extensive evaluation of the developed tools were not possible, instead they were tested in the farm and campus itself.

4.1.1 Mango harvesting

The developed equipment was tested for the Moovandan variety of mango cultivated in the KCAET campus. The advantage of this equipment was that once the stalk was correctly placed between the two blades of cutting mechanism, it could , collect and convey the fruits to ground safely. The motor used for the cutting mechanism could be easily operated by means of a remote-control switch from the ground. Since the cutting action is done by the battery-operated motor, no need of pulling or pushing action of the pole is required by the operator. It reduces the chance of back pain and shoulder pain of operator during the traditional continuous harvesting operations . As the weight of conveying cum collecting unit is very less, it improves the easiness of holding the equipment. During manual harvesting, oozing out of sap from the fruits decrease the appearance and quality of ripened mango but in this equipment, we get mango with proper pedicel length hence sap ooze out can be avoided. Telescopic pole mechanism is useful for easy transportation and handling. One of the main limitations of the equipment was that the insertion of mango into the main frame is difficult in the case of trees with dense leaf and branch conditions.

Plate 4.1 Harvesting Mango with equipment

Plate 4.2 Telescopic pole adjustment

4.1.2 Sapota harvesting

The equipment was tested for harvesting sapota fruits, cultivated in KCAET campus. Handling and cutting actions were smooth during harvesting of sapota fruits. Since the sapota fruits have a stalk smaller than that of mango, a little difficulty is facing when compared to mango harvesting.

4.2 Harvesting of Mango

The mango was harvested with harvester equipment and manually. The results are shown in the table 4.1.

Table 4.1 Comparison on rate of mango harvested manually and with developed equipment

Replication	No of mango harvested per minute	
	Manually	Developed equipment
R1	8	12
R2	9	14
R3	8	15

Average number of mangos that can be harvested by the equipment:

Per minute =14; Per hour =840

Average number of mangos that can be harvested by manually:

Per minute = 8; Per hour =480

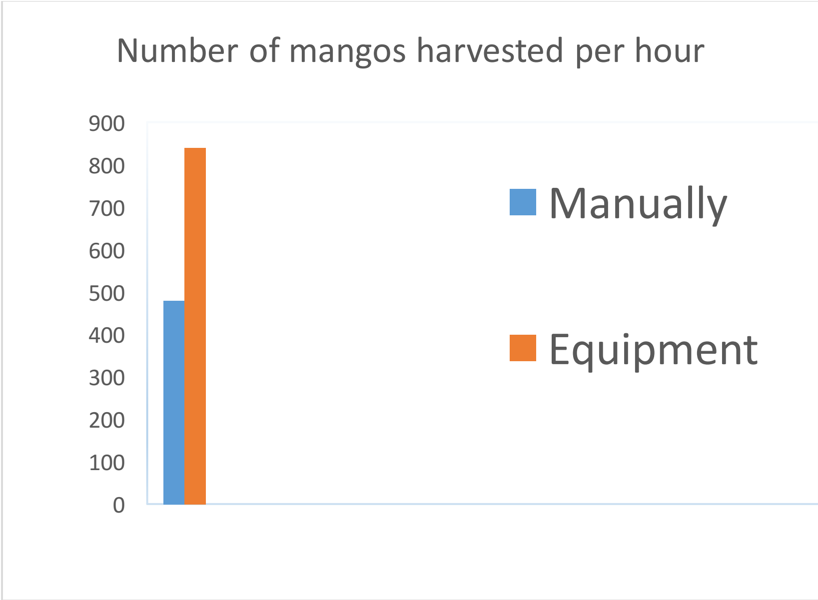

Fig 4.1 Comparison of mango harvesting using manual labour and Equipment

The results showed that there is a significance difference between manual harvesting and harvesting with developed equipment on rate of harvesting.

