Design and development of sitting type coconut palm climbing device – "Kera Suraksha Coconut Climber"

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Abstract

Coconut climbing is considered as a traditional job of some backward communities in Kerala. The height of bearing coconut palm varies from 2 to 30 m. Climbing of coconut palm is difficult due to the height and non branching nature of the palm. Only a professional climber with proper training and skill is able to climb coconut palm. Due to the risk involved, people are not coming forward for climbing job and those who do claim high service charge. In order to overcome this situation, a sitting type coconut palm climbing device was designed and developed. Made of mild steel, it weighed 9.35 kg. Its field performance and ergonomic evaluation were conducted. The total time taken by the operator to climb a 12 m height palm using the developed climbing device was 3.16 minutes. The angle of inclination of the upper metal wire rope, lower metal wire rope and seat with horizontal was found to be below the safe value of 40^0. The strength of wire rope used was tested for breakage and found fit. The bearing capacity of the materials and climbing device as a whole was found to be 165 kg and did not shown any failure. This device could easily be operated by any unskilled person and safety of the operator is assured during climbing.

Keywords: Climbing device, Coconut palm, Lower unit ergonomic evaluation, Upper unit

Introduction

Coconut is mainly grown in tropical countries. Indonesia and Philippines are the first and the second largest coconut producing countries in the world. India is the third largest coconut producing country having an area of about 2.14 million ha with a production of 14911 million tons (NHB, 2015). The production of coconut is mostly in the southern part of India. Among the southern states the production is highest in Tamil Nadu state, which has an area of about 4.65 lakh ha and a production of 4761 million tons. Next largest producers of coconut are Kerala and Karnataka states with production of 4107 and 3490 million tons respectively. Harvesting of coconut palms is mainly carried out by manual climbing of palm and plucking the nuts. The climbing is carried out by people of traditional backward communities. Climbing the palm and harvesting of nuts are tedious and require great skill. It is also a very risky job and climbers may suffer musculoskeletal disorders. Colles, vertebral and maxillary fractures and severe allergies are the medical emergencies which are listed among climbers. Professional and trained climbers are limited in number. The present generation is not coming forward to climb the palms. Due to improved educational background of youths and lower respectability associated with coconut climbing, most of them hesitate to take it up as a profession. So a mechanical device which avoids risk and helps to ease the job is a need of the hour. Standing type and sitting type coconut climbing devices have already been developed in India and are used in Kerala, but not to a large extent.

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Edacheri et al. (2011) studied the performance of sitting type climbing device developed at TNAU and standing type developed by Mr. M. J. Joseph, an agriculturist in Kerala. He reported that in sitting type climbing device, size of the device had to be adjusted as per the diameter of the coconut palm, but in standing type the size was self adjusted. Standing type climbing device was simple in construction and easy in operation compared to sitting type. They also designed and developed a new standing type tree climbing device. The frame of this device was made of mild steel and weighed 5 kg. Steel wire rope of 19 strands was used. They suggested that 6 x19 FC RH OL FSWR would be the suitable steel rope wire for long use without breakage. The working model has been validated in the field. The developed model was lighter than those existing by about 30% and was expected to be less costly on account of aluminum used for its construction in lieu of the steel used in other currently available designs. George et al. (2012) reported that a total 35.5% (78 cases out of 220 climbers) fell down from coconut palm while doing their job manually. The body weight and Body Mass Index (BMI) of the climber showed significant decline as compared to those of the non climbers. Mohankumar et al. (2013) developed an ergo refined coconut tree climbing device. It was a sitting type device and improved the safety and ease of operation. It resulted in 20.6% saving in cost and 11.8% saving in climbing time for harvesting coconut compared to earlier model designed by them. The weight of device was 12.8 kg.

Comparing the sitting type climbing device with standing type, sitting type was more safe and comfortable to the operator. But the cost, weight and climbing time, time taken to attach and detach the device to and from palm trunk were more compared to the standing type climbing device. Considering these facts, a simple coconut climbing device was designed and developed.

