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Design and Development of Ground Collection System for Neem Fruit

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

India is one of the leading producers of neem in the world. But still, there is no mechanical system available for either harvesting the neem fruits from the tree or collecting the neem fruits from the ground. Also, the manual ground collection of neem fruit is a very laborious and time-consuming operation. The cost of ground collection of neem fruit is higher than its selling price which makes neem plantation uneconomical. The introduction of a collection system for collecting the neem fruit from the ground may represent the technological change that is the key factor for improved competitiveness. The main purpose of this work was to develop ground collection system based on the principle of suction. The design of the machinery was based on a determination of fruit geometry and its physical and engineering properties. The proposed innovation enabled a fully mechanical solution for collecting the fallen neem fruit from the ground, achieving a collection capacity of approximately 10 kg.h^{-1} with a collection efficiency of over 90%.

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1. INTRODUCTION

Neem (*Azadirachta indica*), the *"wonder tree"*, belonging to the meliaceae family is one of the most suitable, valuable and versatile tree species found in the Indian sub-continent [1,2]. "India is one of the leading producers of Neem in the world by producing 4.4 lakh tonnes of Neem yielding 88,440 tonnes of oil and 3.5 lakh tonnes of cake annually and globally" [3]. "In India, it occurs throughout the larger parts of the country and majorly in the states of Uttar Pradesh, Bihar, West Bengal, Orissa, Delhi, Maharashtra, Gujarat, Andhra Pradesh and Tamil Nadu" [4]. Generally, Neem trees are often found growing scattered in the farmers' fields and on the boundaries of fields without affecting the crops. Farmers practice this system just to meet the local demand for timber, fodder, fuelwood and also for various medicinal properties. Due to its deep tap root system, it does not compete with other annual crops.

"The flowering season of neem varies from place to place. Generally, it flowers from January to May and the ripening time of fruits is from May to August" [5]. "Neem starts bearing fruits after 5 years and comes to full bearing at the age of 10-12 years" [6]. "In the initial years, fruit yield is 5-20 kg per tree per year. A mature tree produces 35-50 kg of fruit per year [7]. Oil yield varies from 40-43% of seed on dry weight basis" [8]. "It has been estimated that India's Neem production was about 3.5 million tonnes of kernels every year. From this, about 7 lakh tonnes of oil might be recovered" [9].

In recent years, various alternative attempts have been made to mechanize the harvest of neem fruit, but no satisfactory results had been obtained. Recently, olive fruit combing devices has been tried by a few farmers for the harvesting of neem fruit but the main disadvantage brought up was that they also pluck out the leaves with the fruit which in turn requires additional operation and human for the separation of neem leaves from the fruit.

At present, there is no mechanical system available for either harvesting the neem fruits from the tree or collecting the neem fruits from the ground. The ripened fruits fall on the ground on their own and are collected manually by the women laborers [10]. But, the manual ground collection of neem fruit is laborious and time-consuming operation [3]. A women labour can collect up to 10-15 kg per day at the labour wages of □250 per day. The cost of operation for the collection of neem fruit from the ground is □30 per kg whereas the selling price of the neem fruits is only □25 per kg which makes it uneconomical and a loss for the growers [9].

Thus, the cost of collecting the neem fruits from the ground is very high and it threatens the future of neem plantations, also whose conversion to other more modern layouts is not always possible due to several limitations. The introduction of a collection system for collecting the neem fruit from the ground may represent the technological change that is the key factor for improved competitiveness.

2. MATERIALS AND METHODS

2.1 Conceptual Framework

The conventional method of harvesting neem is still widely practiced by most of the farmers. The practice includes hand picking of fallen fruits, cleaning and finally bagging. All the aforementioned tasks are accomplished manually, which takes too much time and energy. In order to replace manual bagging and collection of neem from the ground, this study was carried out by looking at the existing designs of different pneumatically operated machines from developed, emerging and developing countries. Based on the findings, it was decided to adopt, adapt and simplify the good characteristics of the existing designs in order to create the prototype machine. Design criteria that satisfy the local environment were identified based on the accessibility of machine parts and components in the local market. A conceptual drawing was created based on the design specifications and design data. The functional requirements of conceptual frame work is furnished in Table 1.

