Development and testing of tree climbing and harvesting device for mango and coconut trees

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Abstract

The tractor mounted hydraulic elevator (TMHE) powered by tractor P.T.O. was developed and tested for mechanical harvesting of mango and coconuts . The biometric parameters of tree like height, crown, average yield etc of coconuts and mango were considered for the development of TMHE. The TMHE is designed and developed by considering the engineering product development cycle aspects. Accordingly, the different machine components are fabricated and assembled together at Dr. B.S. Konkan Krishi Vidyapeeth Dapoli. The exhaustive field-testing of TMHE on mango and coconut orchard is conducted on plain and sloppy land upto 20.5 per cent slope on University and farmers field. The comparative study of manual and mechanical coconut harvesting has been conducted. The cost of TMHE is Rs 1, 50,000 (Rupees one lakh fifty thousand) only and can be used for tree spraying and tree pruning apart from fruit harvesting operations. The TMHE can be operated upto 20.5 per cent slope. The observed field capacity of the developed TMHE is 2800 mango (700 kg) per day and 4,524 coconuts/ day for mango and coconut orchard respectively.

The hydraulic elevator is suitable for fruit harvesting, tree pruning, and tree spraying operations. The hydraulic elevator is suitable for harvesting of mango and coconut orchard upto 15 meter and pruning of tree upto 10 meters height

Introduction

The area and production of horticultural fruits in Maharashtra state till 2006-07 is 73000 ha. Konkan region is the narrow strip of 40 km width and running 750 kms of length from north to south is a hilly terrain lying between Sahyadri ranges in the east and Arabian Sea in the west. The production of coconut in India is15.84 billion nuts (2006-2007), however Maharashtra state produces 273 million nuts. The Konkan region is indicated 15°36' to 20°21' North latitude and 7°7' to 74°13' east longitude on the world map. The region is comprised of four districts viz. Thane, Raigad, Ratnagiri and Sindhudurg. The hilly terrain receives heavy rainfall ranging from 2000-4000 mm per annum. The climate is hot and humid almost throughout the year. The climatic conditions are suitable for growing various fruit crops. The total geographical area of the region is 29.5 lakh hectares, out of which 9.5 lakh hectares have been brought under cultivation of different crops. Land under forest is 5.54 lakh hectares, barren and cultivable land is 5.34 lakh hectares, land put to non-

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agricultural uses is 1.93 lakh hectares, cultivable waste land is 3.85 lakh hectares, permanent pastures and other grazing land is 1.19 lakh hectare and land under miscellaneous crops is 0.47, fallow land - 3.08 lakh hectare and net sown area is 8.39 lakh hectares.

Konkan region is well known for producing the horticultural fruits like mango, sapota, coconut, cashew, kokum, etc. However, these horticultural fruits like mango (Alphonso variety) and coconut (Tall /Dwarf varieties) are preferred in many European and USA market because of their better taste and more uniformity. The manual harvesting of these fruits is tedious and time consuming. During peak season, it is very difficult to get required number of skilled labours. Moreover, skilled labourers for climbing on coconut are reducing day by day because of the drudgery involved in this operation. Manually operated tree climbers developed during 1980s have some operational problems and safety limitation for coconut trees. However, it requires adequate skill and training. It is observed that manual climbing device operated by a skilled labourer, takes more time. An inertia type limb shaker, hydraulically powered and driven by tractor power take off was used for mechanical harvesting of pistachio nuts (Polat *et al.* 2007). Manually operated low capacity gadgets are time consuming, tedious and damaging to tree branches. The fruits should not be allowed to fall on the ground as the injured fruits cause spoilage to other healthy fruits during packaging and storage. In Gujarat in the state of India, about 382000 tones of mango are produced annually from an area of 57 000 hectare (Gupta *et al.* 2000). Fruits harvested with 8-10 mm long stalks appear better on ripening as undesired spots on the skin caused by sap burn are prevented. Such fruits are less prone to stem-end and other storage diseases (Sapovadia *et. al.* 2001).