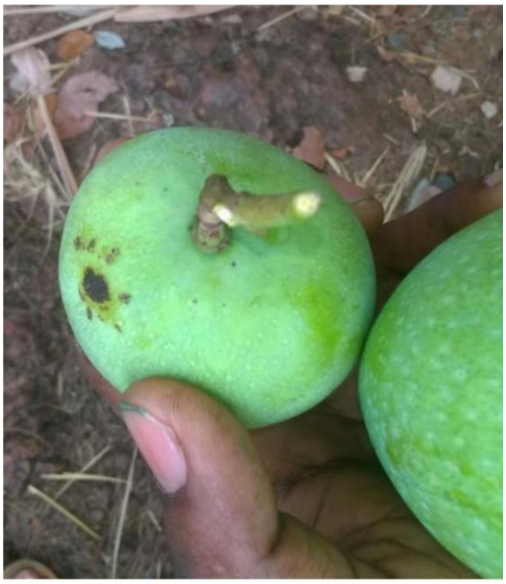

Plate 4.3 Manually harvested mango   Plate 4.4 Mechanically harvested mango

4.3 Harvesting of Sapota

The Sapota was harvested with harvester equipment and manually. The results are shown in the table 4.2

Table 4.2 harvesting details of equipment and manual harvesting

Replication	No Sapota per minutes	
	Manually	Harvester
R1	6	10
R2	5	12
R3	5	11

Average number of sapota that can be harvested by the equipment:

Per minutes = 11

Per hour = 660

Average number of sapota that can be harvested by manually:

Per minutes = 6

Per hour = 360

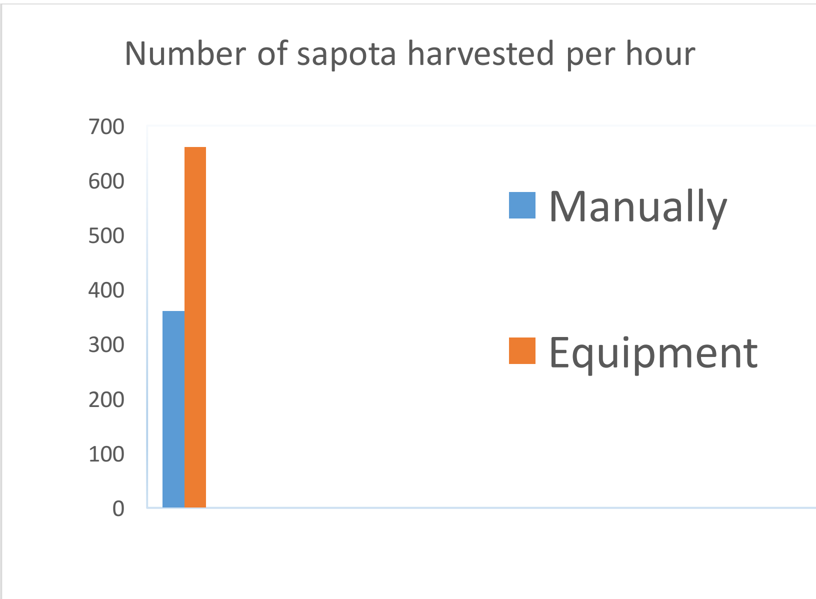

Fig 4.2 Comparison of Sapota harvesting using manual labour and Equipment

Plate 4.5 Collecting cum conveying unit

4.4 Cost analysis

4.4.1 Actual Cost for main frame fabrication

Weight of main frame	= 0.5kg
Average market price of mild steel	=50 rupees per kg
Cost for material	= 0.5 × 50
	= 25 rupees
Fabrication cost	= 500 rupees
Total cost for main frame fabrication	= 525 rupees

4.4.2 Actual Cost for telescopic pole

Weight of Al poles	= 1.2kg
Average market price of Al	=150 rupees per kg
Cost for material	= 1.2 × 150
	=180 rupees
Cost for plastic fittings	= 1000 rupees
Total cost for telescopic pole	= 1180 rupees

4.4.3 Actual Cost for electric works

Average whole sale price of servo motor	= 1000 rupees
Average whole sale price of remote controls	= 1000 rupees
Total cost for electrical works	= 2000 rupees

Table 4.3 Cost analysis of equipment

Sl No.	Items	Cost (Rupees)
1	Main frame	525
2	Telescopic pole	1180
3	Electricals	2000
4	Other accssiries	500
Total cost for the equipment		**4205**

4.4 Over view of the result

From the field tests done for mango and sapota it was evident that the proposed model is good for harvesting both fruit varieties . It is observed that the harvester is more efficient in harvesting mango fruits. Its light weight and easy handling help for better performance and collection of the fruits without drudgery involving less manpower. As this model consists of a cutting mechanism with remote control unit and collecting cum conveying mechanism, the fruits harvested are easily conveyed to the ground with least damage. Also it is economical.

