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Development of Hand Operated Sorghum Thresher

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Abstract

A hand operated sorghum thresher was designed and developed in Fedis Agricultural Research Center with a view to increase the threshing efficiency, threshing capacity and to reduce the cost of threshing in comparison with traditional methods of threshing sorghum crop. The machine is of low cost, simple in structure, convenient in operating and easy for repairing. In the field, it was tested in East Hararghe Zone, Haramaya District at the place *Legeambo* that is not more than 3 km to the North of Haramaya University. In the test the variables considered were variety (*Muira*, *Fendisha* and *Zengada*), three body weight of farmers (50, 60 and 70 kg) and three feed rate (3, 5 and 7 kg/min). The selected experimental design was split-split plot design with three replications. The machine was tested at constant drum-concave-clearance (inlet 25 outlet 17mm) and grain moisture content was maintained 14-16% wet basis. The result indicated that the average efficiency and output capacity were 93.72% and 310.13 kg/h respectively.

Keywords: Development; Performance evaluation; Sorghum thresher; threshing process.

1. Introduction

In Ethiopia cereals are the major food grains both in terms of production area coverage and volume of production. Because they are the principal staple foods, cereals are grown all over the country at different levels. Out of the total area allocated for grain 81% (about 10.22 million hectares) was used for growing of cereals. Teff, maize and sorghum took up 24% (3.02 million hectares), 17% (2.14 million hectares) and 15 % (1.88 million hectares) of the total grain area, respectively.

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As to production, cereals contributed 87% (290.39 million quintals), of which maize, teff and sorghum contributed 27% (78.47 million quintals), 17% (50.20 million quintals) and 16% (47.52 million quintals) respectively. Sorghum covered an area of 1,881,971 hectare for 5,987,038 private peasant holding and which is resulted production in quintals 47,520,956 that gives yield per hectare was 25.25qt [1]. The data clearly showed that sorghum stood 3rd in area coverage and in grain production.

Hand harvesting is done by cutting the heads of sorghum plants with sickles. The cut heads of sorghum are piled up and allowed to dry on the threshing-floor or on sheaves in the field. Indicatively the average duration of a manual sorghum harvest varies from 120 to 160 man- hours (15-20 man - days) per hectare [2]. Threshing of Sorghum can be done manually by striking sorghum heads spread out on threshing floor with a stick. Using this method a farmer can obtain 15 - 40 kg of grain per hour [3].

This traditional method of sorghum threshing is costly, results in lower output, inflicts excessive damages to the grain, exhaustive to the workers, and needs much labor and time. Postharvest losses of peasant farming due to traditional method are about 10 – 20 % of the total production. In this report, it was indicated that half of the loss, is accounted for threshing [4].

Even though, the technologies like combine harvesters, RF-450 multi-crop thresher and IITA (International Institute of Tropical Agriculture) multi-crop thresher are available in the country in limited quantity, their un-appropriation for farmers restricted their promotion and utilization. Combine harvester and RF-450 have superior efficiency and output capacity, but they are imported from abroad with hard currency. Thus, their purchase price and operation cost is high. In addition, the big size of these machines, as compare to sizes of farm plots and the topography of the region, makes them unsuitable for operation and transportation.

The IITA thresher is also inappropriate for its high purchase price and inefficiency for sorghum threshing (below the optimal value) i.e. more un-threshed grain and grain with glum was seen on threshed grain. Due to un-adjustable concave-drum clearance mechanism of the machine user is forced to operate with minimum speed of the engine. Even, with its average-speed of operation caused much breakage of grain, so that we cannot be utilized its full capacity. Because of these drawbacks farmers are not seen using it for threshing sorghum. Therefore, development of hand operated, low cost, simple and portable sorghum thresher is very important. Thus, the objectives of this work were to develop manually operated sorghum thresher and to evaluate the performance of the machine.

2. Materials and Methods

2.1 Experimental Material

The experimental materials were the hand operated sorghum thresher and sorghum. The machine was design and developed in the center according to the design, which was done in its schedule program. The varieties of sorghum tested at the time of experiment were *Muira*, *Fandisha* and *Zengada*.

