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DEVELOPMENT OF PEDAL OPERATED *SYZYGIUM CUMINI* TREE SHAKER WITH CATCHING UNIT

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Abstract: The objective of this research work was to develop a pedal operated tree shaker for jamun (*Syzygium cumini*) fruit harvesting. The prototype machine was constructed and tested on jamun fruit. The tree shaker was powered by manually foot pedal. The output power of the foot pedal was transmitted through a steel wire rope, where it was converted to a reciprocating motion. The eccentricity of the mechanism was constant to provide stroke lengths of 160 mm. The slider motion was transmitted to the shaker clamp to generate the inertia forces to shaking of the branch. The study included frequency and amplitude to obtain maximum fruit removal percentage, harvesting rate of shaker and physical properties of jamun fruit. Harvesting rate was calculated by weighing both the harvested and unharvested jamun. During the test, the limb of tree was attached to a clamp, which was reciprocated at 160 mm amplitude through steel wire rope (4 mm in diameter) and pedal assembly. The frequency of reciprocation was varied from 40, 50, 60, 70, 80 and 90 cpm respectively. The results were recorded to the maximum fruit removal percentage. Maximum fruit removal percentage was observed to 80-90% by operating the tree shaker at amplitude of 160 mm and a frequency of 90 cpm.

Key words: *Jamun, mechanical harvesting, shaker, fruit harvester, branch shaker, tree shaker, branch vibrator, fruit catching unit, fruit detaching mechanism, Perishable fruit harvester*

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INTRODUCTION

Jamun *(Syzygium cumini)* fruit is an important member of the family Myrtaceae. It is considered to be indigenous to India and the West Indies, being cultivated in the Philippines, West Indies and Africa. The tree is tall, evergreen and is generally grown as avenue or as wind north to Tamil Nadu in South. It is also found in the lower range of the Himalaya and Kumaon hills in India. The fruits are a good source of iron and are used as an effective medicine against diabetes, heart and liver trouble. There is no improved variety of Jamun for commercial cultivation. However, the most common type grown in north India is known as Ram-jamun. This is large fruited type with oblong deep purple colors (having small seed) which are available in the month of June- July. A Selection known as Narendra Jamun-6 with desirable traits has also been identified at Faizabad [4].

India is the second largest producer of the fruit in the world. World production of Jamun is estimated at 13.5 million tons out of which 15.4 % is contributed by India. India ranks second in production of Jamun in the world. Maharashtra State is the largest Jamun producer followed by Uttar Pradesh, Tamil Nadu, Gujarat, Assam and others. Among the varieties "Konkan bhardoli" is famous. This variety cultivated especially in Konkan region [1]. At present in India two types of Jamun varieties are grown i.e. Ram-Jamun, bearing big sized sweet fruits and Kaatha bearing small sized fruits with acidic pulp.

For most farmers the cost of harvesting operation is probably considered as a major factor in determining whether or not there will be economically successful season. The harvesting of Jamun fruit is predominantly by handpicking for which the grower has to climb up on the tree, which causes of accidents. However, other method that have been employed include; waiting for fruits to drop to the ground and picking them thereafter, and beating of fruits off branches with long poles or stripping fruits together with leaves, followed by winnowing. In many cases, the high cost and short supply of labour may justify the desire for mechanical harvesters by many growers. Mechanical shakers are large scale harvesting equipment with potential applications in wide range of fruits, berries and nuts. In general, harvesting equipment based on principles of a mechanical shaker consist of the shaker, collecting frame (catching units) and conveying devices, usually mounted on a self-propelled carrier, usually a tractor. The basic principle is to accelerate each fruit so that the inertia force developed will be greater than the bonding force between the fruit and the tree.

A major problem associated with mechanical harvesting is fruit damage. With the advent of mechanized harvesting (shakers fruits) significantly reduced the period of harvesting of fruits per tree [7]. In order to reduce fruit damage, the most common approach has been to remove the fruit by shaking the trees and to collect them on a catching surface placed beneath the tree. This method has shown considerable potential for fruits to be processed.

When the vibration of the harvesting fruits beats per minute, affect the entire mass of the clusters, with berries falling on collecting platform and continue to be directed to the underside of the conveyor belt [3].

