

THE LOSSES OF SUGARCANE HARVESTED FROM A SUGARCANE HARVESTER

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Abstract

This study aimed at a quantitative evaluation of sugarcane losses caused by the operating process of harvesters. A factorial experimental design was used to study the effect of 3 factors: sugarcane type, planting and soil type. The experiments showed the effects of the three factors affecting the sugarcane loss from mechanical harvesting systems. Sugarcane losses from the operation of harvesters are as follows: 49% from base cutter, 26% from rollers, 17% from elevator and 8% from primary extractor. The variance analysis done at a significance level of 0.05, found that sugarcane type and soil type had an influence on the losses of sugarcane from the operation of the base cutter in both terms of main factors and co-factors. Planting and soil type had an influence on sugarcane losses from the operations of feed rollers in the main and co-factor. Sugarcane type, planting and soil type were the co-factor affecting losses from the operation of the primary extractor.

Keywords: Sugarcane, sugarcane harvester, losses of harvest, losses of sugarcane

Introduction

Sugarcane is an economic crop that the Thai government has encouraged planting area expansion by offering farmers incentives (Office of Agricultural Economics, 2013). This is especially true in Northeastern Thailand where the largest sugarcane growing areas are found. There were 0.59 million hectares of sugarcane resulting in 41.5 million tonnes of sugar in 2016 for the entire country (Office of Agricultural Economics, 2017).

The ability to grow sugarcane depends on the local conditions and the use of different varieties of sugarcane which are suitable for the area. A good sugarcane species should have the ability to stubble not less than 2 times and the average yield of not less than 75 tons per hectares. The sugarcane varieties that are popularly planted must be at least 2.5 meters in height. It is easy to grow 10-13 month old drought-resistant sugarcane which yields more

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than 81.25 tons per hectare with sweetness of 11 ccs. or more (Kaset Thai International Sugar, 2014).

Nowadays, Agricultural machinery is widely used to facilitate all steps of sugarcane production, especially the harvesting which takes place during November and May of each year. Manual sugarcane harvesting is a very labor-intensive and laborious activity. Harvest laborers can easily fatigue due to excessive stress on the joints and muscles (Clementson and Hansen, 2008) and are exposed to harmful pests from plantations, creating safety concerns (Carvalho, 2012). Therefore, farmers must burn sugarcane to reduce labor problems, refuse to cut non-burned sugarcane. And there are no weeds and organisms that may be harmful to workers. But the burning of sugarcane has a negative effect on the quality of sugarcane and cause pollution to the environment. So, one of the solutions to reduce the shortage of labor was to replace the worker with the sugarcane harvester to cut canes curing the harvest season.

Various harvesting practices are used in sugarcane production, each requiring different harvesting technologies to ensure effective and efficient field operations. Based on how the sugarcane is presented to the harvester, harvesting practices are classified into two groups; harvesting of canes with pre-harvest burning (burnt cane harvesting) and harvesting of canes without burning (green cane harvesting). (Shaochun *et al.*, 2014).

Generally, sugarcane harvesters can be categorized into whole stalk harvesters and chopper harvesters. A typical whole stalk harvester system consists of a topper, a base cutter, a feeding mechanism, and a discharging mechanism. The topper is designed to sever cane tops and then discharge the severed tops to the side of harvesting rows. Topped cane stalks are then cut by the base cutters at about 30 mm above the ground level (Esquivel *et al.*, 2008). The feeding mechanism includes a set of rollers to convey the cane stalks to the discharging mechanism. The discharging mechanism then delivers harvested stalks to either a wagon or onto the field. The other type of harvester is the chopper harvester. Except

for the components of whole stalk harvesters, chopper harvesters include extra components such as chopper and extractors (Shaochun *et al.*, 2014). The basic functions of the chopper harvester is gathering and topping sugarcane, severing stalks at ground level, feeding cane through a chopper system where it is cut into billets, removing as much adhering dirt, leaf and trash as possible (Ridge and Norris, 2000). By the functionality of the chopper and extractor are to chop whole stalk into billets and separate leafy materials. In the harvesting process by chopper harvesters, the discharging mechanism is used to deliver the billets to a wagon or a truck (Shaochun *et al.*, 2014).

