

Performance Evaluation of Sugarcane Stripper for Trash Recovery

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Abstract- The limited resources of fossil fuels and increasing prices of electricity has resulted severe energy crises in Pakistan. Being an agricultural country, Pakistan has huge potential of biomass that can be used as alternate energy source. The shortage of energy has led to search for alternate sources of energies. In, Pakistan sugarcane trashes can be used as a source of biomass for energy production. The manual removal of trash is a labor extensive and time wasting process. In the meanwhile, sugar cane stripper can be used to remove trashes from the sugarcane stalks. A sugarcane stripper was designed and developed by Agricultural Mechanization Research Institute (AMRI) Wing, Faisalabad. In this study, the performance evaluation of sugarcane stripper has been carried out for the recovery of sugar cane trashes for energy production as well as to improve the socio-economic condition of the rural community. The experiments were conducted on three varieties of sugarcane V₁ (COL1148), V₂ (FH-237), V₃ (MO-240), three sprocket speeds NS₁ (250 rpm), NS₂ (200 rpm), NS₃ (150 rpm) and three blower speeds NB₁ (750 rpm), NB₂ (1000 rpm) NB₃ (1500 rpm). The cost comparison of sugarcane stripper has also been carried out in comparison with conventional method of de-trashing. The result shows that the best combination to get maximum sugarcane stripper efficiency of 79% was using sprocket speed of NS₃ (150rpm) and blower speed of NB₃ (1500rpm) for all varieties of sugarcane. The operation cost of sugarcane stripper and conventional method were calculated as Rs. 17120 and Rs. 19200 respectively.

Keywords—Sugarcane stripper, Sprocket speeds, Blower speeds, Trash removal rate.

1. Introduction

Agriculture sector plays an important role in the economy of Pakistan. The share of agriculture to the GDP of Pakistan is nearly 21%. Agriculture plays a vital role in reducing poverty, ensuring food security, improving overall economic growth, and strengthening industrial sector. Sugarcane is one of the major crops in Pakistan and used for the production of sugar on large scale. It generates income and employment for the farming community. The share of sugarcane in agriculture and GDP of Pakistan is around 0.8 and 3.7% respectively. The cultivated area of sugarcane during 2011-12 was almost 1,046 thousand hectares that was 5.9% higher as compared to the last year. The sugarcane production was 58 million tons during 2011-12 compared with 55 million tons in the last year. The main factor contributing the production is timely availability of inputs (Economic Survey of Pakistan, 2011-12).

As a consequence of the increasing energy demands throughout the world, biomass is considered as an important

source of alternative energy because of the depleting reserves of fossil fuels and their impact on the environment in terms of Green House Gas (Botha, 2009; Duku, 2011; Norris, 2011).

Sugarcane stalks at the time of harvesting is composed of 8% cane-tops, 15% green leaves, 70% stalks for milling, 7% dry leaves and the remaining non-sugar bearing component of sugarcane called as sugarcane trash (Evans and Hardy, 1946; Rozeff, 1994). The tops and leaves (trash) of the sugarcane contain around one-third of the energy content those are generally not recovered from the field due to the burning of trash prior to the harvesting. Paul *et al.* (2007) stated that the potential of energy in the dry sugarcane trash is about 28% and has the potential to overcome 50% of the energy crises in India. Leal (2007) stated that due to increasing prices of coal and electricity, sugarcane trash can be incorporated in the existing energy scheme because it is estimated that total primary energy content of sugarcane that is less than 30% can be converted into two forms of energy i.e. electricity and ethanol.

Nearly 90% of sugarcane biomass is burnt in the fields all over the world (Smithers, 2014). A major cause of air pollution and greenhouse gas effect is the open field burning of sugarcane trash. Furthermore, the energy contents of sugarcane trashes (leaves) are lost during burning process. The proper utilization of sugarcane trash as a fuel source would eliminate the need for open field burning prior to sugarcane harvesting along with reducing the dependence on primary energy sources because sugarcane trash has a great potential for energy production. The fast and effective recovery of trash can be carried out using sugarcane stripper machines. Sugarcane trash also has a high amount of potassium, silica, chlorine and other alkali and alkaline earth metals among a long list of herbaceous crops (Paes *et al.*, 2006).