The fruits are very sensitive and they are subject to rapid deterioration so that must be read carefully and on time. The method and time of harvest has a crucial impact on the fruit quality and hence the possibility of placement. Investments during the raising and maintenance so far are relatively small compared to harvesting costs, so that at hand harvest ranging up to 70% of total costs production [6]. All the operations of hand harvesting ultimately results in loss of considerable human energy, time, money and deterioration of fruits caused by falling on the ground. Due to more drudgery in harvesting of jamun fruits, most of growers have diverted their attention from this fruit crop.

Since the optimal harvesting time depends on the quality of the fruit. Too early harvested fruits with less sugar, more acid, without the aroma, faster shriveling and of inferior quality [2]. It was therefore, necessary to develop harvesting machine with simple design, easy for operation, low cost but with higher working efficiency.

MATERIAL AND METHODS

Experiments were conducted on jamun plantation consisting of eight to ten years old jamun trees at campus of DBSKKV, Dapoli.

Development of an experimental tree shaker

A pedal operated tree shaker was designed and developed for conducting the field experiments on the harvesting of jamun fruit. The shaker consisted of ten main parts, including the foundation frame, middle column, lower arms, upper arm, gear winch, roller assembly, foot pedal, clamping device, fruit catching frame and transportation wheels. The details of component specifications and material were used for the fabrication shown in Tab. 1 and Fig. 1 shows the different components of the shaker.

Table 1. Components, Specifications and Type of Material used for Fabrication

S.N.	*Components/ particulars*	*Specifications*	*Type of material*
1	*Foundation frame*	*1200 mm X 1200 mm and height 1200 mm*	*Mild steel angles (40 mm X 40 mm X 5mm)*
2	*Middle column (two pieces)*	*80 mm X 40 mm X 3 mm and length 3000 mm*	*Rectangular cross section of mild steel material*
3	*Lower arms i) right side lower arm ii) left side lower arm*	*50 mm X 25mm X 3mm and length 3600 mm 50 mm X 25 mm X 3mm and length 4500 mm*	*Rectangular cross sections of mild steel*
4	*Upper arm*	*50 mm X 25 mm X 3mm and length 6000 mm*	*Rectangular cross sections of mild steel*
5	*Gear winch*	*50 mm diameter*	*Alloy material*
6	*Roller bearing assembly*	*50 mm diameter*	*Cast iron*
7	*Foot pedal*	*160 mm X 50 mm and length from centre of the frame 600 mm*	*M.S plate*
8	*Clamping device*	*150 mm X 25 mm,*	*M.S angles (25 mm X 25 mm X 5mm)*
9	*Catching frame*	*1500 mm diameter*	*Mild steel*
10	*Transportation of wheel*	*160 mm diameter*	*Fibre plastic*

Foundation frame

Cross section assembly

Lower arm of lower arms

Gear winch

Roller assembly

Foot pedal

Clamping device

Fruit catching unit

Upper arm with clamp of a developed shaker

Fig.1. Different components of the developed tree shaker for jamun

The square shape foundation of tree shaker was fixed with two rectangular columns vertically at the centre. The vertical columns were supported with four corner supports. The cross shape assembly lower arms were attached to vertical column through pin joint at center point of cross shaped lower arms. Both the outer end of crossed lower arms were attached with wire rope and internally one end was attached to the end point of the upper arm and other internal end of lower arm where attached with rolling assembly which slides on the outer edge of the upper arm. Due to which the height of the upper arm can be increased or decreased by releasing the tension on the lower arm end through steel wire rope. The upper arm was assembled in horizontal direction by fixing one end of lower arm with pin joint and other end were attached with the clamp. As per requirement of height of tree the upper arm can be raised or lowered. The movement of the clamp was fixed by wire rope to clamp and other end was attached to the pedal which was assembled on the foundation frame. At the outer edge of the upper arm pulleys were fixed so as to control the movement of fruit catching unit. A nylon rope whose one end was fixed to fruit catching unit and another end passes over the small pulleys up to the operator hand; which can control the height of fruit catching unit as per requirement. For the operation of the tree shaker two labour required. The assembled view was shown in Fig. 2. and isometric view of the shaker shown in Fig. 3.

