

## **DECLARATION**

I, hereby declare that this thesis entitled “INVESTIGATIONS ON PHYSICO-MECHANICAL PROPERTIES OF COCONUT PALM FOR THE DESIGN AND DEVELOPMENT OF A COCONUT PALM CLIMBER” 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.

Place: Tavanur

**AYISHA MANGAT**

Date:

**(2019-28-011)**



## **CERTIFICATE**

Certified that this thesis entitled “INVESTIGATIONS ON PHYSICO-MECHANICAL PROPERTIES OF COCONUT PALM FOR THE DESIGN AND DEVELOPMENT OF A COCONUT PALM CLIMBER” is a record of research work done independently by Er. AYISHA MANGAT (2019-28-011) 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 her.

Place: Tavanur

Date:

**Dr. P K Sureshkumar**  
Major advisor  
Professor (FPME)  
Dept. of Agrl. Engg.  
College of Agriculture  
Vellanikkara



## ACKNOWLEDGEMENT

*First of all, let me thank the Almighty for blessing me and helping me to complete this task as those blessings were invaluable.*

*I would like to express my profound gratitude to my advisor, **Dr. P K Sureshkumar**, Professor (FPME), Dept. of Agricultural Engineering, College of Agriculture, Vellanikkara, for his invaluable guidance and unwavering support throughout this project, despite his busy schedule. His expertise and insightful feedback have been instrumental in shaping my research and helping me navigate challenges. I am truly thankful for his encouragement, patience, and mentorship, all of which have been essential to my success. I deeply appreciate the time he dedicated to mentoring me.*

*I would like to express my sincere gratitude to **Dr. Jayan, P.R.**, Dean (Ag. Engg), KCAEFT, Tavanur for his invaluable support and guidance, despite his demanding responsibilities. His encouragement and thoughtful insights have significantly contributed to the success of this project. I truly appreciate the time and effort he dedicated to mentoring me, even amidst his busy schedule.*

*I am grateful to all the members of advisory committee **Dr. Suma Nair**, Asst. Professor,ARS, Mannuthy, **Er. Shivaji K P**,Asst. Professor (FMPE),CoA,Padannakkad and **Dr. Anish M C**, Asst. Professor, Dept. of Forest Products & Utilization, College of Forestry for their help and constructive criticism throughout the work. Also, to late **Dr. Anoop E V**, who is no longer with us.*

*Let me take this opportunity to thank all the teachers, technical staffs, office staffs for their support and cooperation. Special thanks to **Dr. Sudheer K P** and Department of Agrl. Engg., CoA, Vellanikkara for allowing me to utilize the facilities in the workshop. I deeply appreciate the technical expertise and timely assistance provided by Sreekesh chettan, Jithin, Alby chettan, Arun Aswin, Suhail, Anuj, Navya and **team ABI** which played a crucial role in achieving the desired outcomes. I will never forget their invaluable support and logistical assistance during fieldwork, which greatly facilitated this study.*

*I would also like to thank all my friends, juniors and seniors who have helped me in one way or the other for the completion of my research work, especially Er.*



Chandrashekhar; Er. N L Kalyan Chakravarthi, Dr. Dipak.S. Khatawkar; Dr. Dayanand Kumbhar.

*I extend my gratitude to team **CAD Solutions**- Jasim and Abhishek for their exceptional technical support in the design aspect without which this project would not have been possible. Sincere thanks to **EC ladders**-Eldho bhai for helping me in the fabrication work.*

*My heartfelt thanks go to Dr. Abdullah, Vishnu and Pratheesh sir for their expertise and assistance with the statistical aspects of this study. My sincere thanks go to Shahanastha, Saritha, Induechi, Jyothi chechi, Tharechi, Eldhose, Sooraj, Bharat, Abuakka & family for their constant encouragement and assistance throughout this journey.*

*I owe my deepest gratitude to my parents-Immachi and Ippachi and loved ones for their constant motivation, understanding, and sacrifices that made this accomplishment possible. I am deeply grateful to my in-laws especially Imma for their unconditional love and support in caring for my child, which played a crucial role in enabling me to complete this journey. This accomplishment would not have been possible without the mental and emotional support of my sisters-Kachutha and Pumtha, who always stood by me with love and encouragement.*

