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Modification and Testing of Replaceable Drum Multi-Crop Thresher

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Abstract

In order to help small scale agriculture increase its contribution ensure food security, threshing operation and its subsequent loss followed is among points requiring proper attention and that generally accounts about 6% cereal crops loss in Ethiopia. In this study emphasis was given to avail compact multi-crop thresher accomplishing maize shelling by modifying the existing crop threshers to accommodate replaceable bar type drum besides units for threshing wheat, teff, sorghum and barley using peg type drum. The thresher operates on the principle of axial flow movement of the material. It was tested on maize, wheat, teff, sorghum and barley crops. The values for highest visible grain damage, optimum thresher's output capacity, threshing and cleaning efficiency were observed at the maximum threshing drum speeds of 910, 1600, 1550, 1600 and 1690 rpm for maize, wheat, teff, sorghum and barley crops respectively. These threshing drum speeds under grain moisture content of 13%, 9.6%, 7.6%, 9.8% and 12.1% wet basis (w.b) indicated optimum threshing performance for the mentioned crops respectively. The mean output capacities of 2526.31 kg/hr, 386.98 kg/hr, 237.2 kg/hr, 780.68 kg/hr and 121.62 kg/hr for average grain-straw (cob) ratios of 1:0.36, 1:2.22, 1:2.56, 1:0.21 and 1:1.29 were recorded for maize, wheat, teff, sorghum and barley crops respectively.

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All these capacity was attained at maximum drum speed of 910, 1600, 1550, 1600 and 1690 revolutions per minute (rpm). The threshing/shelling and cleaning efficiency obtained at these drum speeds was 99.39% and 99.79%, 100% and 98.57%, 98.97% and 64.77%, 98.63% and 98.56% and 100% and 69.33% for maize, wheat, teff, sorghum and barley crops respectively. The corresponding kernel damage and total grain loss was 0.35% and 5.5%, 2.2% and 4.43%, 0% and 2.87%, 1.12% and 3.97%, and 0.1% and 0.1% for maize, wheat, teff, sorghum and barley crops respectively. The result shows that at feeding rate of 55 kg/min, 9 kg/min, 5 kg/min, 16 kg/min and 6 kg/min and maximum drum speeds of 910, 1600, 1550, 1600 and 1690 rpm the thresher had threshing efficiency of 99.39%, 100%, 98.97%, 98.63% and 100% at grain moisture content of 13%, 9.6%, 7.6%, 9.8% and 12.1% (w.b.) for maize, wheat, teff, sorghum and barley crops respectively.

Keywords: Replaceable; Drum; Multi-crop thresher; Maize sheller; Output Capacity; Efficiency;

1. Introduction

Agriculture is the mainstay of Ethiopia's economy that provides all the necessary dietary foods, raw materials for food industries and quality products for export market. The country's agricultural potential for food production is known to be immense and over 90% of its export earnings come from this sector. Available sources indicate that a total of 11.6 million tons of cereals, 1.3 million ton of pulses and 0.5 million ton of oil crops were estimated produced annually [1]. Despite the large production, estimates suggest that the magnitude of post-harvest loss in Ethiopia is tremendous ranging between 5% and 19% for maize and 5% to 26% for other cereals and pulses [2, 3]. According to the African Postharvest Losses Information System, postharvest losses for teff were estimated 12.3%, 11.6%, 9.9% and 16.8% for teff, sorghum, wheat and maize respectively [4].

Recent study conducted by Addis Ababa University and the Swiss Agency for Development and Cooperation (SDC) also showed that postharvest losses can be as high as 30% to 50% [4]. Out of postharvest loss estimated, the threshing/shelling loss for cereals is estimated to reach up to 6% in Ethiopia [5]. In order to help small scale agriculture increase its contribution in ensuring food security in the country, all aspects of production including harvest, threshing and post harvest handling of the produce need equal and proper attention [3]. Ethiopian farmers are engaged in farm works the whole year beginning with land preparation to sowing, cultivating, harvesting, transporting, shelling/threshing and storing. Threshing is one of these activities which is a slow and tedious process. Threshing or shelling is the process of separating the grain from the seed heads, panicles, cobs or pods of the crops [6, 7]. It is important to minimize the damage done to grain during threshing as damaged grain is much more prone to attack by insects and fungi. Consequently, techniques that crush and damage grains such as beating with sticks or trampling by cattle are not recommended. Traditional threshing of crops like wheat, barley and sorghum is one of the time consuming, laborious and in which grain loss occurs [6].