2.2 Description of the Machine

The machine is a stationary wheel driven thresher, which can be driven from place to place (in the farm plot) by single person. It is consist of the following components: - feeding chute, drum, upper and lower cover for the drum, concave, drive pulley, driven pulley, frame, transportation wheel, straw discharging outlet, handle, grain outlet, flywheel, cranking handle and belt. The overall size of the machine is 1170 mm height, 900 mm length and 870 mm width. It has a constant drum concave clearance of inlet 25 and out let 17mm.

Threshing drum**: -** The threshing drum was made of six row plates. The plates are fixed to three wings which are mounted along the length of a shaft one in the middle and the other two at the outer side. The two ends of the drum are closed with sheet metal. The shaft is supported on two ball bearings mounted on the sides of the machine frame. The drum outside diameter and length are 323 mm and 582 mm respectively (see figure1 and 2). The drum has corrugated pegs that are disposed along the length of the plates in a helical arrangement for better rasping action. The peg's height is 50 mm and its diameter 12.

Concave*:* - It is made from corrugated iron, angle iron, flat iron and wire mesh. The concave is fixed beneath the cylinder through which the threshed grains are dropped in to grain outlet. However, straws and chaffs those can't pass through wire mesh should be pushed by pegs and thrown out through the straw outlet.

Procedure of threshing**: -** The threshing operation is conducted by three persons. The first will feed the machine while the second one is rotates the handle and the third person collects the threshed grain. The crop to be threshed should be dropped in to the threshing chamber through feeding chute. By rotation of the handle, power will be transmitted from the operator of the machine to the drive pulley then through belt transferred to the driven pulley that is attached at the end side of drum shaft by which drum speed is multiplied 10 times and results rotation of the drum. When the material comes in contact with drum pegs, the impact shatters the sorghum head and frees a considerable portion of the grain from the straw. Further threshing is achieved by rubbing action as the material passes through the restricted clearance between the rotating drum and the concave. Mean while, big size straw and chaff are forced by helical motion of pegs on the drum towards the straw outlet. The threshed grain, small sized straw and chaff, and dusty particles pass down through the concave mesh to an inclined grain outlet. After the threshing work was finished the pure grain is separated from small size straw and chaff, and other dust particles by traditional cleaning method since, the machine does not incorporate cleaning system.

2.3 The dimensions of pegs (fingers) types drum [5]

The diameter of finger types drum (D) is determined by the formula

$$D = \frac{M\, t_i}{\Pi} + 2\, h \tag{1}$$

Where: M= number of plates for finger type drum.

t_i = space between plates mm.

h = the height of the finger mm.

$\pi = 3.14$

The length of finger type drum is determined by.

$$L_w = \left(\frac{Z}{K} - 1\right) a \qquad (2)$$

Where: Z = number of teeth on the drum.

K = number of gaps screw line.

a = space between teeth on drum mm.

The amount of Z depends up on production of the drum m_1 and restricted feed of grain weight for one teeth m_o.

$$Z = \frac{m_1}{m_0} \qquad (3)$$

$$where: m_1 = 0.05\,kg/\sec$$

The amount of m_0 for normal condition is given 0.00104667 - 0.035 kg/sec. Number of gaps K is given 2, 3, 4, and 5 high values is taken for more production and small value taken for less productive drum.

The plate length of drum (L_π) can be calculated by the formula

$$L_\Pi = L_w + 2\,\Delta\,L \qquad (4)$$

Where: ΔL = 18 - 12 mm

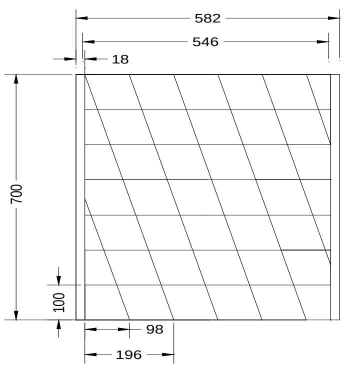

Figure 1: Distribution of teeth on the drum plate surfaceSource: own computation, 2017

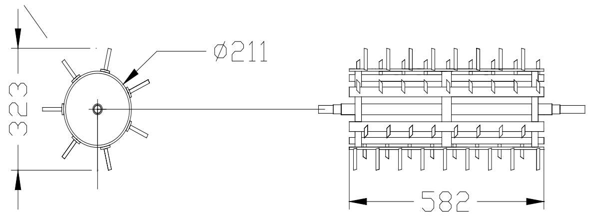

Figure 2: Peg type threshing drum Source: own computation, 2017

2.4 Power required to combing off grains from the straw and glum [6].

The power required to thresh grains from the glum of sorghum heads is expressed as:

$$P = T_t * \omega \tag{5}$$

Where,

P = is the power required (watts)

