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PERFORMANCE EVALUATION OF SUGARCANE STRIPPER FOR TRASH RECOVERY

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The limited resources of fossil fuels and increasing price of electricity has resulted severe energy crises in Pakistan. Being an agricultural country, Pakistan has huge potential of biomass that can be used as an alternate source to produce energy. In, Pakistan sugarcane trash can be used as one of the available biomass resources for energy production. Nearly 5.75 million tons of trash per year is available as a biomass in Pakistan. The manual removal of trash is a labor extensive and time consuming process. Sugar cane stripper can be used to remove trash from the sugarcane stalks. Agricultural Mechanization Research Institute (AMRI) Wing, Faisalabad has designed and developed a sugarcane stripper. In this study, the performance evaluation of sugarcane stripper has been carried out for the recovery of sugar cane trash for energy production. The experiments were conducted on three varieties of sugarcane V_1 as (COL1148), V_2 as (FH-237) and V_3 as (MO-240), three sprocket speeds NS_1 as (250 rpm), NS_2 as (200 rpm)and NS_3 as (150 rpm) and three blower speeds NB_1 as (750 rpm), NB_2 as (1000 rpm), and NB_3 as (1500 rpm). The cost comparison of sugarcane stripper has also been carried out in comparison with conventional (manual) method of de-trashing. The result showed that the best combination to get maximum sugarcane stripper efficiency of 79% was using sprocket speed of NS_3 (150rpm) and blower speed of NB_3 (1500rpm) for all the varieties of sugarcane. The operational cost of sugarcane stripper and conventional method were calculated as Rs. 17120/ha and Rs. 19200/ha, respectively.

Keywords: Sugarcane, mechanization, sprocket speeds, blower speeds, trash removal rate

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. 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. The calorific value of trash on dry basis is 3000 kCal/kg on dry basis. The energy generation potential of cane trash is around 9,475 GWh per year (Naseem, 2014). 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 trash (leaves) are lost during burning process. Nearly 30% of sugarcane energy is contained in the tops and leaves in the form of trash, which is lost during burning process. The burning of trash results 3103.9 kg CO_{2eq} $ha^{-1}y^{-1}$ emission added to environment (Alonso *et al*., 2009). 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). Sugarcane residues are rich with plant nutrients either in the form of trash or ash. Due to the presence of these nutrients less fertilizer are needed to apply to the crops.

Since, sugarcane is a source of sugar making, so to get a good quality sugar, the sugarcane stalks should be de-trashed because the trash reduce the quality of sugar. Furthermore, the trash 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 additional labor. Keeping in view the above problem, a mechanical sugarcane stripper was designed and development by Agricultural Mechanization Research Institute (AMRI) Wing, Faisalabad. This study has been carried out to assess the performance evaluation of sugarcane stripper for the recovery of sugarcane trash. The economic analysis of mechanical sugarcane stripper has also been carried out in comparison of conventional method of sugarcane de-trashing.

MATERIALS AND METHODS

This study was conducted to evaluate field performance of sugarcane stripper and its cost analysis in comparison of conventional method for trash removal. The testing was conducted at 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.

***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 x6 mm). A chute made of MS sheet (8.763 mm thick) was introduced to facilitate the stalks feeding. 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 tractor 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 and used to control the speed of de-trashing drum and speed of grip rollers. 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.

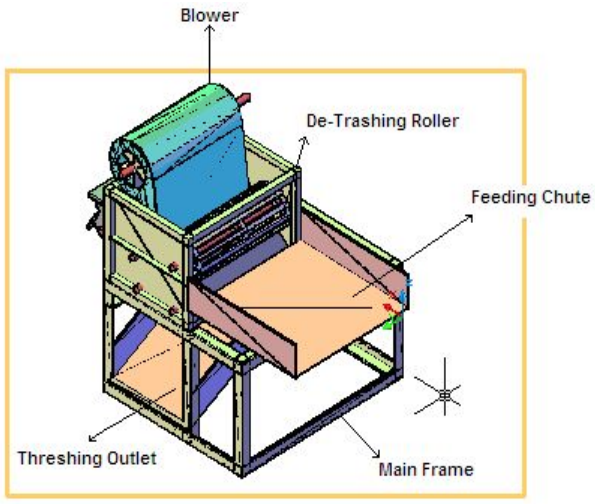

Figure 1.Isometric view of sugarcane stripper.