To solve this problem a number of appreciable works have been done by different bodies among which Bako maize sheller and Asella wheat barley threshers are the prominent one since long time. However, the high cost of the machines and their engines together with their weight which is as heavy up to 302 kg compared to 107 kg with peg type drum and 121 kg with bar type of the currently developed replaceable drums multi-crop thresher was reported to have affected its adoption rate. In addition, the undulating topography of south-western Ethiopia and small and fragmented land ownership of the farmer of this area plays a great role in limiting the adoption rate of the mentioned technologies. Maize, teff, wheat, barley and sorghum are among crops produced in south western Ethiopia and farmers are obliged to have one machine for maize and the other for teff, sorghum, wheat and barley threshing.

In order to have both machines they need to spend an initial capital of up to 150, 000 ETB which is big amount compared to the capacity of most farmers in the area whereas the modified one costs up to 37,000 ETB. To solve the above problems, manufacturing a machine which is affordable, portable, combine the work of two machines in to one and that can use engine power (10hp diesel) available in the market at reasonable price was proposed. Accordingly a multi-crop thresher was developed with the following advantages.

- Smaller in size so that it can be transported to the needed area with 2-4 persons comfortably
- Can thresh teff, wheat, barley and sorghum using only cylindrical drum and
- Can shell maize using replaceable triangular bar type drum interchangeably
- Can be powered using engine power (10hp) which are available on the market at reasonable prices (currently at about 10,000 to 12,000 ETB)
- It can be manufactured at small scale manufacturer level

Objective of the study

- To modify a portable multi-crop thresher to include maize shelling
- To test the performance of the developed multi-crop thresher.

2. Materials and Methods

Observations and performance tests was done in the radius of 30 km, 250 km and 650 km from Jimma in Kersa, Tulu bolo and Arsi Negelle woredas respectively during threshing season of 2014. Testing of replaceable drum thresher (Figure 1) was conducted on five different crop types namely wheat, teff, maize, sorghum and barley. The test was carried out on selected farmers farm sites who allowed use their crops of 2014 harvesting season. Field evaluation took place between November to February 2014 in Kersa, Becho and Arsi negelle woredas of Jimma, East-western Shewa and Shashemene zones respectively.

The thresher with dimension (Length = 1.10m; Width = 0.7m and Height =1.08m) consists of two replaceable threshing units (Figure 2). The threshing/shelling units of the thresher operates on the principle of axial flow movement of the material by the impact of a threshing drum equipped with a number of metallic bars and pegs mounted on its periphery. The crop mass is brushed into grains and cob/fine straw, which resulted in well chopped material for animal feed and whole cob in case of maize shelling. While being threshed, the material undergoes a spiral motion in a closed cylindrical casing the part of which is beating bars for maize shelling and series of pegs for wheat, teff, sorghum and barley crops threshing. Finally, the grain and fine straw drops through the perforated concave, rolls over inclined sheet metallic pan which leads the grain out while the straw is delivered to the straw outlet where it is discharged out. The parameters considered were output capacity, threshing efficiency, grain damage and grain loss. The parameters were compared at 3 levels of threshing drum speed (rpm) repeated three times, fixed concave clearances of 4.5 cm for wheat, teff, sorghum and barley crops and 7 cm for maize at moisture contents of 13%, 9.6%, 7.6%, 9.8% and 12.1% (w.b.) for maize, wheat, teff, sorghum and barley crops respectively. Five types of cereal crops namely maize, wheat, teff, sorghum and barley cultivated and conventionally hand harvested, piled for sun drying by the farmers themselves were the crop material used to evaluate the thresher. The crops used were ones dried in the sun until its moisture content was reduced to allowable level for threshing conditions as practiced by the local farmers.