T_t = torque of the drum (Nm)

ω = angular velocity (rad/s)

$$\omega = \frac{2\,\pi\,N}{60} \tag{6}$$

Where:

N = speed of the threshing drum (rpm)

F = the impact force required to thresh sorghum (N)

r = the distance of point of force application from axis of rotation (m)

The torque resulting from individual force is given by:

$$T\ = F_i\ \times\ r_i \tag{7}$$

Where, F_i and r_i force and radius, respectively

Total torque (T_t) on the drum was calculated as follows:

$$T_t = T \times K_b \quad (8)$$

Where, K_b = the number of pegs on the drum

Torque, $T = F_r$ (9)

Assuming that force acts per unit length of tong, taking force per 10 mm segment of length.

$$F_t = F/10 \text{ mm} = 0.1 \text{ F/mm} \quad (10)$$

The torque resulting from individual force is given by,

$$T = F_i \times r_i \quad (11)$$

Where, F_i and r_i and i^{th} force and i^{th} radius, respectively.

Resultant torque

$$T = F_1 r_1 + F_2 r_2 + \dots\dots + F_i r_i = \sum_{i=1}^{i=n} F_i\, n \quad (12)$$

Where n = number of length segments given by, torque required to combine off grains from straw and glum

This is set by, $P = T_t\,\omega$ (13)

Where ω = angular velocity in rad S^{-1}

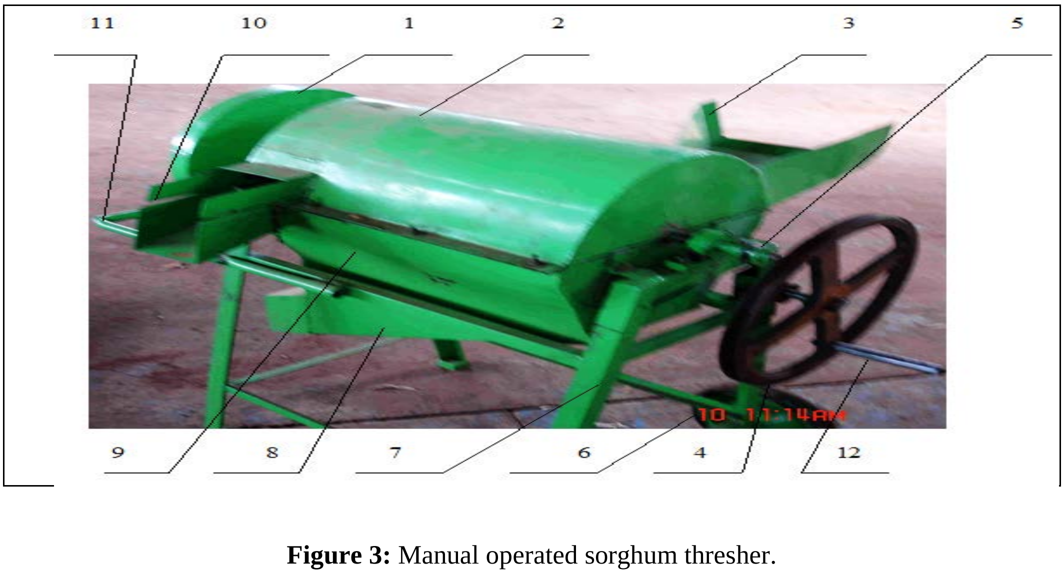

Figure 3: Manual operated sorghum thresher.

1. Flywheel	5.Driven pulley	9. Lower cover
2. Drum upper cover	6. Wheel	10. Straw out let
3. Feeding chute	7. Frame	11. Handle
4. Drive pulley	8. Grain out let	12.Cranking handle

2.4 Experimental site

The performance test of the machine was done in east Hararghe zone, Haramaya district at the place known as *Legeambo*, about 3 km far from Haramaya University. The site is the major sorghum growing area in the region. The experiment was done using the farmer's harvest.