***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-237 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.

***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).

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:

***Effect of sugarcane variety on trash removal rate*:** The statistically analyzed data at 5% probability level showed 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 indicated 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. Reddy and Yang (2005) also found similar results, which shows that the production of sugarcane straw (trashes) not varies according to the variety.

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

***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 88.6% 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 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.

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

***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.

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

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 2, 3 and 4. 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 (Arain *et al*., 2011)

The conventional method of de-trashing is taken as manual de-trashing process. In the manual de-trashing process, the trash from the sugarcane is removed using a sickle. The manual de-trashing is labor intensive 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%) when selling to sugar industry because the trash absorbs 30% of juice during extraction process (Meyer *et al*., 2005). 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.

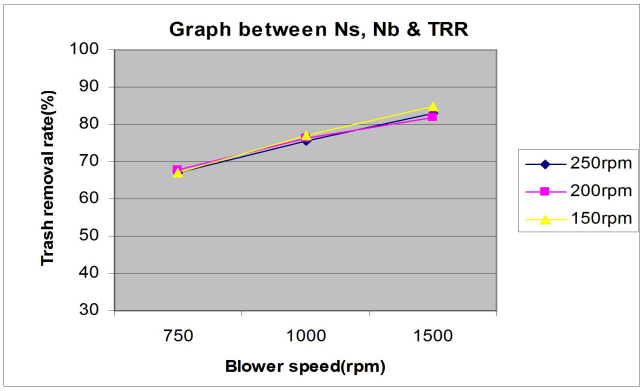

Figure 2. Effect of blower speeds on trash removal rate at three sprocket speeds for sugarcane variety V_1.

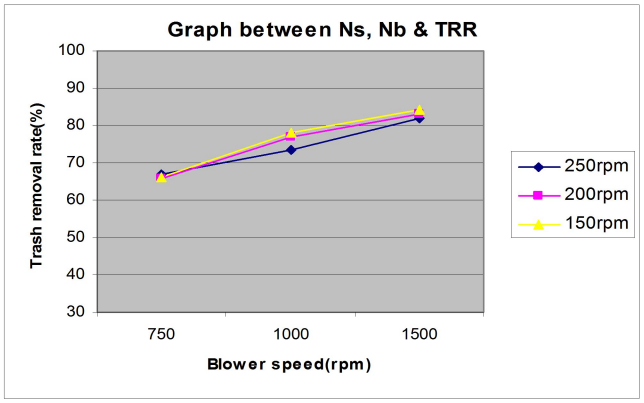

Figure 3. Effect of blower speeds on trash removal rate at three sprocket speeds for sugarcane variety V_2.

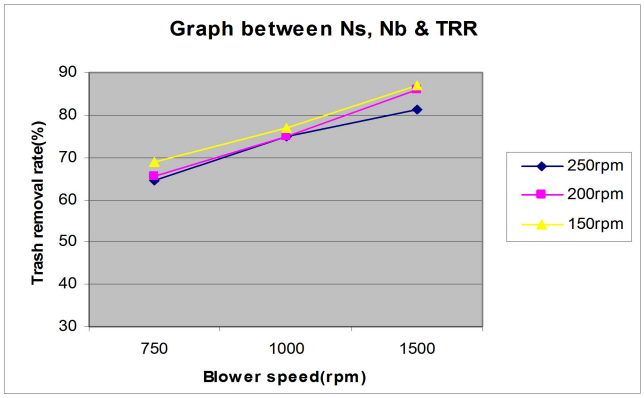

Figure 4. Effect of blower speeds on trash removal rate at three sprocket speeds for sugarcane variety V_3.

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 (Mendoza *et al*., 2003).This shows that the time required for trash removal of sugarcane for one ha is higher in manual method compared with mechanical method. Normally the farmers are paid less at the sugar industries due to improper removal of trash from the sugarcane. Manual sugarcane trash removal is a laborious and time consuming operation. The use of sugar cane stripper will improve the trash recovery, resulting in increased income of the farmers. Moreover, the trash removal process can be performed rapidly as compared with manual trash removal. The time saved by farmers can be used to perform other activities and to interact with the community to improve their social relations. This is ultimately improving their income and socio economic condition.

The cost analysis of the sugarcane stripper and manual method has also been calculated. The cost comparison

Table 4. Conventional method of de-trashing

Sugarcane varity	Height of sugarcane (m)	Weight of sugarcane (g)	Circumference of sugarcane (mm)	Weight of trash removed (g)
V_1	3.0	945	73.66	101.0
V_1	4.0	1128	78.74	84.5
V_1	3.0	771	73.66	93.5
V_2	4.0	876	63.50	89.2
V_2	2.9	973	68.58	98.9
V_2	2.5	1022	60.96	89.9
V_3	4.0	1143	81.28	120.0
V_3	4.0	998	68.58	100.0
V_3	3.0	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	

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.