Figure 1: Replaceable Drum multi-crop Thresher

Figure 2: the threshing drums

2.1 Performance Evaluation

The modified machine was installed on level surface and sufficient quantity of crop materials were taken for evaluation. A combination of feed rate and cylinder speed at two levels for teff crop and at three levels for wheat, maize, sorghum and barley was employed. Wheat, teff and barley bundles, maize cob and sorghum panicles were fed in to threshing unit and the threshed materials was collected at the outlet which was cleaned and weighed. The portion of the material containing un threshed grain was separated from straw and weighed after hand threshing and cleaning in order to determine the threshing efficiency in terms of percentage of the total grain recovered. The thresher was evaluated at three different levels of cylinder speed and feed rate, fixed concave clearance of 4.5 cm for wheat, teff, sorghum and barley crops and 7 cm for maize at moisture contents of 13, 9.6, 7.6, 9.8 and 12.1% (w.b.) for maize, wheat, teff, sorghum and barley crops respectively. The machine was driven by 10hp diesel engine at a varying cylinder speed ranging from 430 to 1690 rpm for different test crops. The output capacity, threshing efficiency, cleaning efficiency and kernel breakage were evaluated.

Table 1: Factors and level values considered on threshing different crops.

Factors	Crop types considered and factors value				
	Wheat	Teff	Maize	Sorghum	Barley
Drum speed (rpm)	970, 1300, 1600	1250, 1550	430, 680, 910	840, 1260, 1600	880, 1200, 1690
Feed rate (kg/min)	9	5	55	16	6
Grain Moisture content (%w.b)	9.6	7.6	13	9.8	12.1
Concave-drum clearance (cm)	4.5	4.5	7	4.5	4.5

2.2 Evaluation of Physical Parameters

2.2.1 Grain moisture content

The grain moisture content of wheat, maize and sorghum was measured using digital moisture meter (DRAMINSKI GRAIN MASTER, GM 667, POLAND) with grinding the samples taken during threshing. Each time the digital moisture meter was calibrated using grain samples whose moisture content was determined by digital hot air drying oven (DHG-9055A) following the instruction in the instrument manual [8]. The moisture content of teff grain was determined using drying oven. The grain samples were dried at 130°C for 18 hours [9, 10]. The weight loss of the samples was recorded and the moisture content determined in percentage. This was replicated twice and mean was taken. The moisture content was then calculated as:

$$MC\,(wb) = \frac{W_i - W_d}{W_i} * 100$$

Where

MC_{wb} = Moisture content, wet basis, %.

Wi = Initial weight of sample, kg.

Wd = Dried weight of sample, kg

2.2.2 Broken/damaged grain

From each of the threshed crop sample of about 550g kernels were randomly selected. All physically damaged/broken grains were visually observed, manually sorted and weighed using digital balance. Damage due to mechanical threshing was determined as the ratio of weight of the actual damaged kernels to the weight of a sample taken [11, 12].

$$\text{Broken grain (\%)} = \frac{\text{Weight of broken (damaged) grains (g)}}{\text{Weight of sample taken (g)}}$$

2.2.3 Grain-Straw Ratio

Grain-straw ratio was determined following procedures of [13, 14]. From the material which is to be threshed, 3 samples were randomly taken of approximately 0.5 kg each. The samples were placed in sealed plastic containers and taken to the laboratory where the grains and straw were separated by hand. The straw and grains from each sample were kept paired. After weighing, the samples were oven dried at 130°C for 15 hours and then reweighed. The moisture content (M) on dry basis, %:-

$$M = \left(\frac{\text{Weight of wet sample (g)} - \text{Weight of dry sample (g)}}{\text{Weight of dry sample (g)}}\right) * 100$$

After determining the weight of dry samples the results of the paired samples were used to calculate the mean Grain/Straw-ratio.

The Grain-Straw ratio (K) was calculated as follows:-

$$K = \frac{\text{Weight of dry grain (g)}}{\text{Weight of dry Straw (g)}}$$

2.2.4 Maize Grains-Spent Cob Ratio

Maize grain/Straw-ratio was also determined following procedures of [13, 14]. From the material which is to be shelled, 3 cobs were randomly selected. The samples were placed in sealed plastic containers and taken to the laboratory. After weighing, they were oven dried at 103^{o}C for 72 hours and then re-weighed. The moisture content on dry basis, %:-

$$M = \left(\frac{\text{Weight of wet sample (g)} - \text{Weight of dry sample (g)}}{\text{Weight of dry sample (g)}}\right) * 100$$

After determining the weight of the dry samples, the cobs and maize grains are manually separated and weighed. The grains-Spent Cob Ratio (K):-

$$K = \frac{\text{Weight of dry maize grains (g)}}{\text{Weight of dry cobs (g)}}$$

2.2.5 Drum speed

During the test period, digital contact type tachometer (DT-838C) was used to measure the threshing cylinder speed (rpm).