*Words are not enough to thank my husband -**Niyaska**, without him my thesis will be an incomplete one. I am deeply thankful for his constant emotional, mental, and physical support throughout this journey. His love, understanding, and encouragement have been my foundation during both the challenges and triumphs. I truly appreciate the sacrifices he made and the strength he provided, especially during my pregnant days and hospital days which made this accomplishment possible. Thanks for the scolding which was intended to motivate me. Special thanks to **Bayan** and **Khalid**-my stress busters, for their patience and understanding, as they missed many days with me during this time. Their love and support have been a source of strength.*

*Finally, I acknowledge the financial support of **ICAR-NAHEP-CAAST** and **Kerala Agricultural University** which provided me with the resources and stability needed to pursue this project.*





*My thanks remain with all those who have helped me in one way or the other,  
directly or indirectly for the completion of the research work.*

***-Ayisha Mangat***



## CONTENTS

Chapter	Title	Page No.
1	INTRODUCTION	1-5
2	REVIEW OF LITERATURE	6-39
3	MATERIALS AND METHODS	40-107
4	RESULTS AND DISCUSSION	108-140
5	SUMMARY AND CONCLUSION	141-149
	REFERENCES	i-x
	APPENDICES	
	ABSTRACT	



## LIST OF TABLES

<b>Table No.</b>	<b>Title</b>	<b>Page. No.</b>
3.1	Instrumentation for measuring important physico-mechanical parameters	41
3.2	Dimensional specifications of the ladder	75
3.3	Specifications of the rope	77
3.4	Design of the power source	80
3.5	Design of the winch mechanism	81
3.6	Specification of the trolley	91
3.7	Properties of aluminum alloy grade 6061 and AISI mild carbon steel	95
4.1	Classification of coconut palm based on the inclination angle	109
4.2	Theoretical indenter area for three different tools at various depths	120
4.3	Average value of hardness at different depth of coconut palm trunk measured with different tool with multiple comparisons	121
4.4	Important features of the popular coconut climbing devices	129
4.5	Specification of components of developed coconut palm climber	132
4.6	Performance evaluation of coconut palm climber with and without load	137



## LIST OF FIGURES

<b>Fig. No</b>	<b>Title</b>	<b>Page. No</b>
2.1	Cross sectional view of Coconut wood	9
2.2	A man and a trained monkey climbing a coconut tree in Malaysia to harvest coconut	13
2.3	Coconut harvesting using pole and knife	14
2.4	Coconut harvesting using straps	14
2.5	Coconut harvesting using bamboo pole with steps	14
2.6	(a) Front foot technique (b) Frog foot technique	15
2.7	Palm climbing apparatus - Horace model	17
2.8	Hang on type palm climbing aid - William Model	18
2.9	Climbing palm stand –Morris model	18
2.10	Joseph model standing type coconut climbing device	19
2.11	Chemberi model coconut climbing device	20
2.12	Standing type climbing device- Joy Varghese	20
2.13	TNAU model climbing device	22
2.14	Multi tree climber	23
2.15	CPCRI model coconut tree climbing device	23
2.16	KAU Coconut Palm Climber	24
2.17	KAU Kera Suraksha coconut climber	25
2.18	Modified coconut climbing device	26
2.19	JAU model	26
2.20	Tractor mounted and self-propelled coconut climber for coconut harvesting	28
2.21	Man carrying bike developed by M/s Mabens Engineering Solutions, Shimoga	28
2.22	Treebot	29
2.23	Top view and front view of harvesting device	29
2.24	Automated coconut tree climbing device	31
2.25	Pneumatic coconut tree climber and harvester	31
2.26	Amaran	32
3.1	Cross section of coconut wood showing different density zones	44
3.2	Schematic Density Distribution in Mature Coconut	46
3.3	Components of the tree hardness tester	47