Materials and Methods

Considering the fact that safety to health and life are the prime concerns to coconut climbing, a coconut climbing device was designed and developed with defined specifications. The important parameters considered for the design of coconut palm climbing device were crop parameters, climbing device parameters, and anthropometric dimensions of the operator.

Crop parameters

Twenty five coconut palms were selected at random from the coconut farm located at Agricultural Research Station, Mannuthy, Kerala. The girth of these twenty five palms was measured at three levels of height as detailed below.

1. Girth of coconut palm at one metre height above ground level
2. Girth of coconut palm at one metre below the bottom most crown level
3. Girth of coconut palm at middle portion

From the measured girth values, average diameter of the coconut palm was calculated. From the calculated upper and lower diameter values of the palm, the size of the climbing device was arrived at.

Climbing device parameters

The climbing device parameters considered were materials used for fabrication, gripping aid, weight and cost of device.

Anthropometric dimensions

Anthropometric measurement included physical features of men operators including linear dimension, reach, weight and volume. The anthropometric dimensions of agricultural workers of Kerala relevant to the development of palm climbing device were taken from the anthropometric data collected and furnished in Table 1.

Table 1. Anthropometric dimensions of the men operators considered for the design of palm climbing device

Dimension	Mean	Standard	5th percentile	95th percentile
	Deviation (%)	value	value	
Weight, kg	59.92	09.19	44.80	75.05
Trochanteric height, cm	80.57	04.20	73.66	87.48
Knee height sitting, cm	51.03	02.39	47.10	54.97
Buttock to knee length, cm	53.14	04.15	46.30	59.98
Hip breadth sitting, cm	32.47	02.17	28.89	36.05
Functional leg length, cm	93.35	11.59	74.28	112.44
Grip diameter (inside), cm	04.81	0.238	04.42	05.20
Heel breadth, cm	05.15	00.55	04.24	06.06
Foot length, cm	23.87	00.95	22.31	25.45
Foot breadth, cm	08.82	00.73	07.63	10.03
Lateral malleous height, cm	06.37	00.88	04.92	07.83

Fabrication details of coconut palm climbing device

The coconut palm climbing device consisted of two units: upper unit and lower unit. These units were movable independently and could be harnessed to coconut palm. Both the upper and lower units were made up of 20 mm dia mild steel oil treated pipe of 2 mm wall thickness with grade of 30X. The upper unit could be operated by both hands and lower unit by both legs.

The upper unit consisted of a seat frame section and an adjustable palm attaching section. The seat frame section include a seating arrangement for the operator, rear support frame with a safety rope and seat support. The seat support was connected to the adjustable palm attaching section. The seat was comfortably made up of rexin with springs and connected to the seat support. The palm attaching section included upper and lower 'Trapezoidal' shaped brackets, gripping aid, two vertical pipes connecting the 'Trapezoidal' shaped brackets which was bent at the top as handles. Gripping aids are 6 mm metal wire ropes and were provided at the upper and lower 'Trapezoidal' shaped brackets. The upper unit was attached to the palm using the 6 mm wire ropes. Holes were provided at right and left side of upper bracket to attach upper unit firmly on different diameter of palm. At the upper bracket three 6mm metal wire ropes and at the lower bracket one 6 mm metal wire rope were provided. The upper metal wire ropes were fixed with 'C' clamps at both ends and attached to 'Trapezoidal' shaped brackets with Stainless Steel locking pins. The locking pins with chains were inserted on holes provided at the right and left side of upper bracket. Generally the diameter of the palm decreased towards the top of palm. In such situations the top two metal wire ropes were adjustable with a lever assembly fitted on the right side of the upper bracket, as per the diameter of the palm without removing locking pins. This adjustment could be easily done by the operator during palm climbing while comfortably standing on the lower unit. The bottom 6 mm metal wire rope was fixed with lower bracket through 'U' clamps to provide firm grip to the palm. Handles provided with the device enabled operator to lift and drop the upper unit while ascending and descending palm respectively.