2.2.6 Determination of output capacity, Threshing and cleaning efficiency and percentage grain loss

Threshing capacity, threshing and cleaning efficiency of the thresher were calculated following the procedure of [13].

Total Grain Input

$$\text{Total grain input (kg)} = A + B + C$$

Where; A= Weight of threshed grain at main outlet per unit time (kg)

B= Weight of threshed grain at all other outlets per unit time (kg)

C= Weight of un-threshed grain at all outlets per unit time (kg)

Output Capacity (kg/h)

$$\text{Output capacity(kg/hr)} = \frac{\text{Weight of threshed grain at main outlet per unit time (kg)}}{\text{time of test runs (min)}} * 60$$

Percentage of Un-Threshed Grain

$$\text{\% Unthreshed grain (\%)} = \frac{\text{Weight of Unthreshed grain at all outlets per unit time (kg)}}{\text{Total grain input (kg)}} * 100$$

Threshing Efficiency

$$\text{Threshing efficiency} = 100 - \text{Percentage of unthreshed seeds}$$

Cleaning Efficiency

$$\text{Cleaning efficiency}\,(\%) = \frac{\text{Weight of whole grain at main outlet per unit time (Kg)}}{\text{Weight of whole material at main outlet per unit time (kg)}} * 100$$

Percentage of Blown Grains

$$\%\ \text{Blown grain} = \frac{\text{Weight of whole grains collected at chaff and straw outlets perunit time (kg)}}{\text{Total grain input (kg)}} * 100$$

Percentage Grain Loss

$$\%\ \text{Grain loss} = \frac{\text{Wt. of whole, damaged and unthreshed grains at chaff \& straw outlets per unit time (kg)}}{\text{Total grain input (kg)}} * 100$$

2.3 Method of Data Analysis

Completely randomized design (CRD) was employed on the treatment factor replicated three times. The collected data was subjected to analysis of variance (ANOVA). Significance of the mean difference was tested by LSD and significance was accepted at 5% level.

3. Results and Discussion

The performance of the thresher was evaluated at fixed concave clearance of 4.5 cm for wheat, teff, sorghum and barley crops and 7 cm for maize and point moisture contents, varying threshing drum speeds and feed rates in terms of threshing capacity, threshing efficiency, cleaning efficiency, kernel damage and grain loss. Tables 2, 3, 4, 5 and 6 give the results of the performance tests.

Threshing capacity and kernel damage of multi-crop thresher on wheat crop

The effect of drum speed on threshing capacity and grain damage of wheat crop is presented in Table 2. The drum speed showed highly significant ($P<0.01$) effect on threshing capacity. Comparison among means using LSD showed that at all drum speeds the capacity was significantly different throughout. The capacity increased from 69 kg/hr at 970 rpm to 386.98 kg/hr at maximum drum speed of 1600 rpm and average grain-straw ratios of 1:2.22. Maximum threshing capacity of 386.98 kg/hr was obtained 1600 rpm and feeding rate 9 kg/min. With an increase in drum speed the threshing capacity kept increasing. This is due to increase in impact force required for crop threshing with increase in drum speed. Table 2 shows drum speed had significantly ($P<0.05$) affected grain damage. Seed damage increases from 0.2% at drum speed of 970 rpm to 2.2% at 1600 rpm. The higher the drum speed the higher was the grain damage (Table 2). Increment in grain damage could be due to increased beating/impact of the seeds by a rotating peg of the drum. The maximum damage of 2.2% occurred at drum speed of 1600 rpm.

Table 2: Effect of cylinder speed on performance of multi-crop thresher on wheat crop

Cylinder Speed (rpm)	Threshing Capacity (kg/hr)	Threshing Efficiency (%)	Cleaning Efficiency (%)	Kernel Damage (%)	Grain Loss (%)
970	69[c]	99.53 [b]	68.77[b]	0.2[a]	4.04
1300	210.5 [b]	99.83[ba]	49.67[c]	1.7[b]	4.57
1600	386.98 [a]	100 [a]	98.57[a]	2.2[c]	4.43
LSD (P<0.05)	141.5[*]	0.47[*]	19.1[*]	0.5[*]	NS

[*] = Significant at 5% level; NS= non significant at 5% level.

