

Research Article

Development and evaluation of a sesame thresher as influenced by crop, machine and operational parameters

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Abstract

The development of a sesame thresher for the purpose has clearly an edge over conventional methods of threshing and reduce the drudgery of work to a great extent. Due to the scarcity of daily labours, it is essential to bring in a sesame thresher, which is cost-effective, compact, reduce threshing losses and easy to use for sesame cultivars. The laboratory experiments were conducted with different levels of variables, from that the combination level of 11.0 ms⁻¹ peripheral velocity of threshing cylinder, 15 mm concave clearance, spike tooth type cylinder and 16.8 % (d.b) moisture content of harvested sesame capsule were selected. The selected combination level yielding the maximum threshing efficiency of 99.0 %, maximum cleaning efficiency of 99.4 % and minimum % visible damage to threshed sesame grains of 0.79 %, was optimized for the development of prototype sesame thresher. A prototype sesame thresher consisting of a mainframe, threshing unit, blower and sieve assembly, feed chute, power transmission system and transport wheels was developed with optimized level of variables. The prototype sesame thresher was evaluated for its performance in comparison with the conventional method of sesame threshing. Compared with the manual method of threshing, the prototype sesame thresher resulted in 17, 12, and 1.2 % savings in threshing efficiency, cleaning efficiency, and % visible damage to threshed sesame grains. The prototype sesame thresher results in 87 % and 83 % saving in time and cost respectively when compared to the conventional method of manual threshing.

Keywords: Moisture content, Peripheral velocity, Prototype, Sesame, Thresher

INTRODUCTION

The traditional threshing operations for all the crops are most time-consuming, energy-intensive, labour intensive, drudgery-prone, and uneconomical (Naveenkumar *et al.*, 2013; Abagisa *et al.*, 2015 and Omale *et al.*, 2015). The development of mechanical threshers for this purpose has clearly an edge over conventional methods and has reduced the drudgery of work to a great extent (Singh *et al.*, 2015; Patil *et al.*, 2016). These stationary threshing machines are based on the quick process, level of performance, reduction of the drudgery of farmers/labours, improved quality of product and economy. With the existing socioeconomic condition of sesame cultivars, the large capacity threshers are inappropriate, and even small-sized threshers with large scale sophistication are difficult to adopt. A worldwide number of studies have been done for the thresh-

ing of various crops, but a few studies have been reported on sesame threshing. Keeping the above facts in view, the research work was carried out to identify the pertinent variables that influence the design of sesame thresher. The experimental sesame thresher test rig were made for investigating the interactive effect of selected levels of variables on the performance under laboratory conditions. The optimization of the selected levels of variables were taken for achieving the desired performance of sesame thresher. From that, the development of a prototype sesame thresher with optimized levels of variables and evaluation of the performance of the prototype sesame thresher was done.

MATERIALS AND METHODS

The conventional method of sesame threshing includes heaping of the harvested sesame stalks for curing for

three days, initial shaking of cured sesame stalks, subsequent drying for one more day and shaking of stalks and manual beating of sesame stalks to separate the remaining grains from stalk. The total cultivated area, production and productivity of sesame in Tamil Nadu are 33181 ha, 17179 tonnes and 518 kg ha⁻¹ respectively (Department of Economics & Statistics, India, 2014). Among the predominant varieties (TMV 3, TMV 4, TMV 6, TMV 7, CO 1, VRI (SV) 1, SVPR1, VRI (SV) 2) of sesame cultivated in Tamil Nadu, the popular variety TMV- 4 in the study region is selected for the investigation.

Identification of pertinent crop parameters

The pertinent crop parameters relevant to the development of functional components of sesame thresher were identified. The mean effective length of sesame stalk of 600 mm was used to arrive at the concave length of 600 mm in the threshing unit of the experimental sesame thresher. The mean value of the width of the sesame capsule of 5.65 mm was used to fix the mesh size of the concave as 5 mm. The thousand-grain weight of sesame and the weight of grains per capsule were used for the calculation of the total weight of the sesame grains input for the experimental sesame thresher. For retention of sesame capsule in the top sieve, the sieve hole for the top screen was fixed as 20 mm and for sesame capsules to through the bottom sieve; the size of the hole for the bottom sieve was fixed as 3.5 mm. The mean values of bulk density of selected sesame seeds were 0.651 kg m⁻³ and the value was used for the selection of size of the grain collection tray of experimental sesame thresher.