Harvesting of coconuts in India is mostly done manually by means of curved knife, pair of scissors or blades attached to a hanging basket to the distal end of bamboo sticks (Devnani, 1980). In countries where there is shortage of skilled labour the nuts are not harvested and allowed to fall and the fallen nuts are collected from the ground at intervals (Thampan, 1983). In Srilanka, harvesting of coconut is done from the ground with the help of a knife attached to a long bamboo pole. Coconut harvesting by this device is very difficult for taller trees. The Tractor mounted hydraulic elevator for the horticultural fruits was designed and developed for the harvesting, spraying and pruning of horticultural fruit trees (Kolhe and Dhande, 2008).

Material and methods

The TMHE was designed by following the product design cycle as shown in fig 1. The design is conceptualized by considering farmers needs and available equipments in the market as input and the final design as output product by following the concepts of engineering like product concept, design engineering, drafting, process planning, production scheduling, quality control etc. The physical features of orchard tree where this machine is to be used are given in table 1.

Table 1 Physical parameter of tree for development of TMHE

Tree details	Mango	Coconut
Variety	Alphonso	T\D
Spacing between two trees (m)	10	7.5
Tree Height (avg. of ten replications) (m)	10	15
Tree Canopy radius (avg. of ten replications) (m)	3	2
Tree Age, (avg. of ten replications) (year)	25	12
Number of fruits / tree	250	100

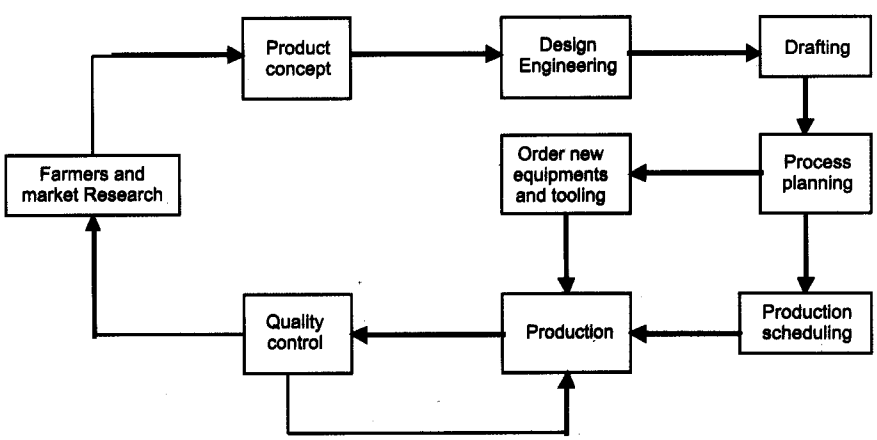


Fig 1. Block diagram product design cycle for development of TMHE

Design Procedure

The TMHE is designed by studying the biometric parameters of the horticultural trees. The total height of lifting mechanism is finalized considering the height of the trees upto 12.20 m. The lengths of lower and upper links are fixed 4.m and 4.50 m respectively. The experimental load lifting capacity of the tractor mounted hydraulic elevator is 5,886 N (Newtons) including the live and dead lot. However the theoretical load lifting capacity of the elevator is 9810 N. The factor of safety is1.6, which indicates the safe operation. The line diagram of line of TMHE is shown in fig. 2