Threshing efficiency and total grain loss of wheat crop

Table 2 shows the effect of drum speed on threshing efficiency and total grain loss of wheat crop. Test results showed that the mean threshing efficiency recorded for the effects drum speed was statistically highly (P<0.01) different. Maximum and minimum means of threshing efficiency were 100 and 99.53% respectively at 1600 and 970 rpm. Threshing efficiency was increasing with increase in drum speed. In Figure 4 the effect of drum speed on grain losses was shown. Test results indicated that the grain losses had not significantly affected by drum speed throughout. However and increasing trend of total grain loss was observed as drum speed increased from minimum of 970 rpm to maximum of 1600 rpm.

Threshing capacity and kernel damage of multi-crop thresher on teff crop

The effect of drum speed on threshing capacity and grain damage of teff crop is presented in Table 3. The drum speed showed significant (P<0.05) effect on threshing capacity. Comparison among means using LSD showed that at all drum speeds the capacity was significantly different. The capacity increased from 116.12 kg/hr at 1250 rpm to 237.20 kg/hr at maximum drum speed of 1550 rpm and average grain-straw ratios of 1:2.56. Maximum threshing capacity of 237.20 kg/hr was obtained at 1550 rpm and feeding rate of 5 kg/min. With an increase in drum speed the threshing capacity kept increasing. This is due to increase in impact force required for crop threshing with increase in drum speed. The result also shows drum speed had no effect on grain damage. Seed damage was found to be 0% at both drum speeds (1250 and 1550 rpm). This could have been due to smallness of size and mass of teff grain.

Threshing efficiency and total grain loss of teff crop

Table 3 shows the effect of drum speed on threshing efficiency and total grain loss of teff crop. Test results showed that the threshing efficiency was highly significantly (P<0.01) affected by drum speed. Maximum and minimum means of threshing efficiency were 98.97% and 97.43 % respectively at drum speeds of 1550 and 1250 rpm respectively. Threshing efficiency was increasing with increase in drum speed. The drum speed had significantly (P<0.01) different effect on grain losses. The grain losses decreased from 24.23% at 1250 rpm to

2.87% at 1550 when drum speed increased from 1250 rpm to 1550 rpm. Decrease in grain loss could be due to reduction in percentage of un threshed and blown grains (which are components of total grain loss) with increase in drum speed.

Table 3: Effect of cylinder speed on performance of multi-crop thresher on teff crop

Cylinder Speed (rpm)	Threshing Capacity (kg/hr)	Threshing Efficiency (%)	Cleaning Efficiency (%)	Kernel Damage (%)	Grain Loss (%)
1250	116.12 ^{b}	97.43 ^{b}	58.77 ^{b}	0	24.23 ^{b}
1550	237.20 ^{a}	98.97 ^{a}	64.77 ^{a}	0	2.87 ^{a}
LSD (P<0.05)	121.10 *	1.54 *	6.00 *	NS	21.36 *

* = Significant at 5% level; NS= non significant at 5% level.

Threshing capacity and kernel damage of multi-crop thresher on sorghum crop

The effect of drum speed on threshing capacity and grain damage of sorghum crop is presented in Table 4. The drum speed showed significant (P<0.05) effect on threshing capacity. Comparison among means using LSD showed that at drum speed of 840 rpm the capacity was 840 kg/hr while at speed of 1260 rpm and 1600 no statistically different capacity was recorded which are 535.29 kg/hr and 780.68 kg/hr respectively which are the maximum threshing capacity achieved at feeding rate of 12kg/min and 16kg/min respectively. The average grain-straw ratio of the crop was 1:0.21. With an increase in drum speed from 840 rpm to 1260 and 1600 rpm the threshing capacity had increased though no significantly different between the latter two drum speed. This is due to increase in impact force required for crop threshing with increase in drum speed. Table 4 shows drum speed had significantly (P<0.05) affected grain damage. Seed damage increases from 0.4% at drum speed of 840 rpm to 1.12% at 1600 rpm respectively. However, no statistically different (P<0.05) mean was recorded between grain damage at 840 rpm and 1260 rpm. The higher the drum speed the higher was the grain damage. However, drum speed increment to 1260 and 1600 rpm never affected grain damage. Increment in grain damage observed above drum speed of 1260 rpm could be due to increased beating/impact of the seeds by a rotating peg of the drum. The least grain damage of 0.4% and 0.5% occurred at drum speed of 840 rpm and 1260 rpm.