<b>LIST OF FIGURES (contd.)</b>		
3.4	Holding jaws with support ring	48
3.5	Load cell with digital indicator	51
3.6	Dial type depth gauge	51
3.7	Height measurement using hypsometer	52
3.8	Variation in diameter while moving upwards	54
3.9	Measurement of physical properties of coconut palm	56
3.10	Measurement of angle of tilt	57
3.11	Chemberi model coconut climbing device	62
3.12	TNAU model coconut climbing device	63
3.13	CPCRI model coconut climbing device	65
3.14	KAU coconut climbing device	65
3.15	Parts of KAU Kera Suraksha coconut climbing device	67
3.16	Chachoos Maramkeri	68
3.17	Engine operated coconut climbing device	69
3.18	Layout of conceptual design and sub systems	72
3.19	Extension ladder	74
3.20	Cross sectional view of W shaped rung	76
3.21	Cross sectional view of 18 X 7 steel wire rope	77
3.22	Human basket with guard rail	89
3.23	Worm gear with rope guides	91
3.24	Isometric view of transport aid with tilting and directional control unit	92
3.25	Transport aid with mounting fixture	93
3.26	Power transmission of the developed coconut climbing device	94
3.27	Top view of the coconut climbing device	102
3.28	Side view of the coconut climbing device	102
3.29	Front view of the coconut climbing device	103
4.1	Pictorial representation of inclination categories	110
4.2	Isometric view of Tree Hardness Tester	110
4.3	Percentage distribution of the heights of tall coconut palm varieties	112
4.4	Percentage distribution of the heights of dwarf coconut palm varieties	113



<b>LIST OF FIGURES (contd.)</b>		
4.5	Percentage distribution of girth of coconut palms at three different positions in Malappuram district	114
4.6	Percentage distribution of girth of coconut palms at three different positions in Palakkad district	115
4.7	Percentage distribution of girth of coconut palms at three different positions in Thrissur district.	116
4.8	Percentage distribution of crown width of coconut palms	117
4.9	Percentage distribution of number of leaves on coconut palm	118
4.10	Categorical frequency distribution of coconut palm inclination	119
4.11	Hardness of coconut palm trunk measured using different tools at different depths	122
4.12	Violin plot of hardness using different indenter tools at different penetration depths	123
4.13	Allometric relation between Crown Width (CrW) and Diameter at Breast Height (DBH)	125
4.14	Allometric relation between Height (Ht) and Diameter at Breast Height (DBH)	127
4.15	Isometric view of developed coconut climbing device	133
4.16	Total deformation of ladder	134
4.17	Equivalent stress of ladder	135
4.18	Total deformation of mounting fixture	136
4.19	Equivalent stress of mounting fixture	136
4.20	Time for ascending and descending for 12 m palm with and without load	138
4.21	Change in speed of palm climber with load	139



## LIST OF PLATES

<b>Plate. No</b>	<b>Title</b>	<b>Page. No</b>
3.1	Hypsometer (Nikon forestry pro Laser range finder)	42
3.2	Haglof Sweden Mantax Black caliper	43
3.3	Developed inclinometer	44
3.4	Sphere, Wedge and Square shaped tools	49
3.5	Tree height measurement using Hypsometer	53
3.6	Inclination measurement of coconut palm using developed inclinometer	58
3.7	Laboratory set-up for calibration of tree hardness tester	59
3.8	Hardness measuring using developed instrument	59
3.9	Lab model of coconut climbing device	73
3.10	Winched electric motor	78
3.11	Wireless remote-control switch	78
3.12	Half ring with rollers	84
3.13	Ring with rubber bushes	84
3.14	Ring with wire rope	85
3.15	Ring with three rollers	85
3.16	Ring with five rollers	86
3.17	Modified ring with five rollers	86
3.18	Ring with seven rollers	87
3.19	(a) Safety harness (b) Helmet (c) Goggle	89
3.20	Coconut climbing device in transport condition	98
3.21	Coconut climbing device is raised	98
3.22	Direction control mechanism is used to rotate the ladder	98
3.23	The inclination of the climbing device is adjusted using titling control handle	99
3.24	Person can climb the first fly section of the ladder	99
3.25	Person can unlock and open the basket	100
3.26	Top fixture ring is closed and locked	100
3.27	Platform is elevated using the remote control	100
3.28	Maximum height is attained	101
3.29	The person can climb down after completing the operation	101
4.1	Tree Hardness Tester	111