2.5 Experimental method

The thresher was operated manually at constant drum-concave clearance (inlet 25 mm and out let 17 mm) and at moister content ranging between 14-16%. The moister content of the grain was determined by moister tester called Dole –400. Three farmers with body weight of 50 kg, 60 kg and 70 kg and who are engaged particularly in crop production were selected. Three sorghum varieties; *Muira*, *Fendisha* and *Zengada* were considered for the test. Three levels of feed rate *i.e*. 3, 5 and 7 kg/min were used.

The threshing time was recorded by a stopwatch for each test run. The threshed grain was collected at main out let and straw out let. Three samples were taken from each test of main and straw out let. From each sample pure (grains after threshing which were found without glum and breakage), with glum (grains which were after threshing can't separated from glum), broken (grains which were broken due to threshing) and un-threshed (grains at the time of threshing which were not detached from straw panicles) grain were separated, weighed and then, the result was recorded. The above procedure was repeated thrice for all combinations of sorghum variety with weight of farmer and feed rate.

2.5.1 Threshing Efficiency [7]

The formulae used in computing the threshing efficiency, threshing capacity and the percentage damaged grain as follow:

Threshing efficiency (Te): It is the ratio of the mass of threshed sorghum to the total mass of the sorghum heads expressed in percentage and is given as:

$$Te = Mt / Ma \quad (14)$$

Where Te = the threshing efficiency (%)

Mt = mass of threshed sorghum (g)

Ma= the total mass of grain head (g)

The optimum condition for thresher evaluation was set threshing efficiency being 95% and the seeds with glumes not exceeding 5%. The grain containing glumes after having passed through the thresher was considered un-threshed [8].

2.5.2 Threshing capacity

Capacity (kg/h): machine capacity was calculated as follows:

$$C = M/t \tag{15}$$

Where:

C = machine capacity (kg/h)

M = the mass of total yield (kg)

t = the time utilized in threshing operation (h)

2.5.3 Grain damage

Damaged grain was calculated as follows (%):

$$\text{Damaged grain} = Dg/Tg \tag{16}$$

Dg = Mass of damaged grain kg

Tg = Total mass of grain, kg

2.6 Experimental design

The selected experimental design was split-split plot design with three replications. This design was selected to analyze the data that was obtained during the experiment and it fits the treatment factors. The three sorghum varieties were taken as the main plot treatment factors, three farmer's weights as sub-plot treatment factors, and three feed rates sub-plot-plot treatment factor with three replications as blocks. To analyze the treatment factors by split plot design laid down 3^3 factorial combinations with three replications, which result 81 numbers of experiments, i.e. 3^3 x 3 = 81.

3. Result and Discussion

Under MSTAT program by selecting R.C.B.D factorial design the processed data was analyzed and the following results obtained. Coefficient of variation was 1.18% for pure grain, 14.55% for grain with glum and

19.91% for un-threshed grain.

During the test maximum threshing efficiency of 94% was obtained for variety *Muira* at feed rate of 5kg/min and weight of farmer 70 kg. The minimum threshing efficiency 91.81% was observed at feed rate 7kg/min and farmer weight of 50 kg. Grain breakage was negligible. From this we can say that threshing efficiency increased with increasing weight of farmer within a given range. Increasing feed rate increased threshing efficiency to certain limit and then decreased. Further increasing feed rate caused more un-threshed grains on straw panicle and no broken grains (Figure 4).

Regarding grain with glum its highest percentage 5.75 was seen at feed rate of 7 kg/min and farmer weight of 50 kg whereas, the lowest percentage 4.33 was recorded at feed rate of 5 kg/min and farmers weight of 70 kg. And-also, highest un-threshed grain of 3.47% was obtained at feed rate of 7 kg/min and weight of farmers 50 kg. But, the lowest percentage was 1.45 at feed rate 5 kg/min and weight of farmers 70 kg. Grain with glum and un-threshed grain were in contrast with threshing efficiency so that, their value is decreased with increasing of drum speed. (The range analysis shows significant difference value for sorghum variety).