The lower unit consisted of a foot frame section and a palm attaching section. The palm attaching section included two metal wire ropes at top bracket and one metal wire rope at bottom brackets. The lower unit was attached to palm using these metal wire ropes. The foot frame section carried foot supports and pair of pipes to insert feet, tilt and lift lower unit during climbing. Holes were provided on right and left side of the upper brackets. The metal wire ropes were fixed with 'C' clamp at both ends and attached to upper bracket with stainless steel locking pin. The bottom metal wire was fixed with lower bracket through U clamps to provide

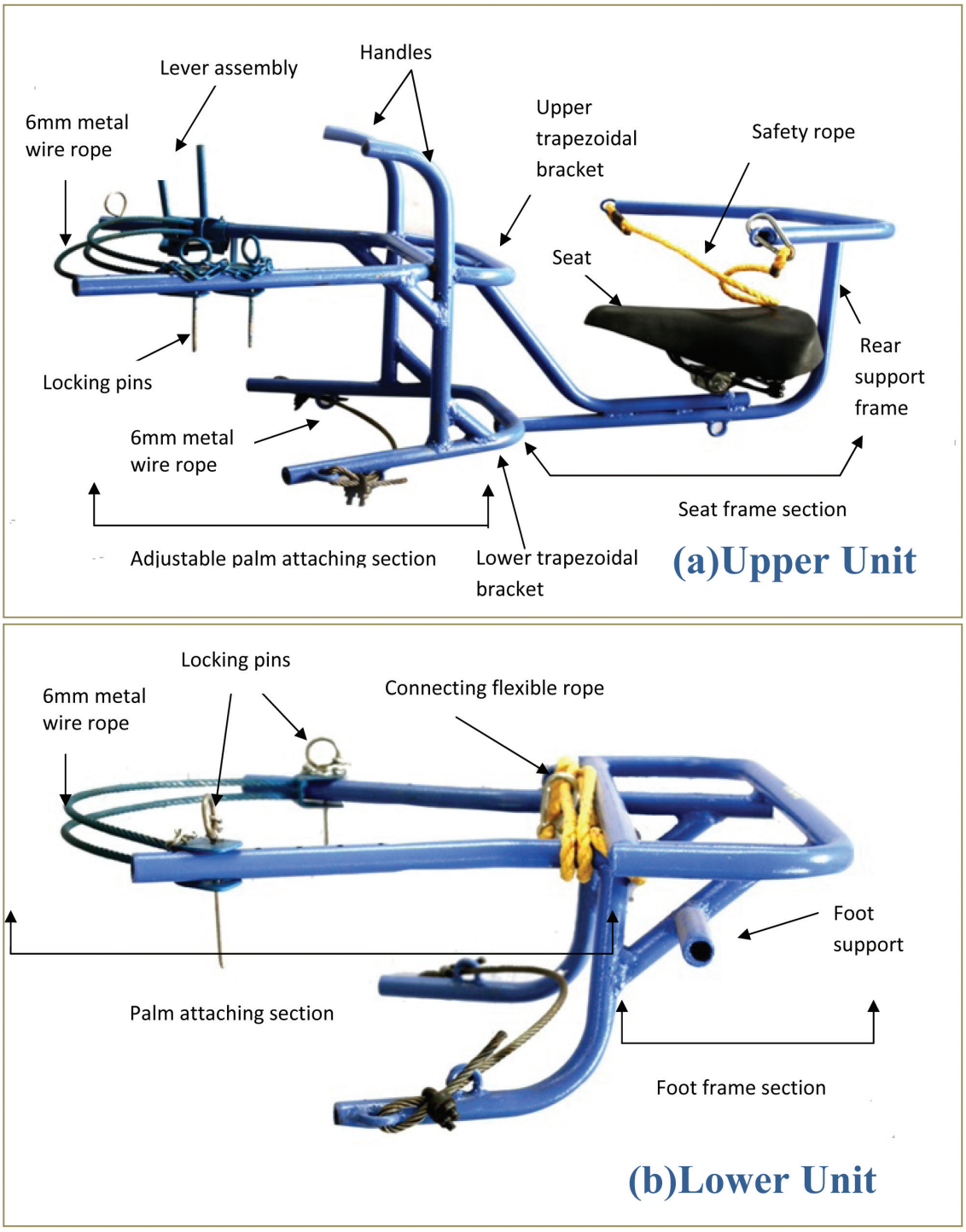

Plate 1. Upper and lower unit of the developed coconut palm climbing device

Plate 2. Operational view of developed coconut palm climbing device

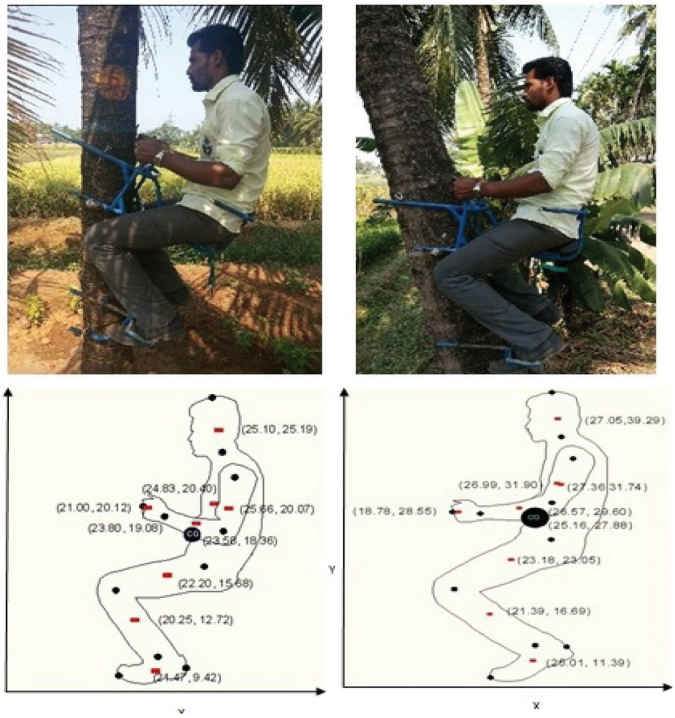

Plate 3. Centre of gravity of the operator located by segmental method for minimum and maximum diameter of palm

firm grip to the palm.

The upper and lower units were connected with flexible nylon ropes and quick fixtures which prevented the lower unit dropping from the operator's leg while climbing.

For climbing the palm, the lower and upper unit of climbing device was attached to the palm such that the inclination of the seat and foot frame being horizontal to the ground. The operator had to place his feet at the foot frame section of the lower unit. The operator had to sit on the seat of the upper unit while lifting his feet and legs in such a way to pull the lower unit upward. The operator then could stand by resting his feet on the lower unit and using his hand, raise the upper unit to waist high position. The operator could then sit and again raise the lower unit with his feet and legs. This process could be repeated till the whole height of the palm was covered, and while descending the palm, the same procedure could be repeated vice versa. The developed coconut palm climbing device is shown in Plate 1. Operational view of the developed coconut palm climbing device is shown in Plate 2.

Estimation of angle of inclination of coconut climbing device

The angle of inclination of the upper unit of the climbing device at minimum diameter and maximum diameter of the palm was determined at three levels. They were: The angle of inclination of the upper metal wire rope, lower metal wire rope and seat with horizontal. These angles of inclinations at three level of the climbing device were estimated from the climbing posture of the climbing device with operator during climbing at different diameters of the palm using AUTOCAD software.