The grain outlet tray was made of mild sheet metal due to the lower frictional angle and coefficient of friction between sesame grains and metal. The inclination of the grain collection tray was fixed as 40° (more than the angle of repose of sesame grains of 30°) to facilitate easy flow of sesame grains.

Selection of machine variables

The pertinent variables that influence the development of sesame thresher were identified and levels of variables

were selected. The interactive effect of selected levels of variables viz., peripheral velocity of the threshing cylinder (7.9, 11.0 and 14.1 ms⁻¹), concave clearance (10, 15 and 20 mm), type of threshing cylinder (wire loop, spike tooth and rasp bar) as shown in Fig.1 and moisture content (d.b.) of harvested sesame capsule 21.4, 16.8 and 15.1 % as shown in Fig.2 was investigated on threshing efficiency, cleaning efficiency and % damage caused to the threshed sesame grains using an experimental sesame thresher test rig under laboratory condition.

A total number of 243 treatments under laboratory condition were conducted with selected levels of variables viz., of the peripheral velocity of the cylinder (7.9, 11.0 and 14.1 ms⁻¹), concave clearance (10, 15 and 20 mm), types of the threshing cylinder (wire loop, spike tooth and rasp bar) and moisture content of harvested sesame capsule (21.4, 16.8 and 15.1 d.b). From the recorded observations, the threshing efficiency, cleaning efficiency and % visible damage to threshed sesame grains were computed.

The threshing effectiveness of the experimental sesame thresher was affected highly by the moisture content of harvested sesame capsule followed by the type of threshing cylinder, the peripheral velocity of the threshing cylinder, and the concave clearance. The combination level of 11.0 ms⁻¹ peripheral velocity of the threshing cylinder, 15 mm concave clearance, spike tooth type cylinder and 16.8 % (d.b) moisture content of harvested sesame capsule yielded the maximum threshing efficiency of 99.0 %, maximum cleaning efficiency of 99.4 % and minimum % visible damage to threshed sesame grains of 0.79 %, is optimized for the development of prototype sesame thresher.

Development of sesame thresher

A prototype sesame thresher was developed with optimized levels of variables. The prototype sesame thresher drawn using 3D CAD software is shown in Fig.3. The prototype sesame thresher consists of a mainframe, threshing unit, blower and sieve assembly, feed chute, power transmission system and transport wheels, as shown in Fig.4.

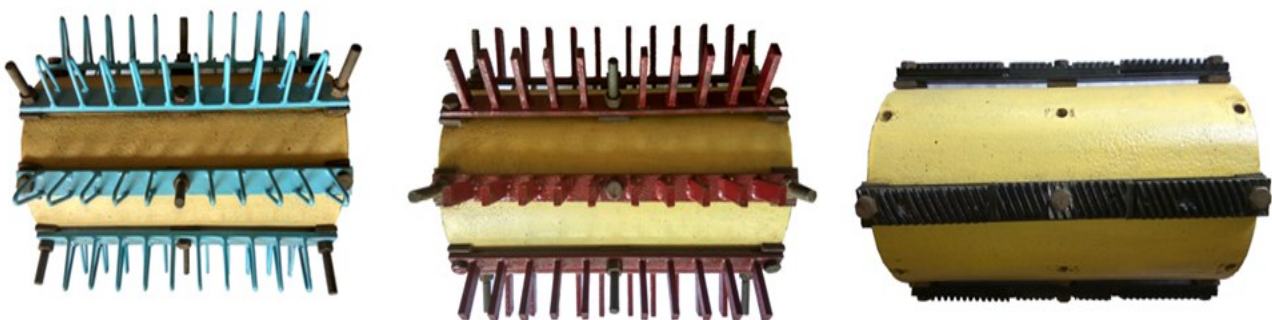


Fig. 1. Threshing cylinder (wire loop, spike tooth and rasp bar).

The mainframe was a welded rectangular box structure of size 1140 x 910 x 1130 mm. It was made by using 50 x 50 x 5 mm mild steel 'L' angle iron section. All the other functional components were attached to the mainframe. The mainframe supports the entire weight of the machine. The feed chute was the component on which the harvested sesame crop was placed and fed into the threshing cylinder. It was made of 1.3 mm mild steel sheet. The feed chute was fixed at an inward inclination of 30° to facilitate the easy feeding of harvested sesame crop in to the threshing cylinder. The chute was trapezoidal section of 600 mm length, 355 mm width and 255 mm height. The feed chute opening at

the outer end and cylinder end was 600 x 255 mm and 600 x 155 mm, respectively. The feeding chute was fixed at 1165 mm height from the ground level for safety and easy feeding.