For variety *Fendisha* maximum value threshing efficiency of 94.72% was recorded at feed rate 5 kg/min and farmer weight of 70 kg. The minimum was 92.72% at feed rate of 7 kg/min and farmer weight 50 kg. At feed rate of 7 kg/min and farmer's weight 50 kg, its highest value of grain with glum 5.65% was observed however, the lowest value was 4.28% at feed rate of 5 kg/min and farmer's weight 70 kg. Moreover, its maximum un-threshed grain of 1.6% was observed at feed rate of 7 kg/min and weight of farmers 50 kg. The lowest was 0.99% at feed rate of 5 kg/min and weight of farmers 70 kg. Increasing weight of farmer increases threshing, efficiency within given range. Increasing feed rate results more un-threshed grain and grain with glum (Figure 5). For this variety also grain breakage was negligible.

For variety *Zengada* the maximum threshing efficiency was 94.91% at feed rate of 5 kg/min and farmer weight of 70 kg and the minimum was 93.93 % at feed rate of 7 kg/min and farmer weight of 50 kg. For this variety also increasing weight of farmer increased threshing efficiency to a certain limit as well as, increasing feed rate increased threshing efficiency to certain limit and then decreased (Figure 6). In related to this, the highest percentage of grain with glum was 4.89 at feed rate 7 kg/min and weight of farmers 50 kg also, the lowest percentage was 4.38 at feed rate 5 kg/min and weight of farmers 70 kg.

In the case of un-threshed grain, its highest value 1.49% was observed at feed rate of 7 kg/min and farmer weight 50 kg whereas, its lowest value 0.67% was at feed rate of 5 kg/min and weight of farmers70kg. The highest value of threshing efficiency was observed for variety *Zengada* because the bonding force between the grain and ear head (glum) is less as compared to that of the other two.

In the same way for this variety also increasing feed rate first increased the threshing efficiency to a certain maximum and then decreased. With the given range of farmers weight threshing efficiency increased with increasing farmer's weight. For variety of *Zengada* as well, grain damage was negligible.

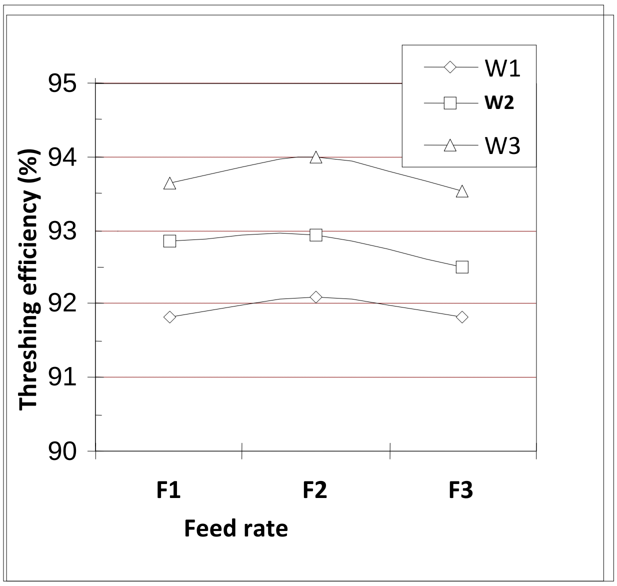

Figure 4: Threshing efficiency of the machine for *Muira* variety as affected by the feed rate and operator weight.

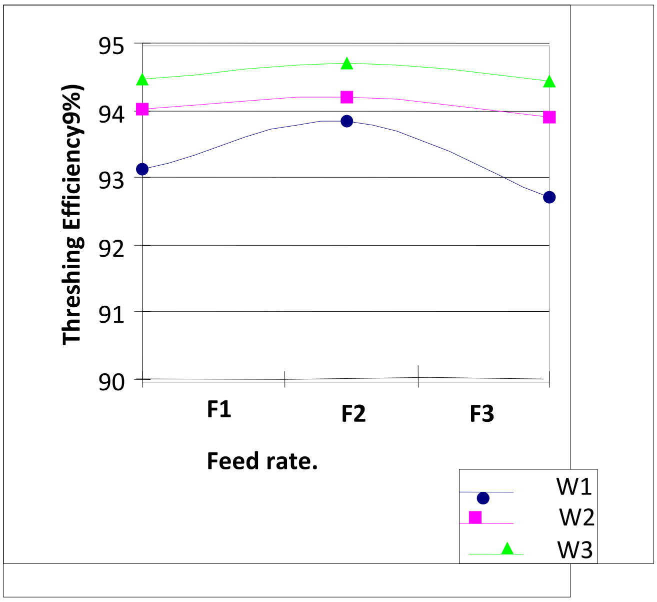

Figure 5: Threshing efficiency of the machine for *Fendisha* variety as affected by the feed rate and operator weight