The objective of past and present harvesting systems should be to deliver the maximum quantity of cane with the highest sugar quality in the most efficient manner (Richard *et al.*, 1996). Sugarcane harvesters used for sugarcane harvesting are both imported from overseas and produced by local manufacturers. In the work of sugarcane harvesters either imported or domestically produced, there are problems that cause loss of productivity. This can be separated into quantitative losses, i.e., the loss of sugarcane during the working process of the sugarcane harvester. The cutting is not completely clean because the sugarcane fall from the belt and the truck (Linedale and Ridge, 1996). According to Opanukul *et al.* (2012), there is a losses of sugarcane 1-4.56 tons per hectare.

From the problem discussed above, the trend of using a sugarcane harvester has increased every year. Therefore, this study aims to determine the loss of sugarcane, and the variables affecting the losses of sugarcane caused by sugarcane harvester processes so that this information can be used for making the correct decision for the proper operation.

Materials and Methods

The method for this research, starting from the preliminary survey by surveying sugarcane planting areas to record various information about sugarcane and soil in designated areas,

was to analyze the cause of the problem and determine the factors used in the experiment. The researcher selected harvesting of Khon Kaen 3 sugarcane variety without burning, in sugarcane fields with dry soil surface and type of sugarcane harvester is the chopper harvester (Austoft 8000 sugarcane harvester series, FPT Cursor 9 engine 4 valves 9 liters - 353hp (260kW) @ 2100 rpm) as the control factors. The type of sugarcane, planting and soil type were the initial factors used to determine the losses of sugarcane and the statistical analysis from sugarcane harvested with sugarcane harvesters.

Experiment to Find Factors Affecting The Losses of Sugarcane with Sugarcane Harvested by Sugarcane Harvesters

The research was conducted by selecting the 2k factorial experiment design. The factors were sugarcane type, planting, and soil type.

1. **Determining the level of factors used in the experiment.** Based on relevant research, the basic experiments and the limitations of the tools used in the experiment. The experiment used two levels of variables; low (-1) and high (1) as shown in 1

2. **Experimental Design.** In this experiment, we used a statistical program (Minitab V. 18) to determine the order of experiments and experimental design (DOE). For the study of three replicates, there are 24 treatments in the experiment.

3. **Experiment was conducted to determine the losses of sugarcane found in the sugarcane harvested by sugarcane harvesters.** The operator adjusted the speed within the limits under the working conditions in order to achieve the requirements of raw material quality and productivity of the process (Peloia1 et al., 2010). In the preparation of sugarcane for testing, when sugarcane harvester operating is completed in each row. Will randomize the area to size; width, cross-section of planting furrows; length, 5 m, total 3 position per line. Than store the remaining sugarcane in that area to record the following data:

a) The losses of sugarcane from cutting height stubble of base cutter; by cutting the

sugarcane stalks at the ground, weighing all the sugarcane, and calculating the losses per unit area by (1).

$$loss_{cane,1} = (W_{cane,1} / A_{simp}) \times 1,600 \quad (1)$$

Where $loss_{cane,1}$ is the losses of sugarcane from cutting height stool of base cutter (kg per ha), A_{simp} is sampling area, is weight of sugarcane (kg)

b) The losses of sugarcane from working of rollers; select only the remaining sugarcane stalks in that area, than weigh all the sugarcane stalks, and calculate the losses per unit area by

$$loss_{cane,2} = (W_{cane,2} / A_{simp}) \times 1,600 \quad (2)$$

Where $loss_{cane,2}$ is the losses of sugarcane from the work of the rollers (kg per ha), $W_{cane,2}$ is weight of sugarcane stalks (kg)

c) The losses of sugarcane from working of primary extractor; select only the remaining sugarcane billets (tops) in that area, than weigh all the sugarcane billets (tops), and calculate the losses per unit area by (3).

$$loss_{cane,3} = (W_{cane,3} / A_{simp}) \times 1,600 \quad (3)$$

Where $loss_{cane,3}$ is the losses of sugarcane from the work of the primary extractor (kg per ha), $W_{cane,3}$ is weight of sugarcane billets (Tops) (kg)

d) The losses of sugarcane from working of elevator; select only the remaining sugarcane billets in that area, than weigh all the sugarcane billets, and calculate the losses per unit area by (4).

$$loss_{cane,4} = (W_{cane,4} / A_{simp}) \times 1,600 \quad (4)$$

Where $loss_{cane,4}$ is the losses of sugarcane from the work of the elevator (kg per ha), $W_{cane,4}$ is weight of sugarcane billets (kg)

Results of Statistical Analysis

The interpretation of the results by statistical analysis was used to determine the relationship between the initial factors and response factors. The statistical analysis was divided into 2 parts, they are as follows:

1. **Residual analysis.** Using the residuals derived from the model chosen in Section 2.1, the residuals must be normalized by distributing the variance of the residuals of various factors. The Constant Variance and decay must be random.

