

Development of a Low Cost Coconut Tree Climber for Small Farmers in Bangladesh

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Abstract - Coconut tree climber is a machine by which climbing on coconut tree is possible without much human efforts. Now a days most of the human activities are either replaced by the use of machines or other kind of equipments. Due to the constant cylindrical structure and single stem manually climbing on coconut is very difficult. There are no branches for holding and to support in coconut trees like other trees. Due to the risk involved nowadays very less people are coming forward to climb on coconut trees. Primary goal of the study is to develop a coconut tree climbing device and disseminate it through the farmers. During operation the height of the trees was taken from 7m to 12.5m (23-40) ft. Different persons were taken with different height, weight and age during operation. Before and after climbing on a tree operators blood pressure data was taken for ergonomic evaluation. The highest speed of machine during climbing on a tree was 7.23 m/min when the height of the tree was 8.90 m and the highest speed of climber machine during climbing down from a tree was 8.06 m/min when the height of the tree was 12.5 m. The price of the machine is about 6000 Tk and harvesting cost per tree was 20Tk.

Keyword- Coconut, Climbing, harvesting, Cost, ergonomics, time, speed

INTRODUCTION

Coconut (*Cocos nucifera*) is a hard-shelled seeds of coco palm growing to a height of 8-30m. Every coconut in a bunch is at the same stage of growth. The lowest bunches are the ripest and the upper bunches are tender. Moreover there is a visible variation of diameter along the height of every tree. The coconuts are harvested on a regular interval of 40 days, wherein the lower most bunches in the tree is harvested (Kawasaki H *et al.*, 2008) In Bangladesh coconut is considered as a crop with economic importance because of its high variety of uses. It has a high utilization potential for shelter, cosmetics, pharmaceuticals, energy and environmental protection. Coconut water is a wonderful safest natural drink, thirst quencher and remedy for diarrhea and cholera. The trees are suitable for climate change adaptation by keeping water table up, controlling erosion, acting as strong windbreaks and reducing storms and cyclones.

Coconut is very popular and common fruits in Bangladesh. At present coconut are grown in an area of

about 43000 ha with a production of 81400 tons (FAOSTAT, 2013) .The southern part of the country contributes about 80% of total production. (BBS, 2002). Unfortunately despite its mass distribution and wide spread around the world, coconut harvesting is still done without proper safety measures which can lead to serious injuries. It is very difficult to climb on coconut tree manually due to the constant cylindrical structure and single stem. If a person wants to climb a coconut tree manually climbing person has to put his hands close to each other on the back of the trunk, and pull one foot in front of the other one in front of the climbing person on the tree. By keeping pressure on the trunk with the balls of the climbing person's feet and toes, walk up alternating moving feet and hands. Technically it seems to be the easiest to learn but requires good balance and arm strength (Jeff Jepson, 2000). People who employed for coconut tree climbing suffer musculoskeletal disorders. It is very hard to learn the necessary skills to climb coconut trees.

A professional climber with proper training only could able to climb coconut tree. In Bangladesh traditional method of coconut harvesting is climbing on a tree which is very risky.

As the coconut trees are very tall so injuries associated with coconut tree climbing, particularly falling from coconut trees is common in Bangladesh. Coconut tree climbing equipment helps to climb on coconut tree without much human efforts. Now a day, different types of coconut harvesting methods are held with the human in other countries of the world like India, Malaysia, and Sri Lanka. Edacheri *et al.* (2011) reported that at present there are mainly two types of coconut tree climbing devices are available in Indian market. The two types are sitting type climbing device and standing type climbing device. In India robotic type of climber has also developed. Hariskrishna *et al.* (2013) reported that most of these climbing robots are capable of climbing regular structures like poles, walls, domes etc. But a very few are capable of climbing trees, main reason being irregular surface and variation of diameter with length. It also requires greater agility and high maneuverability to be used as a product. Also the bark of

some trees may not be strong enough to bear the weight of the climbing device, hence conventional climbing robots cannot be used for tree climbing applications. Therefore, this study has been undertaken to develop a coconut tree climber which will help the user to climb coconut tree easily will be useful for the people who is having large coconut cultivation as well as residents who is having less coconut trees.