The threshing unit included the optimized type of threshing cylinder and concave. The diameter and length of the hollow threshing cylinder was 300 and 600 mm respectively. It was made of 1.2 mm mild steel sheet metal. The upper half of the threshing unit was enclosed with semicircular shield made of 2 mm mild steel sheet metal. The shaft of made of 50 mm mild steel rod was fixed at the center of the threshing drum and the two ends of the shaft rest on plumber block



Fig. 2. Harvested sesame stalks with capsules after curing and drying.

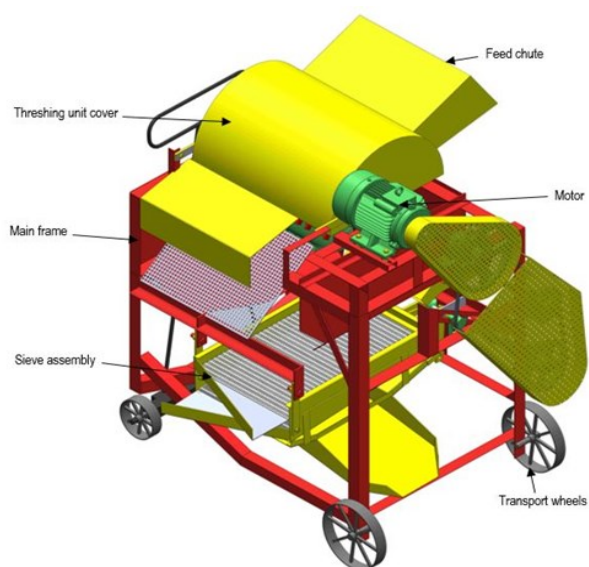


Fig. 3. Sesame thresher - 3D CAD Design.



Fig. 4. Prototype sesame thresher.

bearings mounted on the mainframe. For power transmission, a 150 mm diameter 'V' pulley was fixed on the shaft at one end.

It was a curved unit fitted below the threshing cylinder. The concave near the feeding end was hinged at both ends and connected to a slot with necessary supports to the mainframe. The concave type corresponding to the optimized threshing cylinder type was fitted. The concave clearance was fixed at the optimized level of laboratory investigation. The cleaning unit consists of the blower, sieve and outlet tray.

The blower was made of 1.6 mm mild steel sheet metal work. The blower housing was nautilus shaped with a major diameter of 200 mm, a width of 340 mm and a length of 430 mm. The inner diameter for the air inlet was 80 mm and the throat of the blower housing is 430 x 50 mm in size. The blower fan was made up of four paddle blades of 1.3 mm gauge mild steel metal sheet dimensioned 400 x 55 mm bolted to a 28 mm diameter shaft. The blower outlet was directed towards the sieve shaking mechanism to blow out the chaff and dust from grains. The two ends of the shaft rest on pillow block bearings mounted on the mainframe. For power transmission, a 150 mm diameter 'V' pulley was fixed on the shaft at one end.

The threshers were equipped with two sieves of perforated sheets having rectangular slots. The top sieve was provided so as not to pass the chaffs to the bottom sieve. The top sieve was made up of 1.6 mm mild steel sheet metal of 520 x 790 mm with each slot size of 20 x 5 mm. The bottom sieve sieves out small sesame grains and delivers the clean grain towards outlet. It was made of 1.6 mm mild steel sheet metal of 520 x 790 mm with a rec-

tangular slot hole of 35 x 3 mm. The size of the sieve hole is 3.5 mm. The lower sieve was placed 65 mm below the top sieve.

The upper and lower sieves were placed in a rectangular tray of 520 x 790 mm made of 1.6 mm mild sheet metal. These sieves were oscillated or shaken with a crank attached to the trays. The crank was attached to a cam pulley having slot length of 30 mm in which the circular motion was converted into oscillating motion of sieve. For power transmission, a 200 mm diameter 'V' pulley is fixed on the shaft at one end.