Table 1. Conceptual frame work of the study

Input	• Relevant information gathered on existing design of pneumatically operated suction machines, • Neem fruit characteristics and • Availability of machine parts and components
Process	• Design conceptualization, calculations and design plan of the machine • Fabrication of prototype.
Output	• Mobile engine-driven Neem fruit collector • Operating characteristics of the machine

2.2 Properties of Neem fruit

The physical and aerodynamic properties of Neem fruit that influences the development of ground collection system for Neem fruits have been studied.

2.2.1 Physical property

Some physical properties required for the designing of the prototype had been determined and referred from the previous studies, which encompass the size, weight of a hundred neem fruit (Fig. 1), bulk density and moisture content of the neem fruit [4].

2.2.2 Aerodynamic property

The terminal velocity was determined by an air column made up of a vertical wind tunnel of diameter 44.48 mm and a height of 600 mm (Fig 2(a)). A digital anemometer (Make:Lutron Model:AM-4201) was used to determine the air speed (Fig 2(b)). A sample of the neem fruit was dropped into the air stream from the top of the air column and the air velocity was adjusted until the neem fruit came into a suspended state in the air stream [11]. The respective velocity ($m.s^{-1}$) near the location of the fruit suspension was measured with the help of the digital anemometer having an accuracy of $\pm 0.1 m.s^{-1}$. Measurement of the air velocity was replicated ten times [11].

2.3 Design of Major Components

Based on the findings of numerous studies and from the assessment of various commercially available pneumatic leaf and trash collectors, design requirements for the machine were synthesized. Some of the highlighted design requirements were: 1) the machine should efficiently collect neem fruits on levelled as well as undulated fields; 2) the machine should eliminate stones and leaves of the forage materials during suction of the neem fruit; 3) the machine should reduce drudgery and speed up collection; and 4) the machine should be of intermediate technology, made from local materials using local manufacturing technology, simple and safe to operate and maintain, functionally and structurally sound, and with minimal tooling [5]. The machine majorly consists of a trolley, prime mower, suction chamber with impeller, suction hose, storage bin, etc. The details of the design requirements of the components are as follows:

2.3.1 Engine

The calculation of the power requirement by the machine for the suction of neem fruit was based on the pressure and velocity of airflow [12].

Power consumption,

$$(KW) = \rho_{air} \, . \, Q_{air} \, . \, H_{air} \times 0.746/75 \qquad (1)$$

Where,

ρ_{air} = density of air, 1.293 $kg.m^{-3}$
Q_{air} = air flow rate, $m^3.sec^{-1}$
H_{air} = pressure head, m

Power consumption = 1.293 x 0.0729 x 837.46 x 0.746/75
= 0.8 KW

Since then, according to the requirements and market availability, 0.82 KW engine has been selected.

2.3.2 Impeller

The type of impeller selected for the study was a forward curved type as the pressure head generated by this type of impeller was found to be greater than the backward curve and radial type impellers [13]. The diameter of the impeller was 168 mm. It had been encased within the 180 mm housing all along. The selection of impeller design was based on the operation it had to perform and for the required suction purpose, forward curved impellers suit best [14]. The top view and isometric view of impeller are shown in Fig. 3(a) and 3(b).