Estimation of centre of gravity of coconut climbing device

Centre of gravity is the point where whole weight

Plate 4. Testing set up for estimating the strength of metal wire rope

of the body is acting. Location of the centre of gravity of the whole body is the resultant of location of centre of gravity of each body segments. The stability of the operator during climbing using the climbing device with respect to particular posture depends upon the position of the centre of gravity of the body weight of the operator. The position of the centre of gravity of the operator was estimated by segmental method at minimum and maximum inclination of the upper unit of the climbing device. The inclination of coconut palm climbing device while climbing depended upon the diameter of the palm.

Estimation of strength of wire rope of coconut climbing device

The strength of wire rope is the resistance of wire rope to breaking under force. It was tested with a simple apparatus consisting of an half round metal bracket, lever, handle and a linear spring scale balance of 50 kg capacity. For testing the strength of wire rope, the climbing device and apparatus were connected on opposite side of a coconut palm. An operator was seated on the climbing device. Simultaneously, another man applied a counter force to the wire rope of the upper unit of climbing device by holding down the handle of the apparatus. The counter force was measured from the linear spring scale balance. This testing set up is shown in plate 4.

Estimation of load carrying capacity of materials of coconut climbing device

The upper and lower units of coconut climbing device were made up of 20 mm diameter mild steel oil treated pipe of 2 mm wall thickness with grade of 30X. Load carrying capacity is the strength of materials to support the carrying loads. For testing the load carrying capacity, the climbing device was connected with coconut palm. An operator was seated on the climbing device. In addition to operator's weight, a ballast weight of 100 kg was suspended at seat frame and the load carrying capacity of the material of the climbing device was found out.

Ergonomic evaluation

The developed coconut climbing device was evaluated with fifteen coconut climbers. These climbers were screened for normal health conditions. They were trained in operation of the coconut climbing device. Before starting the experiment, age, weight and height of the selected subjects were measured.

Ergonomic evaluation of the developed coconut palm climbing device was conducted for assessing suitability of climbing device with respect to comfort, safety and ease of operation of the operator. Heart Rate (HR), Overall Discomfort Rating (ODR), Overall Safety Rating (OSR), Overall Ease of operational Rating (OER) and Body Part Discomfort Score (BPDS) of subjects were evaluated. The heart rate data was recorded using polar RS 300 X heart rate monitor.

Heart rate increase over resting values gives work pulse (ΔH). The mean values of work pulse for coconut palm climbing operation were compared with the limit of continuous performance which is 40 beats/minutes. For the assessments of overall discomfort rating (ODR), overall safety rating

(OSR) and overall ease of operation rating (OED), a 10- point physiological rating scale was used (Ceriett and Bishop, 1976). The time of operation was fixed as 30 minutes. For calculating the Body Part Discomfort Score (BPDS), a body map technique was used. Each subject was asked to point out the discomfort body part in the body map.

At the end of each trial climbing, with the climbing device, the operators were asked to point out their ODR, OSR and OER on 10 point rating scale.

Results and Discussion

The diameter of the coconut palm is an important crop parameter that influence the size and performance of coconut palm climbing device. Adjustable length of metal wire rope and size of trapezoidal shape brackets in upper and lower unit were designed based on the average diameter range of the coconut palm. From the collected data, it was observed that the diameter range of the palm is 20-32 cm and the palm climbing device was designed for 20 - 32 cm diameter range of coconut palm. The specifications of newly developed coconut palm climbing device are given in Table 2.

The centre of gravity and angle of inclination of coconut palm climbing device

The centre of gravity of palm climbing device shifts outside of the body at more than 40^0 inclination of the palm climbing device. Hence the safe inclination of palm climbing device is less than 40^0 with horizontal (Mohankumar, 2013). So the climbing device was designed in such a way that its upper unit inclination at upper metal wire rope, lower metal wire rope and seat level was within 40^0. The inclination of upper unit at three levels measured at 20-32 cm diameter range of palm and is shown in figure 1. It was seen that as the diameter of the palm increased inclination of upper unit at three levels decreased with respect to horizontal. The centre of gravity of the operator at 20 cm diameter and 32 cm diameter palm climbing position was determined and is depicted in plate 3. In both cases the centre of gravity of the operator was within the body. As a result centre of gravity of the operator shifted inside the body and the user felt more safety and comfort.