The main goals of the developed machine are given below

- i) to design and fabricate of coconut tree climber
- ii) to evaluate the performance of coconut tree climber
- iii) to ensure the operator safety
- iv) to make an economic analysis of coconut tree climber

Literature review

A.R.C.H (ark) robot is a coconut tree-climbing robot prototype which is controlled remotely from the ground. It's climbing and fastening mechanism is designed to climb a pole of varying diameter. This manuscript deals with the design of a manipulator, with two unique modular end-effectors for the harvesting mechanism of A.R.C.H-1. The two robotic arms with three degrees of freedom are designed in such a way that it can be mounted on either side of the robot head. (Anoop Abraham *et al.*, 2014)

A coconut harvesting machine has been designed for harvesting coconut. The design is made in such a way that the machine fits in various sizes and shapes of the coconut tree. The robotic arm will cut the coconut in more precise manner than any other machine do. It is controlled by an RF remote controller. The machine can be manually controlled under any required circumstances as per the necessity. (A.P.Mohanraj *et al.*, 2014)

An automated a tree climbing robot has been developed which does not require human labor to accompany the device but only to control it from the ground using a remote control. Safety of the worker and the increased labor charges are the primary concerns of the coconut farm owners now. The device is a triangle with a movable third side and consists of three wheels, one attached to each side of the triangle. Two springs, each attached to the other two sides of the triangle help in adjusting to the varying diameter of the tree. Each wheel is driven by a high torque geared DC motor. Two L293D drivers are used to drive the three motors in a bidirectional way. These drivers are fixed on the frame of the device. A RF transmitter/receiver unit is used to provide control signals to the driver. A 12 V3000 mah rechargeable battery pack is used to provide on-board power supply for the receiver, two drivers and the three motors. An arm with a rotary blade at its end is fixed to one side of the Treebot to harvest the coconuts. (Senthilkumar S k *et al.*, 2015)

Mani A *et al.* (2014) has been developed and fabricated o a semi-autonomous tree climber and harvester (COCOBOT). Cocobot comprises of two mechanisms namely a climbing mechanism and a harvesting mechanism. The climbing mechanism consists of a octagon shaped chassis. Four active

wheels are set at specific intervals around the tree of which one pair is for the upper side and the other for the lower side of the chassis. The main features of the climbing mechanism include the location of centre of mass of the cocobot outside the tree and the innovative climbing strategy fusing the straight and spiral climbs. The harvesting mechanism consists of an arm with three degree of freedom with a circular saw as an end effector. The bunch of nuts is located by a vision sensor (camera) which is placed at the wrist of the arm. The nuts are harvested using the saw based on the output received from the camera. The entire movement of the cocobot and the harvesting mechanism is controlled using remote controller.

Rahul V *et al.* (2015) has been developed a semi automated coconut tree climber. Firstly it was made a rough sketch considering average diameter of a coconut tree as 30 cm and designed it in Solid Works. Later a static analysis was done using ANSYS to ensure its stability. After that we moved on to the fabrication part. The material used is GI steel. Three linear electrical actuators are used in this mechanism-two for gripping and one for the vertical up and down motions. Each actuator can carry up to 400kg. The analysis done using ANSYS proved the design to be safe and the fabrication was completed successfully.

The developed tree climbing device was evaluated based on ergonomical parameters and ergo refinements were carried out. The inclination of upper frame of climbing device is increased with respect to the horizontal, while moving towards the top of the tree. As a result, the centre of gravity of the user moves towards outside of the body making him feel insecure and unstable. The upper frame of coconut tree climbing device was suitably modified to avoid downward inclination such that ergo refined device improves the safety and ease of operation. The ergo refined coconut tree climbing device enhanced the comfort and safety of male subjects with 7.8, 12.2, 10.7 and 20.5% reduction in heart rate, energy expenditure, overall discomfort rating and body part discomfort score, respectively and 2.6 and 4.1% increase in overall safety and ease of operation rating respectively. The ergo refined coconut tree climbing device resulted in 20.6% savings in cost and 11.8% savings in time of climbing and harvesting coconut. (A P. Mohankumar *et al.*, 2013)

MATERIALS AND METHODS

The fabrication work of a standing type coconut tree climber is completed at the workshop of the Farm Machinery and Postharvest Process Engineering Division of Bangladesh Agricultural Research Institute (BARI), Gazipur during 2016. It was made of locally available materials. The materials used for fabrication of different parts of the climber were stainless steel, MS flat bar, MS angle bar, MS rod, nut-bolt, rubber and other small items..Construction materials and major component of coconut tree climber with specifications are shown in Table 1.