### LIST OF APPENDICES

No.	Title
I	Measurement of height of coconut palms in different districts
II	Measurement of diameters (cm) at three levels of coconut palms in different districts
III	Measurement of girths at three levels of coconut palms in different districts
IV	Measurement of crown width and number of leaves of coconut palms in different districts
V	Measurement of inclination ( $^{\circ}$ ) of coconut palms in different districts
VI	Hardness of coconut palm using wedge shaped tool at four different depths
VII	Hardness of coconut palm using square shaped tool at four different depths
VIII	Hardness of coconut palm using sphere shaped tool at four different depths
IX	Performance of developed coconut climbing device with load
X	Performance of developed coconut climbing device without load
IX	Cost analysis of developed coconut palm climber





## SYMBOLS AND ABBREVIATIONS

%	: Percent
₹	: Rupees
∠	: Angle
°	: Degree
°C <sup>-1</sup>	: Per degree Celsius
3D	: Three dimensional
AICRP	: All India Coordinated Research Project
CDB	: Coconut Development Board
cm	: Centimeter
CPCRI	: Central Plantation Crops Research Institute
DBH	: Diameter at Breast Height
DC	: Direct Current
eg.	: Example
Eq	: Equation
<i>et al.</i> ,	: And others
etc.	: And other similar things
η	: Efficiency
FEA	: Finite Element Analysis
FEM	: Finite Element Method
Fig.	: Figure
FIM	: Farm Implements and Machinery
FMPE	: Farm Machinery and Power Engineering
g	: Acceleration due to gravity
GBH	: Girth at Breast Height



GI	: Galvanized Iron
GKVK	: Gandhi Krishi Vigyana Kendra,
GoI	: Government of India
ha	: hectare
hp	: Horse Power
Ht	: Height
ICAR	: Indian Council of Agricultural Research
ICC	: International Coconut Community
in	: Inch
InDG	: India Development Gateway
IPR	: Intellectual Property Rights
IRIMEE	: Indian Railway Institute of Mechanical & Electrical Engineering
J kg <sup>-1</sup> °C <sup>-1</sup>	: Joules Per Kilogram Per Degree Celsius
JAU	: Junagadh Agricultural University
KAU	: Kerala Agricultural University
KCAEFT	: Kelappaji College of Agricultural Engineering and Food Technology
KCAET	: Kelappaji College of Agricultural Engineering and Technology
kg	: Kilogram
kg m <sup>-3</sup>	: Kilogram per cubic meter
kg-f	: Kilogram force
kN	: Kilo Newton
KVK	: Krishi Vigyan Kendra
kW m <sup>-1</sup> °C <sup>-1</sup>	: Kilo watt per meter degree celsius
ln	: Natural log
m	: Meter
MegaPa	: Mega Pascal
mm <sup>-2</sup>	: Per millimeter square
mm <sup>2</sup>	: Millimeter square



m s <sup>-1</sup>	: Meter per second
MS	: Mild Steel
N	: Newton
n.d.	: No date
Nmm <sup>-2</sup>	: Newton per millimeter square
nos.	: Numbers
P	: Power
φ	: Phase
π	: Pi
PLA	: Polylactic acid
PVC	: Polyvinyl chloride
rpm	: Rotation Per Minute
RS	: Recommended Standard
Rs.	: Rupees
Rs/hr	: Rupees / hour
RTTC	: Research Testing and Training Centre
S	: Second
SS	: Stainless Steel
t	: Ton
TCIA	: Tree Care Industry Association
TMHE	: Tractor Mounted Hydraulic Elevator
TMSPCC	: Tractor Mounted and Self-Propelled Coconut Climber
TNAU	: Tamil Nadu Agricultural University
V	: Velocity
viz	: Namely
WLL	: Working Load Limit