Ergonomic evaluation

The results of ergonomic evaluation are presented in Table 3. The average heart rate of operator before and after climbing was 93 beats/minute and 127 beats/minute respectively. The average variation in work pulse value of the operator was 34 beats/minute. The value of work pulse was under

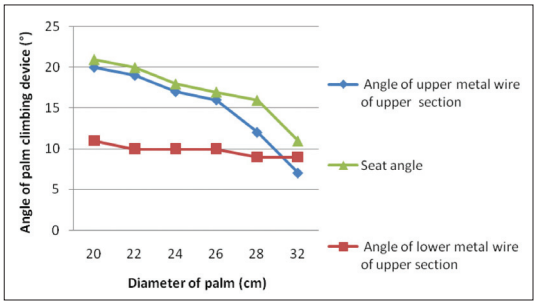

Figure 1. Variation in inclination of upper section of the palm climbing device with diameter of palm

Table 2. Salient specifications of developed coconut palm climbing device

Particulars	Dimension
Size of the upper unit, cm	83 x 52 x 38
Size of the lower unit, cm	59 x 44 x 20
Size of the seat frame section in upper unit, cm	43 x 40 x 30
Size of palm attaching section in upper unit, cm	53 x 50 x 38
Size of foot frame section in lower unit, cm	52 x 15 x 20
Size of palm attaching section in lower unit, cm	44 x29 x 20
Diameter and length of metal wire rope, cm	0.6, 46.88 - 67.5
Length and diameter of flexible nylon rope, cm	190 , 0.8
Weight of the upper unit, kg	6.14
Weight of the lower unit, kg	3.21

Table 3. Ergonomic parameters of the coconut palm climbers

Parameters	Values
Heart Rate beats/minute	127
Work Pulse (ΔH) , beats/minute	34
Overall Discomfort Rating (ODR)	3
Overall Safety Rating (OSR)	2
Ease of Operational Rating (OER)	2-4
Body Part Discomfort Score (BPDS)	21

acceptable limit of 40 beats/minute for sustained working (Kroemer et al., 1997). Overall Discomfort Rating (ODR), Overall Safety Rating (OSR) and Overall Ease of operating Rating (OER) were 3, 2 and 2-4 respectively. The Body Part Discomfort Score is a measure of discomfort related to particular work. Out of 15 operators, 10 operators did not experience any body part discomfort and five operators experienced pain in right and left thigh, lower back and right foot.

Field performance of palm climbing device

The average time taken to attach the device to the palm and detach after climbing operation was 10 sec. The average time taken to ascend and descend 12 m height palm was 1.11 minutes and 2.05 minutes respectively. Thus the total time taken to climb 12 m palm was 3.16 minutes.

Estimation of strength of wire rope of coconut climbing device

After connecting both the climbing device and strength measuring device oppositely with coconut palm, an operator having a weight of 65 kg was seated on the seat of the climbing device. By holding the handle of the strength measuring apparatus another man was forced down the apparatus resulting in the stretching of wire rope in three directions and proved its strength against breakage.

Estimation of bearing capacity of materials of coconut climbing device

The ballast weight 100 kg and operator weight 65 kg proved the bearing capacity of the material and climbing device as a whole in supporting a total load of 165 kg without any failure.

A sitting type coconut climbing device was designed and developed. Its field performance and ergonomic evaluation was conducted. The device could be easily attached and detached from the coconut palm. The device was easy to operate and the operator felt more safety and comfort during climbing. It was suggested that, even ladies and unskilled persons can climb on coconut palm safely and comfortably by using the developed device. Small farm holders with 5-10 palms can use the device to harvest their palms by themselves. The cost of the device was Rs. 3000/- only and it weighed 9.35 kg. The device was cost effective and the weight of the device could be reduced further by using alloy metals for its fabrication instead of mild steel.

Acknowledgement

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