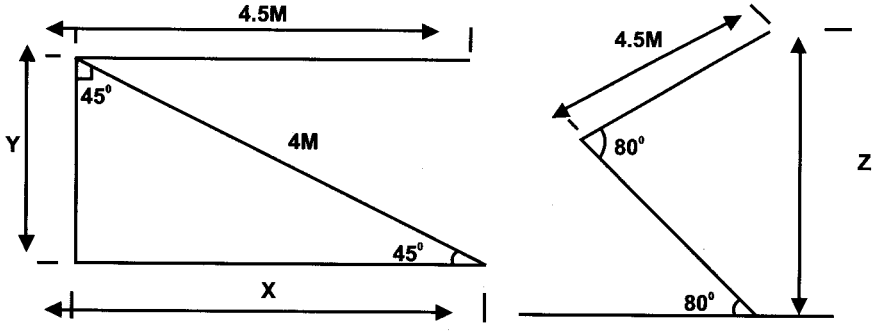


Fig 2. The line diagram of link of Hydraulic elevator

Development of TMHE

The turntable of the elevator is mounted on the three-point linkage of the tractor. The equipment comprises of a hydraulic pump, hydraulic motor, a tank, flow control valve, hydraulic cylinder, direction control valve, the harvesting link and the harvesting bucket. The hydraulic pump is driven by tractor PTO. The oil is pumped to the cylinder 1 and cylinder 2; however one end of the cylinder is attached to the turntable and other end to the lower link AB. The one end of cylinder 2 is connected to the link AB and its second end is attached to the link CD. The flow of oil for both the cylinder is controlled by the direction control valve. The oil is pumped by hydraulic motor to lift the two links. The up-down motion upto 15 m height and the rotary motion upto 360^0 (180^0 in each direction)is provided to the link AB, CD and the turn table. The machine was comfortably used for harvesting mango fruits upto 15 m height (ground clearance 1 m + maximum reach of elevator 7.80 m + operator reach 2 m + reach of mango harvester 3.20 m). The design permits 360^0 rotation of the elevator link about its longitudinal axis. The link absorbs some reactive force of the elevator without causing excessive vibration of the link when the elevator is in operation. The link and the turntable action is controlled by the valve and its pressure on the link is controlled by an adjustable relief valve. The material for the above fabrication work, is as per ASTM specifications and metal joining process are selected according to the thickness of the metal plate to be joined (Kolhe and Datta 2007). The Tractor mounted hydraulic elevator is used for mechanical harvesting of mango and coconut trees. The experiments were conducted to decide on the maximum load capacity of the elevator and maximum reach position to lift the load. The research was conducted on mango trees and coconut trees at University farm of Alphonso and T/D variety respectively. The testing was held in April and May 2008 for mango tree and during February and March 2009 for coconut trees.

The supporting wheel of 30 cm diameter, 4 cm width and 6 mm thickness is designed and developed for the better stability of tractor-mounted elevator in field, as shown in figure 4. The total live load of TMHE in operating condition is balanced by the supporting wheel. The wheel is designed in such a way that the position of this wheel can be easily adjusted in sloppy land. During field-testing of the machine these modifications resulted into better stability of the elevator. A

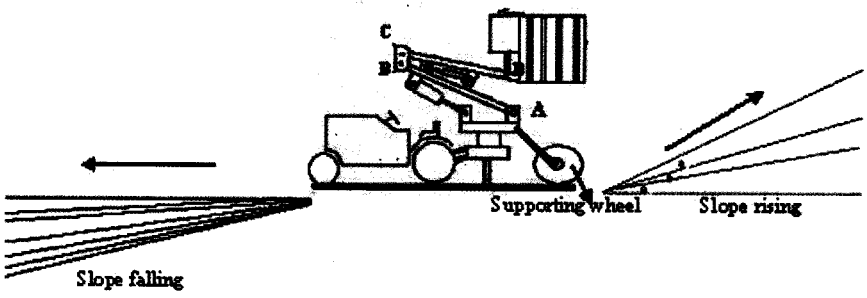


Fig.4 Safe slope for tractor mounted Elevator for operation on field condition

maximum load of 600 kg can be placed in harvesting bucket in maximum reach position without affecting the tractor stability. The slope of land was measured by using level tube at various locations.

Results and Discussion

Table 2 presents the biometric parameter of coconut tree, the maximum and minimum height and stem girth noted for the coconut (T/D) variety are 640 cm, 1080 cm and 77 cm, 126 cm respectively. Significant relation is observed between the tree height and stem girth of coconut trees. The different coconut distribution and coconut maturity time for tree to tree for the same age group tree are noted. These changes in biometric parameters are due to the soil condition, fertilizers and water distribution for the tree and uneven atmospheric condition. The results of the hydraulic elevator for mango and coconut harvesting are shown in table 3. It is observed from figure 5, that the harvesting time and the number of coconuts harvested for different trees varies from tree to tree. Hence there is no significant relation between the harvesting time, harvested nut and tree height for the coconut tree due to variations in fruit maturity period, number of nut, and tree height varying from tree to tree. It is observed that the maximum time needed for harvesting coconut by traditional method is for climbing up and down the tree whereas TMHE reduces this time as presented in fig. 6. From figure 6, it is observed that the net coconut harvesting time is the sum of climbing up time (CUP time) and climbing down time (CDT). Nevertheless, the net coconut harvesting time is depending upon