Table 1.Specifications of different parts of the coconut tree climber

Sl.No	Name of the parts	Specification	Materials
1	Left Main frame,((L×W×D) mm	1070×100×Ø10	Stainless Steel
2	Right Main frame, ((L×W×D) mm	1030×100× Ø10	Stainless Steel
3	Left foot holder, (L×W) mm	150×132×160, 4	MS flat bar and angle bar
4	Right foot holder, (L×W) mm	150×127×330	MS flat bar and angle bar
5	Left handle, (L×W×D) mm	200×140 × Ø10	Stainless Steel
6	Right handle,(L×W×D) mm	110 ×135× Ø 10	Stainless Steel
7	Tree holder,(L×D) mm	360×Ø10	MS rod
6	Left wire, (L×D) mm	1900× Ø6	Stainless Steel
8	Right wire, (L×D) mm	1900× Ø6	Stainless Steel
9	Rubber tier (L×W×T) mm	520×60×20	Rubber
10	U clamp, (L×D) mm	50×30×Ø5	Mild Steel
11	Weight of the machine (left part)	4.40	-
12	Weight of the machine (right part)	4.63	-
13	Helmet	1piece	-

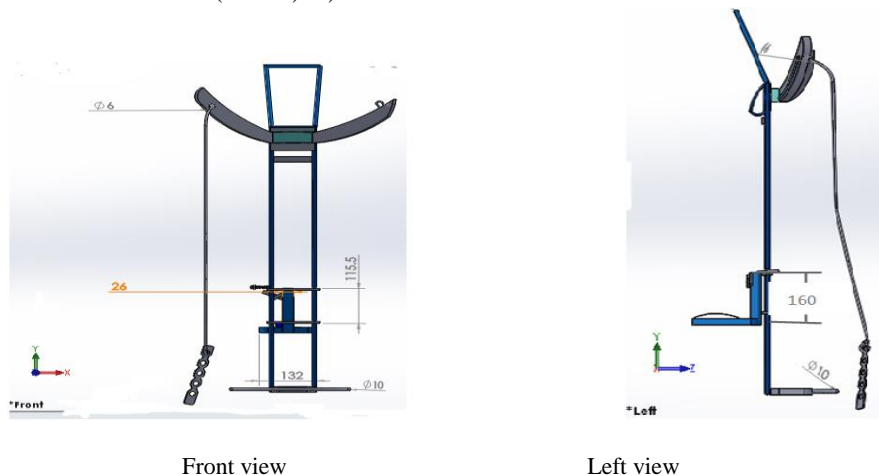
Design consideration

The coconut tree climbing machine was developed based on the following consideration:

- i) Machine was constructed of locally available material to enhance the possibility of replacing damaged parts with less expensive but equivalently satisfactory parts that is readily available.
- ii) The overall cost was considered through critical value analysis in the phases of design and production which at the end would make it affordable by farmers and other intending users.
- iii) Constructed machine would be user friendly, rapid and can be operated safely.
- iv) It is desired that the coconut tree climber should have good ergonomics.
- v) It was developed such a way that would be easy for assemble and low maintenance.

Data collection

The following data were collected during the test: i) Blood pressure of the operator (mm Hg) ii) Height of the tree (m) iii) Time required for climbing on (min) iv) Time required for climbing down (min) v) Spe the machine ed of the machine during climbing on and climbing down from the coconut tree (m/min) vi) Cost of the machine.



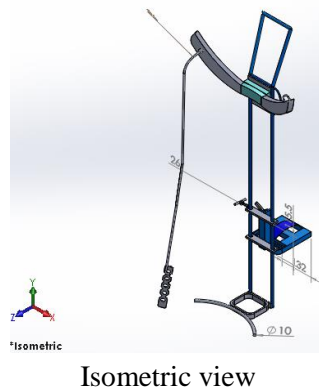


Fig. 1. Drawing of Coconut tree climber in Solidwork software

Coconut tree climbing process

The few first times, peoples barely managed to get a few feet up from the ground. During the initial climbing the skin of palm, chest and foot skin may be disturbed. This is what happens when people slide down hugging a coconut tree as hard as they can. There are two basic techniques of manual climbing on a tree. All techniques should be done barefoot and barehanded. A long sleeve T-shirt might save the user's skin from abrasion against the tree especially when the people are learning. The first method is the front-foot

technique. It is similar to rock climbing. The climbing person has to put his hands close to each other on the back of the trunk, and pull one foot in front of the other one in front of the climbing person on the tree. By keeping pressure on the trunk with the balls of the climbing person's feet and toes, walk up alternating moving feet and hands. Technically it seems to be the easiest to learn but requires good balance and arm strength (Jeff Jepson, 2000).