Since, sugarcane is a source of sugar making, so to get a good quality sugar, the sugarcane stalks should be de-trashed because the trashes reduce the quality of sugar. Furthermore, the trashes absorb significant amount of juice during sugar extraction processes decreasing the quantity of sugar. It is also important to mention here that nearly 10% of the total price of sugarcane is deducted when selling to the sugar industry if farmers did not remove trashes from the sugarcane. The amount of trash removed from sugarcane depends on different factors such as topping height, harvesting system (burnt or unburned sugarcane), sugarcane variety, crop period, soil and climatic condition (Paes, 2005; Romero, 2009; Prabhakar, 2010). The conventional method of trash removal (manual with sickle) is a laborious and time consuming job and delays the sowing of next crop due to unavailability of excess labor. Keeping in view the above problem, a mechanical sugarcane stripper was designed and development by Agricultural Mechanization Research Institute (AMRI) Wing, Faisalabad under local conditions. This study has been carried out to assess the performance evaluation of sugarcane stripper for the recovery of sugarcane trashes. The economics analysis of mechanical sugarcane stripper has also been carried out in comparison of conventional method of sugarcane de-trashing.

2. Materials and Methods

This study was conducted to carry out field performance of sugarcane stripper and its cost analysis in comparison of conventional method for trash removal. The experiments have been conducted in the fields of Machinery Demonstration Unit Farm, AMRI Wing Faisalabad, Pakistan. Before presenting the results, the brief description of sugarcane stripper has been provided to better understand the machine operation.

2.1 Description of Sugarcane Stripper

The major components of sugarcane stripper consist of main frame, feeding chute, threshing outlet unit, de-trashing roller, blower and sprockets. The main frame is the backbone of a machine. It is made of Mild Steel (MS) angle iron (64 mm x 64 mm x 6 mm). To facilitate the stalks feeding, a feeding chute made of MS sheet (87.63 mm thick) has been introduced. During de-trashing, the sugarcane stalks press against rollers having uneven periphery. A 12 rubber strips (64 mm x 30 mm x 15 mm) have been fastened on the circumference of de-trashing roller. Two plain surface de-trashing drums (279.4 mm dia.) were provided to press the sugarcane stalks against the de-trashing rollers. The axial lining on the surface of the roller were made to grip the sugarcane stalks to avoid slippage. The grip rollers are used to increase the grip on sugarcane stalks to decrease the forward movement of cane stalks. Due to slow movement of the cane stalks, the de-trashing roller wings strike repeatedly on the cane stalks and remove the trashes those are blown away by the stream of the air produced by the blower. A blower was provided to produce air thrust for carrying the removed trash. The sugarcane stalks passing through grip rollers and de-trashing drums have further been passed through polishing roller (made of MS sheet 16SWG) mounted on the rear end of the machine. A provision has been made to transport this machine with the help of three point linkages system of the tractors while PTO power of tractor is used to operate this machine. A sprocket is a wheel with teeth that meshes with a chain, track or other perforated or indented material. De-trashing drums and de-trashing roller operate at the same speed; hence three sprockets are of the same size in this machine. The isometric view of sugarcane stripper is shown in Figure 1.

Fig. 1. Isometric view of sugarcane stripper

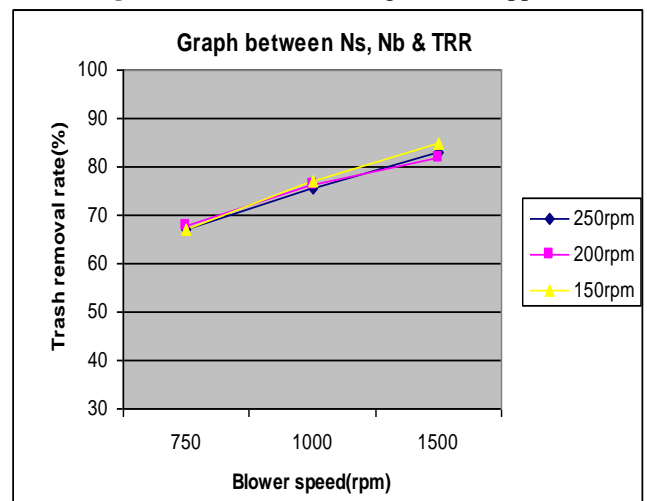


Fig. 1. Effect of blower speeds on TRR at three sprocket speeds for sugarcane variety V₁