4.5 Future line of work

Following modifications on the existing mango harvesting equipment is suggested to overcome certain drawbacks experienced during its operation.

- There should be a conveying mechanism which does not clogg with leafs and branch of tree during operation.
- We suggest blades coated with Titanium for better sharpness and smooth cutting.
- The telescopic pole should be properly insulated in order to avoid accidents when the equipment comes to contact with electric supply lines
- Suitable mechanism should be incorporated with the equipment to deflect the leaves that may cause hindrance to operate the equipment.

CHAPTER - 5
SUMMARY AND CONCLUSION

The developed countries have advanced technologies in many areas, but fruits, for the most part, are still being picked by hands, worldwide. Apple, pear, apricot, peach, mango, avocado, litchi, kiwi, olives, and sweet cherries are few examples of fruit crops which are still being handpicked. Fruit growers in the developed countries are facing two significant problems that could determine the future of their business:

- Lack of adequate labor supply
- Competitiveness in the global market

Many labor saving robotic machines are available worldwide, but, unfortunately, even those solutions which are available are only partially employed, and in many cases their use is not justified economically. The major deterrent to the introduction of labor-saving machines is the excessive mechanical damage incurred during mechanical harvest. Thus, although productivity can be increased significantly, the commercial implementation of labor-saving machines is limited to fruit which are destined for processing (such as olives) or are not prone to mechanical damage like nut crops.

Picking-aids or equipment increase the supply of labor, reduce seasonal demands, stabilize the labor force and increase the potential of pool of laborers by improving working conditions. None of the picking-aids makes the harvesting competitive with standard methods and thus, their use is not justified economically. As long as picking is done manually, the potential for increasing productivity is limited. Prolonged working time causes pain and stress at neck and hand.

A model was developed at KCAET Workshop for harvesting the tree fruits like mango ,sapota etc and it was tested at KCAET farm . It was developed based on a study of the merits and drawbacks of the existing manual fruit pluckers and harvesters .The basic concept was to develop a simple ,cost effective equipment that should be easy to handle and should operate with minimum damage to fruits. The developed Fruit harvester model consists of the following part Power source –Battery

- Main Frame
- Cutting unit
- Collecting cum conveying bag
- Telescopic pole
- Remote controls

The harvester basically consists of a cutting device that is attached to an adjustable aluminium pole. The total weight of the pole is 1.55kg and maximum of 6m height can be reached. This cutting device works on a DC motor which is controlled by a remote control device operated from the ground by the operator. The remote control can send a signal up to 10m.The pole is guided to the fruit and when it touches the pedicel of the fruit, the remote control is operated. The operating torque of the motor is very high and it weighs about 62.6g.The cut mango falls on the collecting and conveying unit which is made up of nylon net. The harvested mangoes or sapota fruits reaches on the ground by gravitational force without any damage by passing through the collecting and conveying unit.

From the field tests done for mango and Sapota fruits, it was evident that the proposed model was good for the both these tree fruits. Out of these, mango is easy to harvest with the developed equipment. The conveying mechanism helps to lead the fruit directly to the ground. From the field operations, practical analysis and cost analysis it is clear that the developed fruit harvester equipment is technically and economically suitable for harvesting fruits.

CHAPTER - 6

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ABSTRACT

The harvesting of fruits is of great concern to the farmers. The damage of fruits during harvesting and the drudgery to labors are the major problems faced by farmers. The delay in harvest reduces the quality. As a solution to these problems , development of an equipment for harvesting fruits was undertaken in KCAET Tavanur under the project entitled

"Development of Harvesting Equipment for Tree fruits" and a model was fabricated. The developed model basically consists of a servo motor, remote control, main frame, telescopic pole and collecting cum conveying unit. Primary testing of the developed model was conducted under field condition. The developed equipment could harvest 840 fruits per hour where as manually only 480 mango fruits could be harvested. The equipment was used for harvesting Sapota fruits also. The harvester performed better for mango crop. Practical analysis revealed that the developed equipment is effective for harvesting mango, Sapota etc. Cost of the developed equipment was Rs 4205. With few modifications, the harvester could be made available for commercial production.