Fig. 1. Weighing of 100 neem seed using digital weighing balance

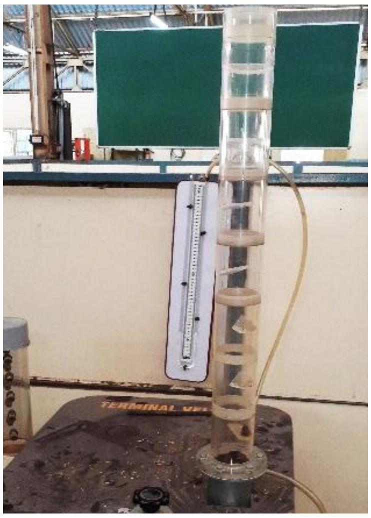


Fig. 2(a). Vertical wind tunnel

Fig. 2(b). Digital Anemometer

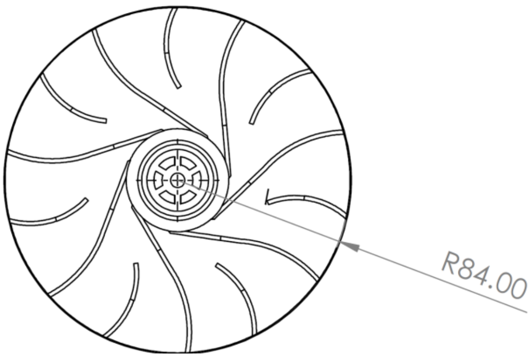


Fig. 3(a). Top view of impeller

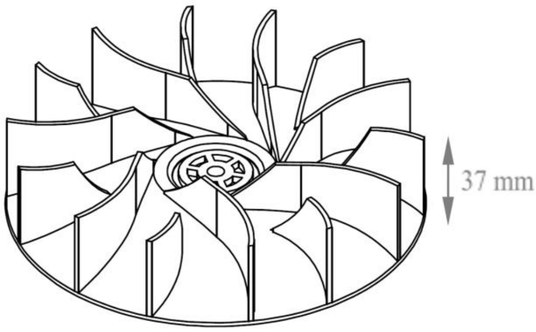


Fig. 3(b). Isometric view of impeller

2.3.3 Suction hose

A flexible Poly vinyl chloride material hose pipe of 80 mm in diameter has been selected for the machine. The pipe is having spiral reinforcement of copper wire, which provides strength and also aids it to sustain its shape during the action of suction pressure inside the pipe. It is tightened at both ends with the help of a GI clamp.

2.3.4 Suction nozzle

The design of the suction nozzle assembly was based on the Walinga design. The following design data were required: 1) the thickness of the fruit when spread on the ground, 2-3 cm [4]; 2) the diameter of the suction pipe, 80mm; and 3) anthropometric data such as knuckle-to-elbow length, elbow height, and hand grip diameter. The overall length of the suction nozzle assembly was determined using equation (2) [14].

$$\mathbf{z} = \frac{\mathbf{y + xCos\beta}}{\mathbf{Sin\theta}} \qquad (2)$$

Where z = Overall length, mm
y = Elbow height, mm
x = Knuckle-to-elbow length, mm
ß = Angle made by arm from the vertical, 110^{o}
θ = Angle made by the handle with horizontal, 45^{o}
Z = 200 mm

2.3.5 Storage bin

A plastic storage bin is placed in the trolley below the duct. The placement of the bin is such that it catches all the neem falling out of the shutter when it gets open. The storage bin was designed based on the density and working capacity of the machine. The volume and storage capacity can be determined by using equation (3) and equation (4).

Volume of Storage bin = Volume of truncated square pyramid

$$= (\mathbf{a^2 + ab + b^2})\frac{\mathbf{h}}{\mathbf{3}} \qquad (3)$$

where, a = 330 mm
b = 230 mm
h = 400 mm

Therefore, Volume = [330^2 + (330 x 230) + 230^2] 400/3

= 31693333.33 mm^2
= 0.0317m^3

The density of neem seed in an average is 360 $kg.m^{-3}$ [4].

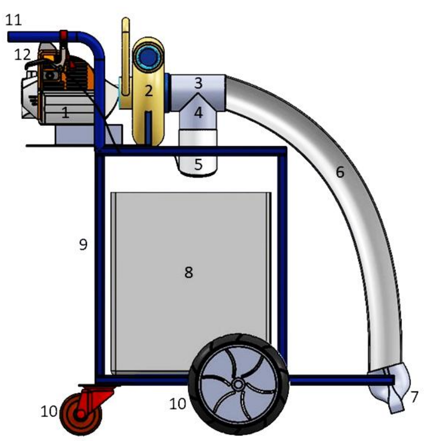
Therefore, the storage capacity of the bin can be estimated as:

Storage capacity = Volume of container x Density of Neem (4)

= 0.0317 m^3 x 360 $kg.m^{-3}$
= 11.412 kg ≈ 12 kg

Hence, based on the design requirements and market availability, the storage bin of size 330 x 330 x 400 mm with the volume of 12 kg was selected.

The final conceptual drawing of the prototype is shown in Fig 4.