Table 4: Effect of cylinder speed on performance of multi-crop thresher on sorghum crop

Cylinder Speed (rpm)	Threshing Capacity (kg/hr)	Threshing Efficiency (%)	Cleaning Efficiency (%)	Kernel Damage (%)	Grain Loss (%)
840	52.53 ^{c}	26.62 ^{c}	17.22 ^{c}	0.4 ^{a}	9.2 ^{c}
1260	535.29 ^{a}	92.69 ^{b}	85.86 ^{ba}	0.5 ^{a}	6.47 ^{b}
1600	780.68 ^{a}	98.63 ^{a}	98.56 ^{a}	1.12 ^{c}	3.97 ^{a}
LSD (P<0.05)	482.8 *	5.93 *	68.64 *	0.62 *	2.5 *

[*] =Significant at 5% level.

Threshing efficiency and total grain loss of sorghum crop

Table 4 shows the effect of drum speed on threshing efficiency and total grain loss of sorghum crop. Drum speed significantly (P<0.05) affected the threshing efficiency. The threshing efficiency increased with differing mean from minimum value of 26.62% at 840 rpm to maximum value of 98.63% at 1600 rpm. The result showed for each increment in drum speed the threshing speed was observed to rise. This implies the increment in impact force that increased with drum speed resulted in better detachment of seeds from its panicle hence better threshing efficiency.

Threshing capacity and kernel damage of multi-crop thresher on maize crop

The effect of drum speed on threshing capacity and grain damage of maize crop is presented in Table 5. The result on effect of drum speed on the capacity indicated that the threshing capacity was significantly (P<0.05) affected by drum speeds (Table 5). Mean values of threshing capacity obtained at 680 rpm and 910 rpm were not different. The capacity increased from 1956.51 kg/hr at drum speed of 430 rpm to 2526.1 kg/hr and 2526.31 kg/hr at 680 rpm and 910 rpm. Maximum threshing capacity of 2526.31 kg/hr was obtained 910 rpm and feeding rate 55 kg/min at an average grain-cob ratio of 1:0.36. With an increase in drum speed to 680 rpm and 910 rpm, the threshing capacity increased which might be due to increase in impact force required for crop threshing with increase in drum speed. Table 5 shows drum speed had highly significantly (P<0.01) affected grain damage. Seed damage increases from 1.87% at drum speed of 430 rpm to 0.35% at 910 rpm. Table 5 shows, the higher the drum speed the higher was the grain damage. Increment in grain damage could be due to increased beating/impact of the seeds by a rotating peg of the drum. The maximum damage of 5.5% was recorded at drum speed of 910 rpm.

Table 5: Effect of cylinder speed on performance of multi-crop thresher on maize crop

Cylinder Speed (rpm)	Threshing Capacity (kg/hr)	Threshing Efficiency (%)	Cleaning Efficiency (%)	Kernel Damage (%)	Grain Loss (%)
430	1956.51^{b}	81.86^{c}	84.2^{c}	0.1^{a}	1.87^{a}
680	2438.1^{a}	99. 60^{a}	87.93^{ba}	0.12^{a}	2.17^{b}
910	2526.31^{a}	99.39^{b}	99.79^{a}	0.35^{b}	5.50^{c}
LSD (P<0.05)	481.58*	17.53*	11.86*	0.23*	3.33*

* = Significant at 5% level.

Threshing efficiency and total grain loss of maize crop

Table 5 shows the effect of drum speed on threshing efficiency and total grain loss of maize crop. Drum speed showed highly significant (P<0.01) effect on threshing efficiency. Comparison among means using LSD showed that at all drum speeds the threshing efficiency was significantly different throughout changes in drum speed. The threshing efficiency increased from 81.86% at 430 rpm to 99.6% at maximum drum speed of 680 rpm. The efficiency then decreased to 99.39% at 910 rpm. With an increase in drum speed the threshing efficiency kept increasing till 680 rpm after which it showed a slight reduction to 99.39% at 910 rpm. Drum speed had significantly (P<0.05) affected grain losses (Table 5). The grain losses increased from 1.87% to 5.5% at an increased drum speed from 430 rpm to 910 rpm.