Figure 2. Assembled view of developed tree shaker

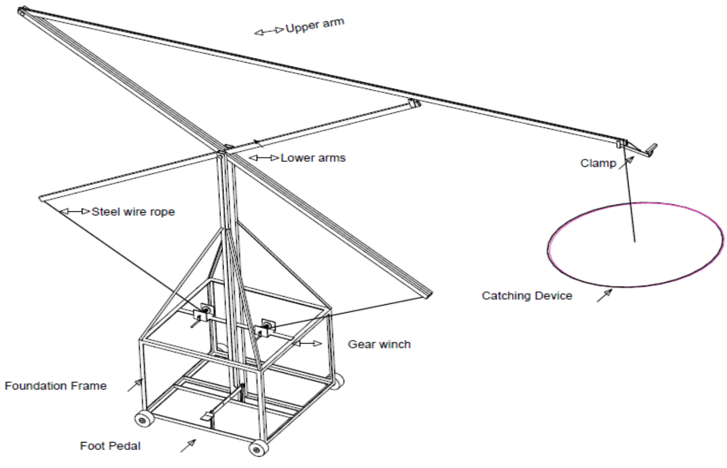

Figure 3. Schematic view of developed pedal operated tree shaker for jamun (Syzygium cumini)

Fruits catching unit

One of the most important disadvantages of mechanical harvesting is fruit damage. In order to resolve this problem, the most common approach has been made to remove the fruit by shaking the trees and collecting them on a catching unit placed beneath the tree.

For this purpose, a circular catching surface as shown in Fig.1, was developed and fabricated. The size of the circular ring was 1500 mm in diameter. The catching surface was made of light weight nylon cloth material from knitted plastic mesh strips and strong yarn. According to the fruit branches the position of catching unit was adjustable through nylon rope. The movement of the wire rope made easier by passing the rope through small pulleys of size 20 mm in diameter were fixed at the top surface of the upper arm.

Determination of the parameter of fruit detachment force/fruit weight

The ratio of fruit detachment force to fruit weight (FDF/W) is used for comparing the suitability of jamun fruit. The fruit detachment force was measured by the help of load cell (0-125 kg) capacity with least count 0.1 kg. The fruit weight was determined with an electronic scale 2.0 kg capacity and 0.01 g divisions.

Determination of branch spring rigidity

In order to observe the sustainability of the branch under the varying shaking frequency it was necessary to find out the spring rigidity index. To determine the branch spring rigidity of jamun trees, a spring dynamometer were used. One end of the dynamometer was attached to the branch of the tree via rope; and other end was held by the hands of the person. The connection point at the branch was chosen to be same as that of the shaker. The branch was pulled horizontally by a person. The maximum displacement of branch was kept up to the detachment of the fruit. The displacement value of branch and dynamometers values were recorded. The spring coefficient was calculated by placing these values in the following equations.

$$C = F/X \tag{1}$$

Where:
C [N·mm^{-1}] - spring rigidity of tree,
F [N] - pulling force,
X [mm] - displacement quantity of branch.

Determination of the effects of shaking frequency on fruit removal percentage

The two most influential parameter on the process of harvesting of berries were the amplitude and frequency of fruit trees [5].

The trees with mature jamun fruits were identified and three to five limbs with appropriate properties and sizes on each tree in different directions were selected for shaking. The remainders of the tree were harvested by workers using traditional harvesting methods. Afterwards, the remaining limbs with fruits were attached to the shaker individually and harvested by applying different frequency combinations. Fruits removed from each limb were collected on the catching surface, filled into polythene bags and then weighed. In the tests, the limbs were shaken at 40, 50, 60, 70, 80 and 90 cpm and 160 mm amplitude. The results of three replicates were analyzed to determine the effects of frequencies and amplitude on the fruit removal percentage.

RESULTS AND DISCUSSION

The results were found on the basis of field performance of a developed tree shaker.

Variation of the fruit detachment force (FDF)/ weight at different maturity times

For the purpose of detachment of fruit from the branch it was necessary to find out the fruit detachment force, the fruit maturity has on important effect on the force required for detachment of fruit. The changes in FDF/W ratio as a function of maturity time were shown in Tab. 2 and Fig. 4; it was observed that the ratio was higher for the unripe fruits and less for the ripe fruits. From graphical representation shows in fig 3.1, it was found that FDF/W ratio for Jamun was decreased from 1.94 to 0.32 $N \cdot g^{-1}$. within month of days of test.