Table 2. Biometric parameters and Machine performance of coconut orchards

Tree No	Biometric parameters				Machine performance		
	HOT, m	SG, Cm	C D, Cm	HST, min	HCT min	TRHmin	CHPT
54	7.50	96	8.90	8.45	8.50	5	10
55	6.70	89.5	9.10	8.50	8.55	5	39
56	8.40	101.5	9.70	8.55	8.60	5	23
89	6.30	115.5	10.60	8.60	8.62	2	5
90	8.90	99.5	9.30	8.63	8.65	2	14
161	8.0	106	9.90	9.13	9.14	1	11
162	7.30	108.5	8.30	9.14	9.15	1	22
163	7.40	116	10.60	9.16	9.19	3	31
164	7.20	88	9.20	9.19	9.22	5	34
197	7.20	92	8.20	9.25	9.26	1	12
200	6.5	77	8.90	9.28	9.30	2	2
233	7.80	91	9.30	9.31	9.33	2	17
234	7.30	126.5	9.10	9.34	9.35	1	20
235	6.40	97.5	10.10	9.38	9.39	1	2
236	10.20	103	11.20	9.39	9.40	1	12
269	7.90	98	9.30	10.32	10.37	5	12
270	9.10	115.5	10.10	10.37	10.40	3	19
271	9.45	121.5	9.90	10.41	10.45	4	27
272	10.80	101	8.60	10.45	10.48	3	5
306	8.10	99	9.60	10.49	10.52	3	16

HST : Hydraulic start time; HCT : Hydraulic close time; NHT : Net harvested time; TRH : Time requires to harvest; NH : Nut harvested; CHPT : Coconut harvested per tree, HOT : Height of tree; SG : Stem girth

Table 3. Performance of the hydraulic elevator for mango and coconut harvesting (avg. of three replications)

Particulars	Mango	Coconut
Period of trials, day	1	1
Number of fruit harvested, hr	350	377
Number of fruit harvested, per day	2800	4,524
Weight of fruit harvested, kg/hr	87.5	—
Capacity of Hydraulic elevator, kg/day.	700	—
Capacity of hydraulic elevator No. per day.	2800	4,524

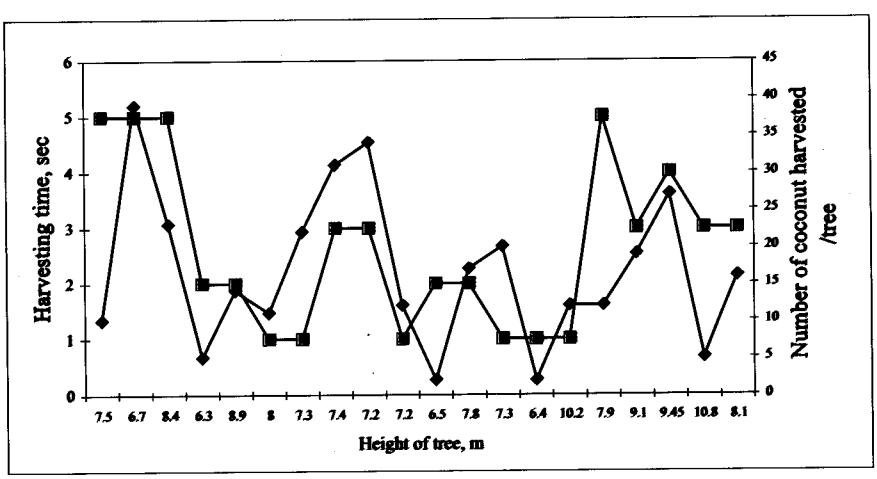
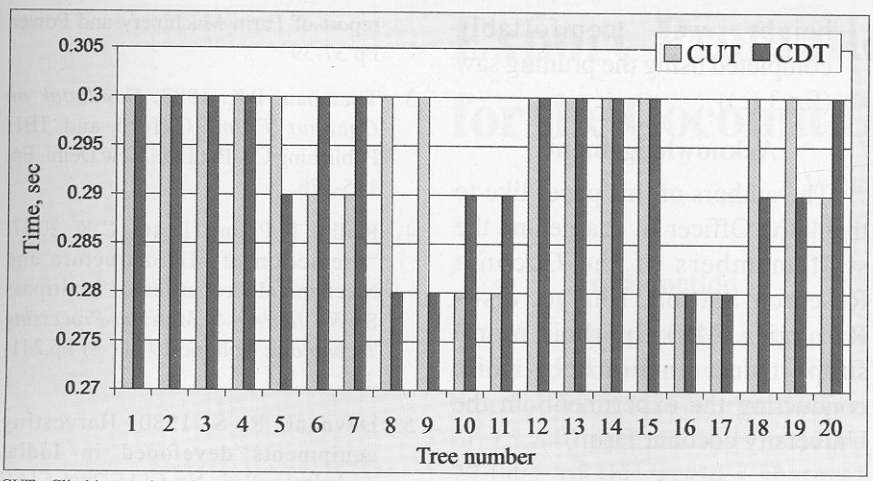