Parts No.	Parts Name
1	Engine
2	Suction impeller with casing
3	Suction duct
4	Fruit Trapping duct
5	Shutter mechanism
6	Hose
7	Suction nozzle
8	Storage container
9	Frame with wheels
10	Wheels
11	Handle
12	Shutter Lever

Fig. 4. Conceptual drawing of the machine prototype

2.4 Development of Prototype

The developed prototype for the ground collection of neem fruit essentially consists of the following functional system:

2.4.1 Power transmission system

A 0.82 hp air cooled, single cylinder, two-stroke petrol engine was used as the prime mower for the Neem collector. The engine is directly connected to the impeller via a shaft of 10 mm in diameter which rotates the impeller at a speed of 2800 rpm. The engine was mounted on the bed provided at the top of the trolley using 4 mm diameter x 25 mm bolt.

2.4.2 Suction unit

A plastic forward curved type impeller with a casing was used in the suction blower of the machine. The 168 mm diameter impeller consists of 14 blades, comprising 7 small and 7 large blades cast at an angle of 30° from the centre. The blades were 37mm tall and rotated in a horizontal axis inside a 180 mm diameter casing. The suction orifice provided at the eye of the impeller was 110 mm diameter. Prior to the installation of the centrifugal impeller, a 10 mm diameter hole was drilled at the centre. Then, the impeller was tightened to the engine's grooved shaft with a 5 mm diameter nut and a washer.

2.4.3 Conveyance system

The conveyance system of the machine included a suction nozzle assembly, suction hose, outlet shutter and diverter assembly.

2.4.3.1 Suction nozzle assembly

The suction nozzle is an important device in the vacuum conveying system. The suction head was completely flat. A 16-gauge mild steel sheet was used in the fabrication of the rectangular suction nozzle head of 200 mm x 20 mm dimension. The suction nozzle assembly's downstream portion was made of 80 mm diameter mild steel pipe. A sieve with 25.4 mm of square mesh was placed inside the nozzle to allow the neem fruit to pass and restrict the bigger to mesh size material to enter inside the hose. The assembly was fixed on the elongated bottom side of the frame.

2.4.3.2 Suction hose

An 80 mm diameter, 500 mm long copper wire reinforced flexible plastic hose was used as a conveyance line from the suction nozzle assembly to the inlet of the diversion duct.

2.4.3.3 Diversion duct

A 110 mm diameter, T-shape poly vinyl chloride duct with shutter mechanism at the diversion exit, was used as the diversion unit. Inside the duct, a sieve of 10 mm square mesh at the impeller opening had been placed to retain the neem fruit and divert it towards the collection box. At the bottom exit of the collection duct, a lever-operated shutter mechanism has been provided to let out the sucked neem into the storage bin whereas the foreign materials of smaller size than neem fruit will pass the sieve and blow away through the blower end.

2.4.3.4 Outlet shutter

A lever-operated shutter mechanism made up of mild steel had been provided at the bottom exit of the diversion duct for arresting the vacuum generated in the duct, during the suction operation. Once the suction of the neem fruit below a neem tree gets completed, the shutter can be opened by the operator by pressing the lever provided at the right-side handle against the spring pressure, for letting out the sucked neem fruit. Once after releasing the lever, the shutter shuts off again due to the spring as well as suction pressure.

2.4.4 Storage section

The storage section below the diversion duct supports a plastic box for bagging neem during operation. It was fixed to the channel provided in the main frame. Hence, can be removed easily as and when required. The dimensions of the plastic container was 330 x 330 x 400 mm.

2.4.5 Supporting frame

The main frame was fabricated using 12 mm MS square pipe. A channel was also fabricated using a 12 mm MS flat bar for arresting the plastic container. On the top of the frame, a bed was provided for mounting the engine. In order to facilitate mobility, the overall structure was outfitted with one swivel caster rear wheel of 100 mm diameter, two solid rubber front wheels of 127 mm diameter, and push handles made out of metal pipe with a 12 mm diameter.

2.5 Cost Analysis

A cost analysis was done to determine the financial and economic indicators of the ground collection machine for neem fruit. The annual cost equation (5) by Hunt [15] was used in performing the simple cost analysis.

$$AC = FC + W(Vc)/C \qquad (5)$$

where: AC = Annual cost, $Rs.yr^{-1}$
FC = Fixed cost, $Rs.yr^{-1}$
W = Total weight of Neem seed, $kg.yr^{-1}$
Vc = Variable cost, $Rs.h^{-1}$
C = Collecting capacity, $kg.h^{-1}$

3. RESULTS AND DISCUSSION

3.1 Properties of Neem Seed

The physical properties required for the design of the prototype have been studied and referred to in the existing studies. The trials for obtaining the terminal velocity of the neem fruit have been carried out in the laboratory setup available in the Department of Farm Machinery and Power Engineering, Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore. The results obtained are tabulated in Table 2.