2.2 Experimental Procedure

The sugarcane stripper was tested in the field and its performance evaluation has been carried out for de-trashing the sugarcane stalks. Three different sugarcane varieties namely COL-1148, FH-236 and MO-240 have been selected to perform trash removal analysis using sugarcane stripper. The effect of three levels of grip roller speeds 250, 200 and 150 rpm and three level of blower speeds 750, 1000 and 1500 rpm on three varieties of sugarcane have been investigated on de-trashing rate of sugarcane stripper. A sample of 100 kg sugarcane was selected and fed into the machine at constant feed rate. The experiment was replicated three times. Total weight of the sample, time of operation, weight of the trash removed and weight of the un-trashed trashes were determined by weighing the sample before and after the machine operation. The data collected has been analyzed for machine capacity and machine efficiency. The cost analysis has also been carried out to compare the economics of sugarcane stripper with conventional method of sugarcane de-trashing.

2.3 Statistical Analysis

A 3x3x3 factor factorial design was employed to evaluate the effect of three levels of grip roller sprocket speeds 250, 200 and 150 rpm and three levels of blower speeds 750, 1000 and 1500 rpm on three varieties of sugarcane for trash removal. The statistical analysis has been carried out using PROC GLM (General Linear Model) procedures of SAS Institute, version 9.1 (SAS, 2002-03).

3. Results and Discussion

The statistically analyzed results of grip roller sprocket speeds, blower speeds and sugarcane varieties on sugarcane de-trashing rate and machine efficiency have been discussed as follows:

3.1 Effect of Sugarcane Variety on Trash Removal Rate

The statistically analyzed data at 5% probability level shows that sugarcane variety has non-significant effect on trash removal rate (TRR). The interaction of sugarcane variety with blower speed sprocket is also non-significant as shown in ANOVA given in Table 1. The statistically analyzed data indicate that the sugarcane varieties V_1 , V_2 and V_3 have means with the same letter are not significantly different at 5% probability level.

Table 1. Effect of sugarcane variety on trash removal rate

Sugarcane variety	Trash removal rate (%)
V_1	75.56 ^a
V_2	75.19 ^a
V_3	75.89 ^a
Mean	75.46
LSD (0.05)	1.1359

3.2 Effect of Sprocket Speeds on Trash Removal Rate

The effect of sprocket speeds on trash removal rate is shown in Table 2. The statistically analyzed data indicated that sprocket speed had significant effect on trash removal rate. The maximum trash removal rate was found to be 88.59% at sprocket speed NS_3 (150 rpm) and minimum at NS_1 . The lower value of de-trashing at speed NS_1 (250 rpm) was due to higher speed of de-trashing drum resulting quick passage of sugarcane trash hence reducing the trash removal rate. The quick passage of sugarcane decreases effect of air thrust due to lesser time on sugarcane stalks reducing the trash removal rate.

3.3 Effect of Blower Speed on Trash Removal Rate

The effect of different blower speeds on trash removal rate is shown in Table 3. The statistically analyzed data indicated that blower speeds significantly affected trash removal rate. Of the selected blower speeds, the trash removal rate was found to be highest at blower speed NB_3 (1500 rpm) that is 76.88% and lowest at blower speed NB_1 (750 rpm). By increasing the blower speed, the air thrust on sugarcane stalks increases resulting higher trash removal rate.

The effect of the three different blower speeds on trash removal rate at three different grip roller sprocket speeds for three varieties of sugarcane are shown in the Figure 1, 2 and 3. It is clear from all three figures that the trash removal rate is higher at blower speed NB_3 (1500 rpm) followed by NB_2 (1000 rpm) and NB_1 (750 rpm) for all the three varieties. Similarly, the trash removal rate increases by decreasing the speed of the sprocket. Therefore, it could be concluded that the maximum trash removal rate was determined at blower speed NB_3 and sprocket speed NS_3 for all the sugarcane varieties.