Fig. 5. Influence of tree height on harvesting time and number of coconut harvested



CUT : Climbing up time; CDT : Climbing down time;

Fig. 6. Influence of Tree number on CUT and CDT

the actual nut harvesting time only. The TMHE can be economically and piously used for harvesting coconut and other orchard fruits on time and it is possible to cover one hectare in one day. Hence the TMHE is very useful to the farmer's community for coconut harvesting.

The TMHE is tested on field at various slopes for checking the stability of the elevator on hilly region. It is observed that this TMHE can be safely used upto 12 per cent slop in forward direction for more than 12 per cent tools operated in reverse direction need to use this tractor-mounted elevator for a slope, upto 12 per cent forward direction. After 12 per cent slope it is recommended to operate the tractor-mounted elevator in reverse direction.

(a) Coconut harvesting

(C) Tree pruning

(b) Mango harvesting

Fig.3(a,b,c). Tractor mounted hydraulic elevator used for harvesting and pruning operations

Performance of machine on slope

The machine performance including hydraulic start time, hydraulic close time, time required to harvest coconut and number of coconut harvested per tree is shown in table 2. From table 3, the number of coconut harvested per hour is 377 coconuts per hour. About 13 coconut tree are comfortably harvested by using this TMHE in one hour. The hydraulic elevator can be comfortably operated on plane land. The performance of machine on sloppy land was tested at different slopes ranging from 2.6 per cent to 20.5 per cent. Beyond 12 per cent slope, instability was observed i.e. front lifting of tractor. Hence beyond 12 per cent slope of land, the elevator was operated in reverse direction. It was comfortably operated in reverse direction upto 20.5 per cent slope. Hence machine should be operated on the sloppy land up to 12 per cent slope in forward direction and for 12- 20.5 per cent in reverse direction.

Field performance of the machine

i) Fruit harvesting: -The hydraulic elevator was evaluated for harvesting the mango and coconut from trees. The details of the results are shown in table 2. The machine was comfortably used for harvesting the mango fruits upto 15 m height (Ground clearance 1 m + maximum reach of elevator 7.80 m. + operator reach 2 m. + reach of harvester 3.20 m.) (Refer fig.3 (a,b))

ii) Tree pruning: - The hydraulic elevator was used for pruning of suru trees. It was observed that pruning operation upto 10 m. height was comfortably completed using the pruning saw (fig.3 (c))

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Conclusion

1. The hydraulic elevator is suitable for fruit harvesting, tree pruning, and tree spraying operations.
2. The hydraulic elevator is suitable for harvesting of mango and coconut orchard upto 15 meter and pruning of tree upto 10 meters height
3. The hydraulic elevator is suitable for operation on plain field as well as hilly terrain having slope upto 20.5 per cent.

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