Fig. 2. Coconut tree climbing method without any device



Fig. 3. Photographic view of coconut tree climber and climbing process

DESCRIPTION OF THE MACHINE

This machine is standing type climber. It is a manual operated machine. One person can easily operate this machine. It has two parts. One part is used in left leg and another part is in right leg. These frames are independently movable and positionable along the coconut tree trunk. In this machine the tree gripping section consists of stainless steel wire and rubber tires. The materials used for the machine are stainless steel, MS flat bar, MS angle bar, MS rod, Mild Steel, Rubber etc. The functional parts of the machine are left and right handle, foot holder, tree holder, wire etc. The total weight of the machine is 9.7 kg.

WORKING PRINCIPLE

It has mainly two assemblies of similar construction. The user has maintained these two assemblies simultaneously by using hands and legs to climb on coconut tree. In this construction, the user has to stand and operate the device. Initially the steel wire of both assemblies has to be looped with the tree and to be locked. Then the one person can stand by placing foot on both assemblies and has to hold on the handles. As the user raise the assembly by foot and by hand the steel wire will get loosen and when he push back with foot after reaching to a particular height it will get tighten. By this process the user can climb to the tree easily. The descending the tree is exactly the reverse procedure. The machine works on the body weight and the steel rope wire will get adjusted as per diameter of the tree by the force applied by the user towards gravity.

The coconut tree climber was tested for climbing coconut tree at different locations in BARI campus and RARS, Rahmotpur, Barisal. At first, outer diameter from 122 cm above the ground of 40 number of coconut trees was taken. This outer diameter were varies from 82-107 cm. The outer diameter from bottom to top of the length of 3 trees at 122 cm interval was taken which is found 92-56 cm approximately. This data helped to select wire length so that it can be suitable for different diameter of coconut trees. During operation the heights of the tree were taken from 7m to 12.5m (23-40) ft. Different persons were taken with different height, weight and age. Before and after climbing on a tree operators blood pressure data was taken. The persons who climbing on a tree were not given the same performance. Some persons are trained and some are completely untrained. Performance of the climber is depends on person capability, slippage condition of trees, curving length of the tree trunk, weight of the machine, physical condition of operator, height of the tree etc. The highest speed of climber machine during climbing on a tree was 10.72 m/min when the height of the tree was 8.90 m and the highest speed of climber machine during climbing down from a tree was 8.06 m/min when the height of the tree was 12.5 m. From the above data we can concluded that the average speed of climber during climbing on a coconut tree was 4.93 m/min whereas it was 5.55 m/min during climbing down from the tree. Performance of coconut tree climbing by manual method and using machine is shown in table 2 and 3. Data of the experiment was taken at BARI HRC mango field and RARS Barisal.

RESULTS AND DISCUSSION

Table 2. Performance of conventional method of coconut tree climbing

Operator age (year)	Operator weight (kg)	Blood pressure (mmHg)		Height of the tree (m)	Time (minute)		Speed (m/min)	
		Before climbing on a tree	After climbing down		Climbing on	Climbing down	Climbing on tree	Climbing down
30	55	110/80	140/90	9.15	0.67	0.60	13.65	15.25
25	52	120/80	130/90	9.15	0.42	0.33	21.78	27.72
50	54	130/80	180/100	8.84	1.08	0.45	8.18	19.64
30	50	110/70	120/90	11.5	0.57	0.78	20.17	14.74
35	53	120/70	130/90	10.4	0.87	1.01	11.95	10.29
25	55	90/70	120/90	12.1	0.70	0.68	17.28	17.79

It was observed from the the manual data(Table 2) that it took less time to climb on a tree manually but there have an involvement of risk and most of the time operator wounded in their hand, chest and leg when they climb on tree manually. Eventually manual operator loss their eagerness of regular climbing on a tree. During operation of the machine some problems were observed. The weight of the right leg holder is little bit more. So operator felt sometimes inconvenient when climbing on a tree. This problem will be solved by reducing the weight of the machine.

