Introduction

1. INTRODUCTION

The coconut palm (*Cocos nucifera L.*) is a versatile tree that thrives in tropical and subtropical regions around the world. It is known as the "tree of life" (Newport, 2018) due to the multitude of products and resources it provides and is considered as a remunerative crop (Mathew, 1986). Coconut cultivation is not only economically beneficial (Beveridge *et.al.,* 2022) but also provides livelihoods (Kumar and Kunhamu,2022) for millions of people worldwide. It supports small-scale farmers, laborers involved in harvesting and processing, as well as traders and exporters in the coconut industry.

The global cultivation area for coconuts spans approximately 12 million ha. India is a leading producer of coconuts worldwide, consistently ranking at the top in both production and productivity. India stands first in production and accounted for approximately 31.45 % of the world's total coconut production, with an output of around 19,310 million nuts (ICC, 2021).

It is a multipurpose perennial palm widely grown in the coastal zones of India (Pham, 2016). It strengthens the economy and is a source of income for 10 million families (Abraham, 2014). The average national productivity of coconuts is estimated to be around 64 nuts per palm per year (Niral et al., 2019). The total area of cultivation in India has increased from 10.83 lakh hectares in 1980-81 to 22.77 lakh ha in 2022-23 (CDB, 2023).

It is grown in almost all homesteads in the state of Kerala. Predominantly, it is grown in small and marginal holdings. It is the second most important crop next to paddy in the state and has the largest area under the crop with 8.09 lakh ha which is 41.6% of national acreage (CDB 2020). Kerala tops in terms of coconut production (Thamban *et al.,* 2016) with a total yield of 5,921 million nuts per year.

However, productivity was lesser compared to other states like Andhra Pradesh and Tamil Nadu (Preethi *et al*., 2018). The state, with production of 6,990 coconuts per hectare, stands 5th in terms of productivity among coconut producing states. During 2020-21, Kerala's coconut production accounted for 3,307.78 t. As a result, the state achieved a market share of 24.22% in India. Kerala alone contributes to 45% of India's coconuts production (CDB, 2023).

Coconut climbers form a vital link in the production chain of coconut cultivation. Climbing the palms has long been a concern for farmers. From an economic and social point of view, it is exceptionally challenging. Harvesting methods may differ from countries to countries, or even within the country itself. The two most common conventional types of harvesting the nuts are climbing methods and using a pole. In some countries like Papua New Guinea, the coconuts are left on the palm to fall to the ground and collected thereafter. (Tetrapak, 2016). In some regions, steps or notches are carved on the palm trunk for easy climbing and harvesting (Manoharan and Megalingam, 2019).

The traditional method adopted for harvesting is manual climbing using muscle power and cutting with a knife which is considered as a perilous operation (Kerure *et al.,* 2016). The only aid used is a coir loop (straps) to hold the tree. By fixing the legs through the loops and tightening, one can press against the palm trunk and climb up the tree. Additional loops for hands can also be used if necessary. Since this method involves real hard physical exertion, youth labourers are losing interest with potentially harsh implications for palm cultivation. This leads the farmers in many locations to rely on migrant labourers, who demand high charges while having little experience in coconut climbing. Due to this labour shortage, harvesting cycles are disrupted, resulting in a loss of income for producers.

Regular harvesting schedule is ineluctable for the consistent availability of raw nuts in the market as well as in the production sector. As against the general norm of harvesting cycles of 45-60 days, farmers are currently forced to harvest only once in three to four months (CDB, 2022). Also, another threat when regular harvesting is not done is 'falling nuts', which is very hazardous in fields like home gardens, beaches or parks where people spend time (Chan and Elevitch, 2006).

Manual climbing of coconut palms and harvesting the nuts has been recognized as the most tedious task which requires special skill. Traditional palm climbers are becoming very rare nowadays. The art of tree climbing has lost its luster over time, and finding such expert climbers has become increasingly difficult. Lack of such skilled labours, reluctance of youth to consider coconut harvesting as a job carrier, high chances of health disorders, unavailability of proper mechanical climbing devices are some of the reasons behind this. Besides all these, the physical structure of the tree trunk (stipe) as a straight pole (Manoharan and Megalingam, 2019) unlike other trees also impart to the difficulties in climbing.

Various types of climbing devices have been developed and some of them are becoming popular among common people. Standing type and sitting type are the main categories of climbing devices available in the Indian market so far (Jahan *et al*, 2018). But one of the main disadvantages which the farmers quoted was their inaccurate performance while climbing on slanting trees and the majority of the coconut trees of south coastal India belong to this type (Bincy *et al*., 2012). Moreover, complicated designs of some existing climbers, weight of equipment, their cost, need of prior experience etc. makes the climbing devices less accepted by the farmers (Mathew and Krishnan, 2015)

The most popular and widely used climbing device in Kerala is a standing type climber, known as Joseph Model or Chemberi model. This easy-to-use

climbing device has gained much acceptance among the climbers. However, the main constraint is that the continuous use of this model has been associated with physical strain, often leading to musculoskeletal disorders, joint pain, and fatigue. These health issues are particularly common among regular climbers who rely on the device for their livelihood. Additionally, the risk factor associated with its use significantly increases with the height of the palm, making it more challenging when dealing with tall trees. Despite its popularity, these drawbacks highlight the urgent need for ergonomic improvements or alternative climbing technologies to ensure the safety and long-term health of coconut climbers (Sam *et al.,* 2019).

Unmanned automatic/robotic climbers for harvesting coconuts were developed in some places, but these are not adequate for many other operations other than harvesting, such as Neera tapping, spraying plant protection formulations, harvesting tender coconuts without damage etc. Another advantage of climbing the palm is that it allows the harvester to clean and inspect the crown for pest and disease attack (FAO, 2022). Also, the structure of coconut leaves makes it more difficult for the unmanned climbers to harvest the nuts from the tree. Usually, leaves are seen crowded together along with the spathe and inflorescence at the top of the palm trunk; which forms a crown (TNAU, 2022). All these operations require a person to climb to the top of the trunk. This ensures the importance of a manned climbing device.

The physical and mechanical properties of the coconut palm play a crucial role in the design and development of effective palm climbing devices. One of the key characteristics is the variation in trunk girth along the height of the palm. Except in trees with structural deformities, the base girth of the coconut palm is generally larger than the mid and top girths. These variations in girth, along with the overall height of the palm, are critical factors in determining the dimensions and adaptability of the climbing device (Manoharan and Megalingam, 2019).

In addition to girth, other parameters such as palm height and trunk inclination vary significantly. These variations influence the design and stability requirements of climbing mechanisms. Furthermore, the hardness of the trunk, which represents its resistance to deformation and impact, is an important mechanical property. It indicates the palm's ability to withstand the forces exerted by climbing devices during ascent and descent (Rana et al., 2015). Understanding these properties is essential for designing safer, more ergonomic and efficient climbing solutions tailored to different growing conditions and palm types.

Introduction of climbing devices for palms are one of the distinctive innovations in the agricultural field. It helps to reduce harvesting losses and improves the working conditions for farmers in this field. So, developing a self-rising type coconut palm climber which can reduce human effort will be a needful intervention. Keeping all this in consideration, the study entitled “investigations on physico-mechanical properties of coconut palm for the design and development of a coconut palm climber” has been outlined with the following objectives.

Objectives

- To study the mechanical and physical properties of coconut palm which influence manual/mechanical climbing.
- To study the features of the existing manual/mechanical coconut palm climbers.
- To design and develop suitable instrumentations for measuring certain physico-mechanical properties of coconut palm.
- To design, develop and evaluate the performance of a mechanical coconut palm climber.