The grain outlet was a rectangular tray of 980 x 415 mm made of 1.6 mm mild sheet metal and fitted with a bottom sieve at an inclination of 40° to facilitate easy flow of sesame grains. The thresher was provided with four wheels, two in the front and two in the rear portion for easy transportation. These wheels are made with 2.6 mm mild steel sheet metal rolled to circular wheels of 300 mm diameter and 50 mm width at the rear and 200 mm diameter and 40mm width at the front. The wheels are attached to the axle, which was attached to a handle for moving the unit.

The prime mover was a two hp single phase electric motor (1440 rpm) mounted on one side of the top corner of the mainframe with the necessary support. The power was transmitted from the motor to the threshing cylinder shaft, blower shaft, sieve shaker shaft through a V-belt and pulley arrangement.

The specifications of prototype sesame thresher are furnished in table 1.

RESULTS AND DISCUSSION

The operational view of sesame thresher is shown in Fig. 5. The performance of developed prototype sesame thresher compared with the conventional method of threshing was carried out and the observations viz., weight of grain, weight of chaff, weight of sesame stalk after threshing were recorded. From the recorded observations, the threshing efficiency, cleaning efficiency and % visible damage to sesame grains were computed and compared with the conventional method. From the measured observations during the evaluation of prototype, sesame thresher, the cost of operation of the developed prototype sesame thresher was computed and compared with manual threshing. The saving in cost, time and labour computed for the developed prototype sesame thresher in comparison the traditional method of sesame threshing were as follows:

The cost of threshing by manual method are computed as detailed below.

No. of men labours required for manual threshing
= 5 (480 kg)

Man hours required to thresh 480 kg of crop stalks



Fig. 5. Operational view of sesame thresher.

$$\begin{aligned} &= 3 \text{ hours} \\ \text{Cost of threshing @Rs. 50/man/hour} &= 5 \times 50 \times 3 \\ &= \text{Rs. 750 /480 kg.} \end{aligned}$$

The cost of mechanical threshing are computed as detailed below.

$$\begin{aligned} \text{No. of men labours required for threshing} &= 2 \text{ (480 kg)} \\ \text{Man hours required to thresh 480 kg of crop stalks} &= 1 \text{ hour} \end{aligned}$$

$$\begin{aligned} \text{Cost of threshing @Rs. 50/man/hour} &= 2 \times 50 \times 1 \\ &= \text{Rs.100 /480 kg.} \end{aligned}$$

Initial cost of prototype sesame thresher (P), Rs. 30,000

Salvage cost 10% of initial cost (S), Rs. 3000

Expected life period of thresher (L), years - 8

Annual working hours (A), hours per year - 312.5

Rate of interest (I), % - 14

i. Fixed cost of operation of sesame thresher

$$\text{Depreciation, Rs. h}^{-1} = \frac{P-S}{L \times A} = 10.8$$

$$\text{Interest, Rs. h}^{-1} = \frac{P+S}{2} \times \frac{I}{100 \times A} = 7.392$$

Taxes, Insurance and housing (2 % of the initial cost of thresher), Rs. h⁻¹ = 1.92

Fixed cost of operation of Thresher, Rs. h⁻¹

$$\begin{aligned} (\text{Depreciation} + \text{Interest} + \text{TIH}) &= 10.8 + 7.39 + 1.92 \\ &= 20.11 \end{aligned}$$

ii. Variable cost of operation of prototype sesame thresher

Cost of electricity one unit = 7

Output power of 2 HP = (2 x 0.746) kW = 1.49 kW.

Unit consumed = Power in kW x Number of hours of operation.

$$\begin{aligned} &= 1.49 \times 1 \\ &= 1.49 \end{aligned}$$

$$\begin{aligned} \text{Electricity cost, Rs. h}^{-1} &= 1.49 \times 7 \\ &= 10.43 \end{aligned}$$

$$\begin{aligned} \text{Total cost of operation, Rs. h}^{-1} &= 20.11 + 10.43 \\ &= 30.54 \end{aligned}$$

Total cost of threshing = (fixed cost + variable cost + operator cost) = 20.11 + 10.43 + 100 = 130.54

(Fixed and variable cost are calculated as per IS: 9164-1979, Guide for estimating cost of farm machinery operation.)

$$\begin{aligned} \text{Cost saved over manual threshing} &= 750 - 130.54 \\ &= \text{Rs.619.46} \end{aligned}$$

Saving in cost of threshing with prototype sesame thresher when compared to manual method of threshing = ((750-130.54) x 100)/750

$$= 82.59 \% = 83 \%$$

Saving in time of threshing with prototype sesame thresher when compared to manual method of threshing = ((15 - 2) x 100)/15

$$= 86.6\% = 87 \%$$

The comparative evaluation of prototype sesame thresher with the conventional method of threshing is furnished in table 2.