Table 2. Variation of fruit detachment Force/Weight at different maturity level

Days after fruiting	*FDF (N)*	*Weight of fruit (g)*	*FDF/W*
7	*7.75*	*4*	*1.94*
15	*6.54*	*5*	*1.31*
22	*5.61*	*6*	*0.93*
28	*4.54*	*8*	*0.56*
35	*3.23*	*10*	*0.32*

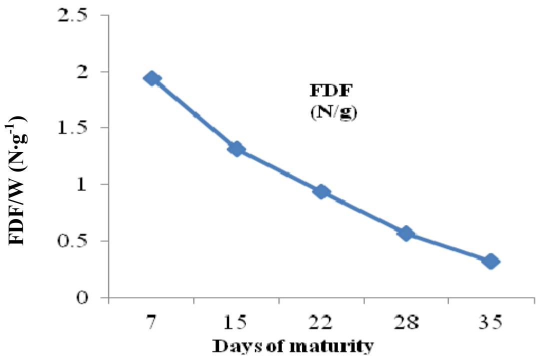

Figure 4. Variation of FDF/W at different maturity level

Branch Spring Rigidity of Jamun

Branch spring rigidity increases with branch diameter. In order to displace the branch up to 150 mm distance minimum force was recorded as 7 kg (68.67 N) and coefficient of spring rigidity was found to be 0.457 $N \cdot mm^{-1}$ for 26 mm branch diameter and maximum force recorded as 38 kg (372.78 N) with coefficient of rigidity as 2.071 $N \cdot mm^{-1}$ for 42 mm branch diameter. It was observed that for the average diameter of branch 34 mm average force of 23.24 kg was required to displace 137.2 mm distance. Correspondingly the average coefficient of spring rigidity was found to be 1.719 $N \cdot mm^{-1}$. This result was supported for different fruit branches by [6] and [3].

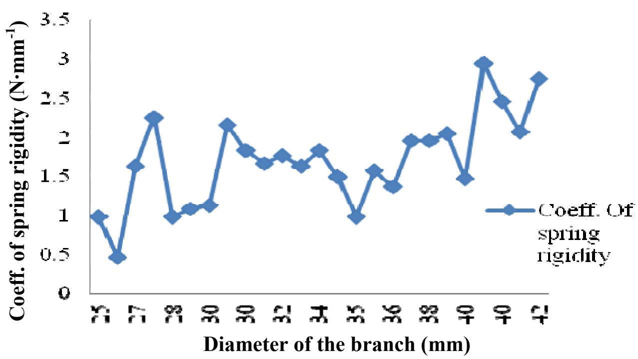

Figure 5. Effect of diameter of the branch on coefficient of spring rigidity

The Effect of Shaking Frequency on Fruit Harvesting

The effects of different frequencies were measured for fruit harvesting and respective observations were placed in Table 3 for different indigenous varieties. From observations it was seen that at 40, 50, 60, 80, and 90 cpm, the average fruit removal percentage of Jamun varieties were 18.17, 50.04, 61.04, 73.29 and 87.08 % respectively. The higher average fruit removed percentage 87.08 % was found at 90 cpm. It might be due to the inertia force develops at this frequency level much greater than the bonding force required detaching the matured fruits. In this process only frequency was varied and amplitude (160 mm) was kept constant.

Table 3. The effects of different shaking frequencies on fruit harvesting

Branch	*Weight of fruits remove (g)*	*Weight of Fruits un remove (g)*	*Total weight (g)*	*Fruit removal (%)*	*Frequency (cpm)*
1	160	440	600	26.67	40
2	120	606	726	16.53	40
3	220	526	746	29.49	40
			Average	24.23	40
1	390	440	830	46.99	50
2	450	660	1110	40.54	50
3	580	220	800	72.50	50
			Average	53.34	50
1	337	530	867	38.87	60
2	468	320	788	59.39	60
3	890	380	1270	70.08	60
			Average	56.11	60
1	378	564	942	40.13	70
3	752	240	992	75.81	70
3	960	260	1220	78.69	70
			Average	64.65	70
1	780	510	1290	60.47	80
2	1030	360	1390	74.10	80
3	820	206	1026	79.92	80
			Average	71.49	80
1	1386	270	1656	83.70	90
2	1138	130	1368	83.19	90
3	1560	130	1690	92.31	90
			Average	86.40	90