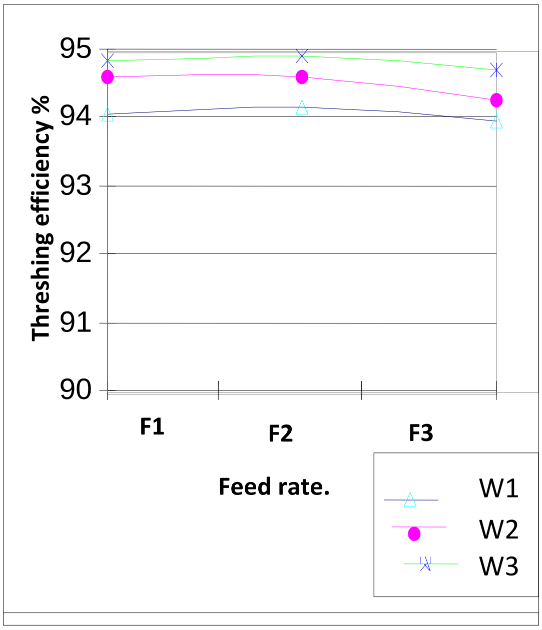

Figure 6: Threshing efficiency of the machine for *Zengada* variety as affected by the feed rate and operator weight.

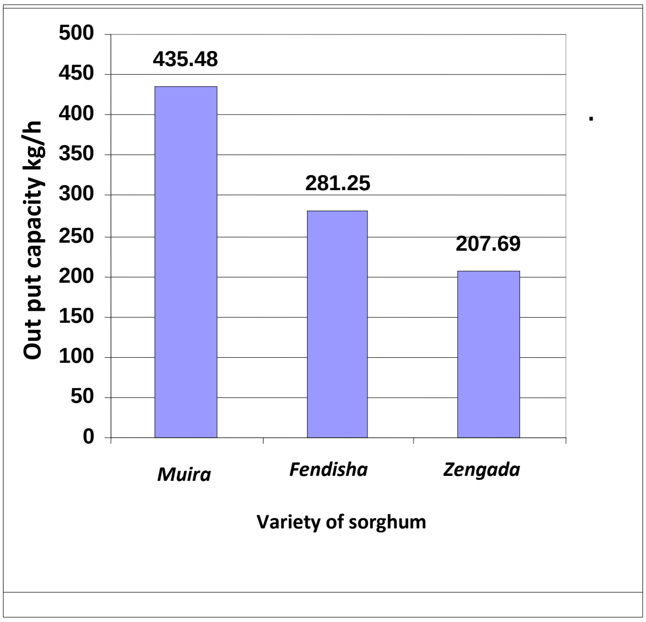

Figure 7: Average output capacity of the machine kg/hour.

The average output capacity of this machine was recorded 435.48, 281.25 and 207.69 kg/h for *Muira*, *Fendisha* and *Zengada* respectively (Figure 7). *Muira* showed the highest average output per hour due to its compact head containing more amount of grain. Moreover, its straw and chuff are short in length, so that it can be thrown easily through straw out let and was not warped on the drum unlike that of *Zengada*.

4. Conclusion and Recommendation

A few numbers of threshers have been in existence for quite a long time, but due to high acquisition price and poor appropriation, they have not been adopted to a significant extent.

On the other hand, the developed hand operated sorghum thresher found to be better in threshing capacity (average 3.37 qt/h) as compared to threshing done by hand 0.15-0.40 qt/h The obtained average threshing efficiency (93.72%) is promising even though, the optimum condition for threshing evaluation was set for threshing efficiency being 95%. At the time of threshing breakage of grain was negligible.

As the machine is hand operated it is tire some for the people to use it continuously and thus the capacity and efficiency will be affected (reduced) in prolonged use. To solve this problem and to improve the performance of the machine further, incorporation of small engines (5hps) which are available in the market appears to be a possibility. At this time such engines cost between 5,000-7,000 birr and could lift the cost of the machine to 13,000 – 15,000 birr which is affordable by many farmers individually or in group. Thus it is advisable to extend this work by including engine power supply and determine the most economical and efficient speed of operation.

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