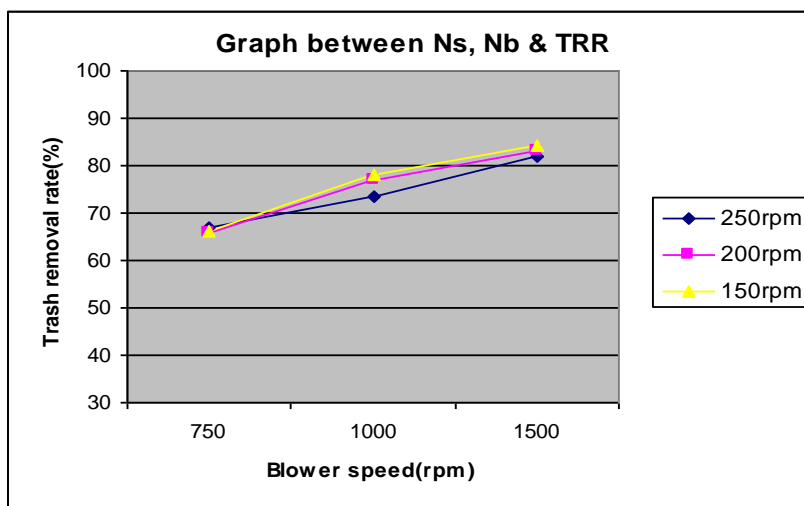


Fig. 2. Effect of blower speeds on TRR at three sprocket speeds for sugarcane variety V₂

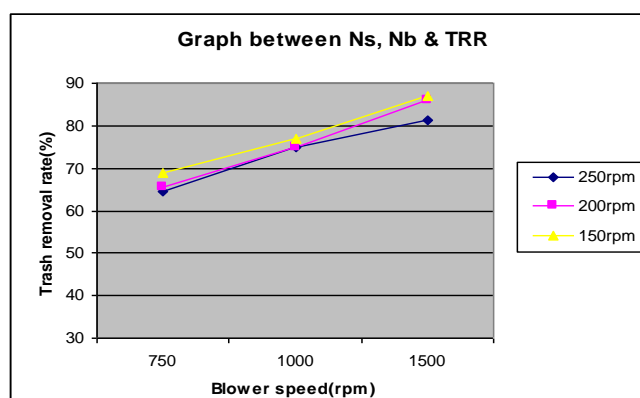


Fig. 3. Effect of blower speeds on TRR at three sprocket speeds for sugarcane variety V₃

The conventional method of de-trashing is considered as manual de-trashing method. In the manual de-trashing, the trash is removed with the help of sickle and by pick sugarcane stalks one by one. The manual de-trashing is labor extensive and time consuming job. Due to unavailability of labor at the time of harvesting, the farmers usually do not de-trash the sugarcane losing their income (10%) at sugar industries because the trash absorbs 30% of juice during extraction process. Furthermore, the sowing time of following crops is delayed resulting decrease in the crop yields. Therefore, keeping in view the above problems, the use of sugarcane stripper could reduce the problem of de-trashing. The data recorded during manual de-trashing process is shown in Table 4.

The performance analysis of sugarcane stripper has also been calculated by determining its efficiency and machine capacity. On an average the efficiency of sugarcane stripper was calculated to be 79%. The capacity of sugarcane stripper was calculated to be 57 tons per day in comparison of manual method which is nearly 1 ton per day. This shows that the time required for trash removal of

sugarcane for one ha is higher in manual method compared with mechanical method.

The cost analysis of the sugarcane stripper and manual method has also been calculated. The cost comparison revealed that the cost of manual method of trash removal was higher than sugarcane stripper. A farmer can save Rs. 2080 per ha using sugarcane stripper as compared with manual method of de-trashing. The complete cost analysis of manual method and sugarcane stripper is shown in Table 5.