***Conclusions*:** The limited resources of fossil fuels and increasing price of electricity has resulted severe energy crises in Pakistan. Being an agricultural country, Pakistan has huge potential of biomass that can be used as an alternate energy source. In, Pakistan sugarcane trash can be used as a source of biomass for energy production. The conventional (manual) method of trash removal is a labor extensive and time consuming process. 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 V_1 (COL1148), V_2 (FH-237), V_3 (MO-240), three grip roller sprocket speeds NS_1 (250 rpm), NS_2 (200 rpm), NS_3 (150 rpm) and three blower speeds NB_1 (750 rpm), NB_2 (1000 rpm) NB_3 (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 NS_3 (150rpm) and blower speed of NB_3 (1500rpm) for all varieties of sugarcane. The operation cost of sugarcane stripper and conventional method were calculated as Rs. 17120/ha and Rs. 19200/ha respectively.

REFERENCES

Alonso-Pippo, W., C.A. Luengo, F.F. Fonseca, P. Garzone and G. Conacchia. 2009. Energy recovery from sugarcane biomass residues: challenges and

opportunities of bio-oil production in the light of second generation biofuels. J. Renew. Sustain. Energy 1:1-15.

Anonymous. 2010-11. Economic Survey of Pakistan. Government of Pakistan, Finance Division, Economic Advisor Wing, Islamabad, Pakistan.

Arain, M.Y., R.N. Panhwar, N. Gujar, M. Chohan, M.A. Rajput, A.F. Soomro and S. Junejo. 2011. Evaluation of new candidate sugarcane varieties for some qualitative and quantitative traits under Thatta agro-climatic conditions. J. Anim. Plant Sci. 21:226-230.

Botha, F.C. 2009. Energy yield and cost in a sugarcane biomass system. Aust. J. Plant Physiol. 27: 81–85.

Duku, M.H., S. Gu and E.B. Hagan. 2011. A comprehensive review of biomass resources and biofuels potential in Ghana. Renew. Sustain. Energy Rev. 15:404-15.

Evans, L.J.C. and F. Hardy. 1946. Yields of sugarcane trash. Tropical Agriculture (XXIII), 12:224-225.

Leal, M.R.L.V. 2007.The potential of sugarcane as an energy source. Proc. Int. Soc. Sugarcane Technol. 26:23-34.

Meyer, E., C.P. Norris, E. Jacquin, C. Richard and J. Scandaliaris. 2005. The impact of green cane production systems on manual and mechanical farming operations. Proc. ISSCT 78: 294–303.

Mendoza, T.C. and R. Samson. 2003. Estimates of CO_2 production from the burning of crop residues. Envi. Sci. & Manage. 3: 25-33

Naseem, A. 2014. Biomass potential in Pakistan.Available online at http://www.bioenergyconsult.com/biomass-pakistan.

Norris, C. 2007. Trash Separation.Available online at http:// www.norrisect.com/index.php?option= com.

Paes, L.A.D. and M.A. Oliveira. 2005. Potential trash biomass of the sugar cane plant, pp.19-23. In: S.J. Hassuani, M.R.L.V. Leal and I.C. Macedo (eds.), Biomass power generation: sugarcane, bagasse and trash. Piracicaba, SP, Brazil. Available online at www.sucre-ethique.org/IMG/pdf/CTC_energy_-_biomass_1_.pdf.

Paul, H.V. and M. Krishnamurthi. 2007. Sugarcane trash collection at the small farms in Southern India. Int. Soc. Sugarcane Technol. 34:114-20.

Rozeff, N. 1994. Sugarcane biomass and burning: An empirical scenario for the lower Rio Grande valley of Texas. Sugarcane 2:2-5.

Prabhakar, N., D.V.L.N. Raju and S.R. Vidya. 2010. Cane trash as fuel. Proc. Int. Soc. Sugarcane Technol. 67:234-244

Romero, E.R., J. Scandaliaris, P.A. Digonzelli, L.G. Alonso, F. Leggio and J.A. Giardina. 2009. Effect of variety and cane yield on sugar cane potential trash. Proc. Int. Soc. Sugarcane Technol. 58:421-425.

Reddy, N. and Y. Yang. 2005. Biofibers from agricultural by products for industrial applications. Trends in Biotech. 23:22-27.