Farmers face lot of production constraints which include high cost of labour, non-availability of quality seeds etc. whereas they are also not using improved technologies and high yielding varieties. Due to uneven maturity of pods, seasonality in production and poor post-harvest practices, the post-harvest losses were also high, thus reducing further availability of sesame for consumption and value addition. The traditional methods of threshing operations are most time consuming, energy intensive, labour intensive, drudgery prone and uneconomical (Naveenkumar *et al.*, 2013 and Omale *et al.*, 2015). The development of mechanical threshers for this purpose has clearly an edge over conventional methods and has reduced the drudgery of work to a great extent (Singh *et al.*, 2015 and Patil *et al.*, 2016). The important parameters which influence the threshing efficiency are mechanical damage, moisture content, threshing cylinder speed, feeding rate and concave clearance (Naveenkumar *et al.*, 2013 and Timothy Adesoye Adekanye., 2016). The speed of threshing cylinder and moisture content had significant effect on threshing efficiency and damaged grain percentage (Khazaei, 2003). The performance of the unit has been evaluated in terms of threshing efficiency, cleaning efficiency, and seed damage (Kepner *et al.*, 1978, Ajayi *et al.*, 2014, Munusamy *et al.*, 2015, and Olaye *et al.*, 2016).

In present study, a prototype sesame thresher developed with optimized levels of variables is cost effective, compact and easy to use for sesame cultivars. Compared with the manual method of threshing, the prototype sesame thresher resulted in 17, 12 and 1.2 % saving in threshing efficiency, cleaning efficiency, and % visible damage to threshed sesame grains. The prototype sesame thresher resulted in 87 and 83 % saving in time and cost respectively when compared to the conventional method of manual threshing.

Conclusion

The combination level of 11.0 ms⁻¹ peripheral velocity of threshing cylinder, 15 mm concave clearance, spike tooth type threshing cylinder and 16.8 % (d.b) moisture content of sesame capsule was adjudged as the optimized level for the development of prototype sesame thresher as it yielded the maximum threshing efficiency of 99.0 %, maximum cleaning efficiency of 99.4 % and minimum % damage caused to threshed sesame grains of 0.79 %. A prototype sesame thresher consisting of a main frame, threshing unit, blower and sieve assembly, feed chute, power transmission system and transport wheels

Table 1. Specifications of prototype sesame thresher.

S.No.	Details	Values
A	Overall dimensions (Lx B x W),mm	1140 x 910 x 1035
B	Type of thresher	Throw-in
C	Threshing unit	
i	Type of threshing cylinder	Spike tooth
ii	Diameter of the drum, mm	300
iii	Length of the drum, mm	600
iv	Concave clearance, mm	15
v	Peripheral velocity of threshing cylinder, ms ⁻¹	11.0
D	Power required	2 hp single phase electric motor
E	Cleaning unit	
i	Type of blower	Centrifugal type
ii	No. of blades	4
iii	Length of blade, mm	400
iv	Width of blade, mm	55
v	Number of sieves	2
F	Feed chute	
i	Shape	Trapezoidal
ii	Size at the feeding end, mm	600 x 255
iii	Size at the cylinder end, mm	600 x 155
G	Power transmission	V- belt and pulley
H	Transport wheels	Four iron wheels

Table 2. Results of comparative evaluation of prototype sesame thresher with the conventional method of threshing comparison of sesame thresher with manual threshing.

S.No.	Parameters	Conventional method of sesame threshing	Threshing with prototype sesame thresher
i	Threshing efficiency, %	82%	99%
ii	Cleaning efficiency, %	87%	99%
iii	% visible damage to threshed sesame grains, %	2%	0.79%
vi	Number of workers required	Minimum 5	Maximum 2
v	Time consumed to thresh 120 kg of sesame grains, man h ⁻¹	15	2
vi	Cost of operation of threshing sesame grains, Rs. per 120 kg	750*	130.54**

* Cost of threshing by manual method ** Cost of threshing by mechanical method

developed with optimized levels of variables is cost-effective, compact and easy to use for sesame cultivars.

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Conflict of interest

The author declares that he has no conflict of interest.

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