Table 3. Performance of coconut tree climbing machine

Operator age (year)	Operator weight (kg)	Blood pressure (mmHg)		Height of the tree (m)	Time (minute)		Speed (m/min)	
		Before climbing on a tree	After climbing down		Climbing on	Climbing down	Climbing on tree	Climbing down
42	62	130/90	140/110	7.00	1.50	1.18	4.67	5.93
50	60	130/80	140/100	8.50	1.20	1.00	6.06	4.00
30	56	120/80	130/100	10.00	2.50	2.39	4.00	4.18
42	62	160/120	170/110	12.07	3.20	2.40	3.77	5.02
42	62	150/110	160/130	12.5	2.25	1.55	5.55	8.06
42	62	140/120	150/130	8.84	1.25	1.13	7.07	7.82
25	52	120/80	130/80	8.90	1.23	1.35	7.23	6.59
30	56	110/70	120/80	8.84	2.31	1.45	3.82	6.09
25	52	120/80	130/90	9.15	1.50	1.32	6.10	6.93
30	56	110/80	130/90	10.67	2.30	2.20	4.64	4.85

ERGONOMIC EVALUATION

The developed coconut tree climbing devices was evaluated with eight male persons. The subjects were screened for normal health. The age, weight and height of the selected male were 25-50 years, 52-62 kg and 160-167 cm respectively. Ergonomic evaluation of the selected coconut tree climbing practices was conducted for assessing the suitability of the user with respect to comfort, safety and ease of operation. The evaluation was carried out with the eight selected persons in terms of blood pressure and discomfort rating, safety rating, over all ease of operation rating. The blood pressure data was recorded using sphygmomanometer and stethoscope. Blood pressure data for each person was taken before and after the climbing operation using machine and manual process. From the Table 2 and Table 3 it was observed that most of the cases before climbing on a tree and after climbing down from a tree, in both manual and mechanical operation blood pressure data were varied from 10-20 mmHg of systolic and diastolic pressure. It is quite normal for every person because blood pressure of every people literally increased after hard physical work. Sometimes blood pressure data

showed little bit high value due to fear of height and use of new machine for the first time. Some operator urged that they felt pain in their right leg when they use the machine for the first time. This problem will be solved by reducing the weight of the machine and by using the machine regularly. While operator moves towards top of the tree, operator felt insecure and unstable. To solve this problem, a safety belt was provided for avoiding the possibility of a fall which increased confidence of the climber to work without fear at any height of the tree.

Cost analysis

Cost analysis of coconut tree climber is shown in Table 4. The initial cost of coconut climber was Tk. 6000. The fabrication cost of the machine was calculated including cost of materials, labour, incidental expenses and manufacturing. Profitability analysis revealed that the method of coconut climbing incurred fixed and variable costs. Fixed cost included two cost items namely depreciation and interest whereas variable cost included labour, repair and maintenance cost. The coconut harvesting cost using machine was 20 Tk/tree.

Table 4. Cost analysis of coconut tree climber

Sl.No.	Items	Cost
1	Price of the climbing machine, Tk/unit	6000
2	Life of the climbing machine, year	5
3	Annual use, hour	2000
4	Annual Fixed cost	
	a) Depreciation, Tk/yr	1080
	b) Interest (5%), Tk/yr	165
	Total fixed cost, Tk/yr	1245
	Total fixed cost, Tk /h	0.62
5	Variable cost	
	a) Labour for climbing, Tk/h	62
	b) Repair and maintenance, Tk/h	0.09
	Total operating cost, Tk/h	62.09
6	Total cost (4+5), Tk/h	62.71
7	Harvesting cost, Tk/tree	20

CONCLUSION

In Bangladesh, farmers are habituated climbing on a coconut tree manually. During operation the highest speed of climber machine during climbing on a tree was 7.23 m/min when the height of the tree was 8.90 m and the highest speed of climber machine during climbing down from a tree was 8.06 m/min when the height of the tree was 12.5 m. During ergonomic evaluation, before climbing on a tree and after climbing down from a tree, both manual and mechanical operation blood pressure data was varied from 10-20 mmHg of systolic and diastolic pressure. At the beginning it is time consuming but with continuous use and practice it will reduced the time required for the Climbing. Though there are some problems in coconut climbing machine but it will be useful for both the residential growers and commercial cultivators.

Farmer's opinion

- i) Coconut tree climber can accelerate harvesting operation and risk free climbing on a tree.
- ii) Labour shortage can be minimized with coconut tree climber
- iii) Coconut tree climber to be improved again for reduces its weight.
- iv) Training must be arranged for making this machine user friendly

Recommendation

The weight of the equipment can be reduced by the use of alloys or composite material. It can be automated. Also better safety accessories can be thought of and included along with the equipment.

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