Table 2. Effect of grip roller sprocket speed on trash removal rate

Grip roller sprocket speed (rpm)	Trash removal rate (%)
NS ₁	66.74 ^c
NS ₂	76.29 ^b
NS ₃	83.59 ^a
Mean	75.54
LSD(0.05)	1.1359

Table 3. Effect of different blower speeds on trash removal rate

Blower speed (rpm)	Trash removal rate (%)
NB ₁	74.37 ^c
NB ₂	75.37 ^b
NB ₃	76.88 ^a
Mean	75.54
LSD(0.05)	1.1359

Table 4. Conventional method of de-trashing

Sugarcane Variety	Height of sugarcane (m)	Weight of sugarcane (gm)	Circumference of sugarcane (mm)	Weight of trash removed (gm)
V ₁	3	945	73.66	101
V ₁	4	1128	78.74	84.5
V ₁	3	771	73.66	93.5
V ₂	4	876	63.5	89.2
V ₂	2.9	973	68.58	98.9
V ₂	2.5	1022	60.96	89.9
V ₃	4	1143	81.28	120
V ₃	4	998	68.58	100
V ₃	3	876	60.96	84.5

Table 5. Cost analysis of manual and sugarcane stripper

Particulars	Tractor (MF-240)	Sugarcane stripper
Purchase price (Rs.)	3,50,000	35,000
Salvage value, S (10% of P) (Rs.)	35,000	3500
Useful life, L (Year)	10	10
Annual use (hrs)	1200	500
Fixed Cost		
Depreciation, $D = (P-S)/L$ Rs./hr	26.25	6.3
Interest, $I = [(P+S)/2]*i$	19.25	4.62
Taxes, insurance and shelter (2% of P)	5.83	-
Variable Cost		
Repair & Maintenance (15% of P)	43.75	10.5
Fuel charges (6 L/hr)	222	-
Lubrication charges (15% of the fuel charges)	33.3	-
Driver charges	31.25	-
Helper charges	-	25
Total Cost	381.63	46.42

Cost comparisons (Cost with sugar cane stripper)

Particulars	Values
Machine capacity	57.6 ton/day
Operational cost	Rs. 428/hr
Total operational cost of machine	Rs.10272/day
One ha	96 ton
Total operational cost	Rs. 17120/ha

Cost comparisons (conventional Trashing)

Particulars	Value
Estimated weight of cane stalks/day/labor	1 t/day
De-trashing rate	Rs. 200/ton
Average time consumed for 1 ha	96 days
Manual charges per ha	Rs.19200/ha
Cost-Benefit	Rs.19200-Rs.17120
	= Rs. 2080/ha

4. Conclusions

Introduction of modern technologies, smooth availability of farm inputs, improved management practices, high input use efficiency enhance the productivity that ultimately ensure food security. The limited resources of fossil fuels and increasing prices of electricity has resulted severe energy crises in Pakistan. Being an agricultural country, Pakistan has huge potential of biomass that can be used as alternate energy source. In, Pakistan sugarcane trashes can be used as a source of biomass for energy production. The conventional (manual) method of trash removal is a labor extensive and time wasting process. In the meanwhile, sugar cane stripper can be used to remove trashes from the sugarcane stalks. A sugar cane stripper was designed and developed by Agricultural Mechanization Research Institute (AMRI) Wing, Faisalabad. In this study, the performance evaluation of sugarcane stripper has been carried out for the recovery of sugar cane trashes for energy production as well as to improve the socio-economic condition of the rural community. The experiments were conducted on three varieties of sugarcane V₁ (COL1148), V₂ (FH-237), V₃ (MO-240), three grip roller sprocket speeds NS₁ (250 rpm), NS₂ (200 rpm), NS₃ (150 rpm) and three blower speeds NB₁ (750 rpm), NB₂ (1000 rpm) NB₃ (1500 rpm). The cost comparison of sugarcane stripper has also been carried out in comparison with conventional method of de-trashing. The result shows that the best combination to get maximum sugarcane stripper efficiency of 79% was using sprocket speed of NS₃ (150rpm) and blower speed of NB₃ (1500rpm) for all varieties of sugarcane. The operation cost of sugarcane stripper and conventional method were calculated as Rs. 17120 and Rs. 19200 respectively.

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