3.2 Description of Ground Collection Machine for Neem Fruit

A simple mobile engine-driven pneumatically operated ground collection system for neem fruit, was designed and fabricated for collecting of Neem fruit from the field. The mobile engine-driven pneumatic Neem collector had the following major components: power transmission system, suction unit, conveyance system, storage section and frame. The ground collection machine for Neem fruit and its operation are shown in Fig. 5(a) and Fig. 5(b) respectively. The specifications of the developed prototype are presented in Table 3.

Table 2. Properties of Neem Seed

S.No.	Properties	Value
1.	Size	
	1.1. Length	15 – 20 mm
	1.2. Geometric Mean Diameter	8 -12 mm
2.	Weight of 100 seeds	59 g
3.	Volume	4.55 - 4.57 mm^3
4.	Bulk Density	354.2 – 375.1 $kg.m^{-3}$
5.	Terminal Velocity	8.8 – 9.2 $m.s^{-1}$

Fig. 5(a). Ground collection machine for Neem fruit.

Fig. 5(b). Operational view of the ground collection machine for neem fruit

Table 3. Specification of the Ground collection machinery for Neem fruit

Components	Specifications
Overall Dimensions and weight	
Length x Width x Height	950 x 440 x 955 mm
Weight	20 kg
Suction Unit	
Type	Centrifugal
Overall Dimension	255 x 150 x 360 mm
Overall Weight	5.6 kg
Impeller :	
Type	Forward Curve
Dimension (Dia. x Width)	165 x 30 mm
Number of blades	14
Suction Side	
Shape	Circular
Diameter	120 mm
Material	Plastic
Suction Nozzle Assembly	
Type	Flat
Diameter of downstream side	80 mm
Dimension of pick-up side (L X W)	200 x 25 mm
Material	Mild Steel
Suction Line	
Type	Flexible hose
Size (Diameter x Length)	400 x 500 mm
Material	Vinyl Copper wire reinforced
Wheel	
Front:	
Type	Swivel caster wheel
Size (diameter X width)	127 mm X 50 mm
Material	Plastic
Number	2
Rear:	
Type	Solid Rubber wheel
Size	100mm X 50mm
Material	Rubber
Number	1
Prime mover	
Type (Stroke/Ignition)	2 stroke
Rated power	0.82 hp
Rated speed	2800 rpm
Cooling system Air cooled	Air-cooled
Starting system	Rope ranking
Dry weight	5 kg

3.3 Simple Cost Analysis

A simple cost analysis was conducted to guide potential users of possible benefit projections in using ground collection machinery for neem fruit. The machine is assumed to be utilized for 400 h per annum at eight hours of operation per day. A single operator is required to operate the machine. The collection capacity of the developed machine is 10 kg.h^{-1}.

The total cost of the machine was □ 30,000.00. The fixed cost for collecting neem fruit using the machine annually was □ 26.60 per hour while the variable cost was □ 51,169. The cost of collecting neem seed using the designed machine was □ 2.55.kg^{-1} whereas the cost of neem fruit collection in conventional method was □30 kg^{-1}.

The break-even point was 127 kg.yr^{-1}. Utilizing the machine for 400 hours per year will generate an income of □10,980 yr^{-1}. The projected time (based on 10 kg.h^{-1} collecting capacity) needed to recover the cost of the machine was 3.64 years.

4. CONCLUSION

This study was conducted to design, develop and evaluate the ground collection system for neem fruit. It attempted to mechanise the process of collecting neem fruit from the ground, and it addresses the issue to the greatest extent possible.

The ground collection machinery for neem fruit had the following major components: power transmission system, suction unit, conveyance system, storage section, and frame. The estimated collection capacity of the machine was 10 kg.hr^{-1}. The results so far have been promising. Further improvements are advisable based on the extensive field trials.

The machine entailed an investment cost of □ 30,000; an annual generated income of Rs. 10,980. yr^{-1} at a collecting cost of □ 2.55 kg^{-1}. The payback period of the machine was estimated at 3.64 years.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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