Effect of vertical distance of catching unit from limb on fruit damage

Jamun fruits normally fall on the ground when they become mature. The fruits were very delicate, after falling on the ground they become destroyed and deterioration takes place. In this case fruits were catch at certain required distance from branch by using catching unit to reduce the damage percentage of the fruits. The study was conducted to find out the exact vertical distance of the catching unit from the branch, so as to get minimum fruit damage. The table 5.8 shows the fruit damage percentage and catching efficiency at various distances from fruit limb. It was observed that the highest fruit damage percentage and catching efficiency i.e. 20% and 60.1% were occurred at 4m were as at 1m distance of fruit catching unit the damage percentage was nil and catching efficiency was 89.74%.

Table 4. Fruit damage percentage

Catching unit from fruit limb (m)	*Fruit damage percentage (%)*	*Total fruits collected in catching unit (kg)*	*Total fruits dropped on the ground (kg)*	*Catching efficiency (%)*
1.0	*0*	*22.76*	*2.6*	*89.74*
1.5	*2*	*18.22*	*2.9*	*86.26*
2.0	*6*	*15.65*	*3.5*	*81.26*
2.5	*10*	*11.70*	*3.8*	*75.48*
3.0	*15*	*8.20*	*4.0*	*67.21*
3.5	*18*	*7.60*	*4.0*	*65.51*
4.0	*20*	*6.18*	*4.1*	*60.10*

CONCLUSIONS

1. The performance of fruit harvester was found to be satisfactory.
2. The Fruit detachment force/weight ratio of Jamun fruit decreased with increasing maturity time. Consequently, the most appropriate time for harvesting of Jamun was found in the month of May, June and July.
3. To obtain maximum fruit removal with minimum vibration and reactive force, the limb shaker should be operated in the range of 160 mm amplitude and 90cpm frequency. The maximum fruit removal percentage 86.4% was obtained at 90cpm frequency and the harvesting capacity was observed to be 0.06 ha/day.
4. The efficiency of the catching unit was obtained to be 89.74 % at 1 m height from the fruit limb towards the ground.
5. The catching unit of nylon cloth material surfaces which are at 1 m height from the fruit limb towards the ground reduced or no fruit damage percentage by compared to that caused by impact with the ground.
6. Fruit removal percentage increased with an increased in shaking Frequency.
7. Limb position, limb length and size of the tree affected the fruit removal percentage.
8. The maneuverability of the shaker was satisfactory but sometimes the operator had some trouble in swinging the shaker through the tree canopy to attach on to the limbs and in positioning the shaker when operating on sloping terrain.

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RAZVOJ TRESAČA SA HVATAČEM ZA STABLA *SYZYGIUM CUMINI* NA NOŽNI POGON

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Sažetak: Cilj ovog istraživanja bio je da razvije tresač sa pogonom od pedala za berbu jamuna (*Syzygium cumini*). Prototip mašine je konstruisan i testiran na voću jamun. Tresač ima pogon od nožnih pedala. Izlazni pogon sa pedala je prenet čeličnim užetom i pretvoren u oscilatorno kretanje. Ekscentrični mehanizam je konstantno proizvodio oscilacije sa hodom od 160 mm. Kretanje klizača je preneto na hvatač tresača da generiše inercijalne sile za trešenje grane. Studija je uključila frekvenciju i amplitudu za postizanje maksimalnog procenta skidanja voća, norme ubiranja tresača i fizičkih svojstava voća. Norma ubiranja je izračunata merenjem ubranih i neubranih plodova. Tokom testiranja, grana drveta je stezana hvatačem koji je oscilovao sa amplitudom od 160 mm preko čeličnog užeta (prečnika 4 mm) i sklopa pedala. Frekvencija oscilovanja je iznosila 40, 50, 60, 70, 80 i 90 min^{-1}, redom. Rezultati su praćeni pri maksimalnom procentu skidanja plodova. Maksimalni zabeleženi procenat skidanja iznosio je 80-90% pri radu tresača sa amplitudom od 160 mm i frekvencijom od 90 min^{-1}.

Ključne reči: *jamun, mehanička berba, tresač, berač voća, tresač grana, tresač stable, vibrator grana, uređaj za hvatanje voća, mehanizam za odvajanje voća, berač za kvarljivo voće*

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