Threshing capacity and kernel damage of multi-crop thresher on barley crop

The effect of drum speed on threshing capacity and grain damage of barley crop is presented in Table 6. The drum speed showed no statistically significant (P>0.05) effect on threshing capacity. Though not statistically different the capacity showed an increasing trend from 53.69 kg/hr at 880 rpm to 121.62 kg/hr at maximum drum speed of 1690 rpm and average grain-straw ratios of 1:1.29. Table 6 shows drum speed had significantly (P<0.05) affected grain damage. Seed damage increases from nil at drum speed of 880 rpm to 0.1% at 1690 rpm. The result shows, the higher the drum speed the higher was the grain damage throughout changes in drum speed (Table 6). Increment in grain damage could be due to increased impact of the seeds by a drum. The maximum damage of 0.1% occurred at drum speed of 1690 rpm.

Table 6: Effect of cylinder speed on performance of multi-crop thresher on barley crop

Cylinder Speed (rpm)	Threshing Capacity (kg/hr)	Threshing Efficiency (%)	Cleaning Efficiency (%)	Kernel Damage (%)	Grain Loss (%)
880	53.69	85.31	61.66	0^a	0.61
1200	105.77	99.92	65.59	0.04^b	0.24
1690	121.62	100	69.33	0.1^c	0.1
LSD (P<0.05)	NS	NS	NS	0.04^*	NS

* =Significant at 5% level; NS= non significant at 5% level.

Threshing efficiency and total grain loss of barley crop

Table 6 shows the effect of drum speed on threshing efficiency and total grain loss of barley crop. Comparison between means showed that the threshing efficiency and grain loss did not differ significantly (P>0.05) between all of the drum speeds 880 rpm, 1200 rpm and 1690 rpm.

4. Conclusion

The result showed that threshing efficiency increased with increase in cylinder speed. It was found in the range of 81.86 to 99.39%, 99.53 to 100, 97.43 to 98.97%, 26.62 to 98.63% and 85.31 to 100% for maize wheat, teff, sorghum and barley crops respectively. At recommended maximum cylinder speeds of 910, 1600, 1550, 1600 and 1690 rpm, the maximum output of the thresher was 2526.31 kg/hr, 386.98 kg/hr, 237.2 kg/hr, 780.68 kg/hr and 121.62 kg/hr respectively. The threshing drum speed was observed to significantly affect the output capacity, threshing efficiency, grain damage and grain losses during threshing. Threshing drum speed for the tested crops to obtain higher output capacity, threshing efficiency, lower grain damage and grain losses was attained at 910, 1600, 1550, 1600 and 1690 rpm and feeding rate of 55 kg/min, 9 kg/min, 5 kg/min, 16 kg/min and 6 kg/min for maize, wheat, teff, sorghum and barley crops respectively. The capacity of the thresher ranged from 1956.51 to 2526.31 kg/hr, 69 to 386.98 kg/hr, 116.12 to 237.2 kg/hr, 52.53 to 780.68 kg/hr and 53.69 to 121.62 kg/hr at minimum and maximum drum speeds for maize, wheat, teff, sorghum and barley crops respectively.

The threshing efficiency was found to be in the range of 81.86 to 99.39%, 99.53 to 100%, 97.43 to 98.97%, 26.62 to 98.63%, and 85.31 to 100% at minimum and maximum drum speeds for maize, wheat, teff, sorghum and barley crops respectively. The maximum value of visible grain damage was 2.2% and 3.97% recorded on wheat and sorghum crops respectively at drum speed of 1600 rpm. The thresher performed better at maximum cylinder speeds and feed rate. The output of the thresher was best at the highest threshing/shelling speed and it requires at least three persons to operate during threshing. Means of damaged grain across threshing speeds on teff crop and percentage of grain loss on wheat and barley crops were not statistically significant between changed threshing drum speeds.

5. Recommendations

- The thresher should be operated at around cylinder speed of 910, 1600, 1550, 1600, 1690 rpm for maize, wheat, teff, sorghum and barley crops respectively. This will result in higher threshing capacity, threshing and cleaning efficiency, and reasonable visible grain damage and grain loss for wheat, teff, sorghum and barley crops.
- Supplementing the thresher with cleaning system without causing it lose much of its portability is recommended as it resulted in relatively low cleaning efficiency for teff and barley crops.
- Few participant farmers during the field evaluation of the thresher were seen to show interest regarding the technical performance of the thresher; it is now recommended for scaling up and further dissemination with its current performance.

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