2. **Analysis of variance.** Examined the variability source of the model by considering the P-values of the various terms in the table for the analysis of variance compared with the statistically significance, ($\alpha = 0.05$).

Results and Discussion

The Losses Of Sugarcane Found in Sugarcane Harvesting Trial

The experiment was conducted to determine the amount of loss of sugarcane harvested by sugarcane harvesters. The Minitab 18 was used to help plan the experiments in a 2k factorial design in three factors: sugarcane type, planting and soil type. Whiteing, Norris & Paton (2001) mentioned sugarcane loss and extraneous matter are higher with green-cane harvesting especially under poor harvesting conditions, which would include high leaf and soil moisture or severely lodged cane. In this research, the sugarcane harvester has an average field efficiency of 54.49% and sugarcane loss in the field of 4.86 tons per hectare. When the experimental results are presented in the form of pie charts to determine the sequence of the losses of sugarcane found harvested by the sugarcane harvester, shown in Figure 1. Sugarcane yields were 49% from base cutter, 26% from feed rollers, 17% from elevator and 8% from primary extractor, respectively. Details are as follows:

49% of sugarcane loss from the cutting height stool of base cutter and there are more losses for sugarcane planted on slopes than planted on flat land because the slope of the planting area results in the inability of base cutter of a harvester to work in a horizontal plane. And the research from Yang *et al.*, (2007) found that leveling crop field can reduce the loss of stool.

26% of sugarcane loss from feed rollers is caused by the working system of the base cutter with rollers having to work together. Namely, if the base cutter cuts more sugarcane, the series of the roller speed is adjusted higher to increase the conveyance of sugarcane to the choppers, without a loss of sugarcane during this process. If there are losses in this process, this show that there is a defect during the work of the base cutter with the roller series.

17% of sugarcane loss from the elevator is caused by the position control of the elevator of the operator for unloading sugarcane billets to the truck. If the area has a slope, this makes the harvester or the truck slip. The distance between the two cars changed. As a result, the conveyance of sugarcane cannot reach the truck.

8% of sugarcane loss from the primary extractor is because the speed of the primary extractor is unsuitable due to amount of sugarcane throws from the chopper. Results from Viator *et al.*, (2007) indicated the harvester performed well under ideal conditions with a primary fan speed of 1050 rpm but had a decreasing performance under poor conditions regardless of fan speed. Additionally, increasing the primary extractor fan settings can reduce extraneous matter, but excessive fan speeds can also remove mature billets (Richard *et al.*, 2001).

There will be different quantities of losses of sugarcane arising from the work processes of the sugarcane harvester depending on the nature of the planted area,

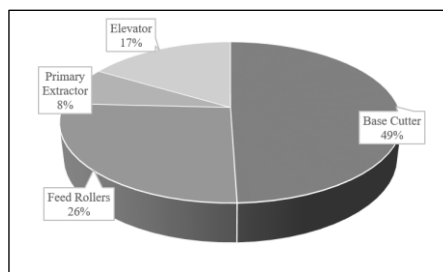


Figure 1. Steps of units of the sugarcane harvester that resulted in the losses of sugarcane

type of sugarcane, performance of the sugarcane harvester and operator skill. Results in Australia from Shaw and Brotherton, (1992) indicated that a 1% reduction in extraneous matter resulted in a 4.2-Mg ha⁻¹ sugarcane loss; often when fan speed is increased to remove leafy material, billet pieces are also removed. Additionally, the research in Iran by Najafi *et al.*, (2015), indicated feed rollers and hydraulic subsystems have maximum recorded failures and engine and extractor fans subsystems have minimum recorded failures in the working hours of the machine.

Statistical Analysis

1. Residual analysis. In Figure 2 show that when the residuals were analyzed, it was found that the model of each response was not abnormal because the distribution of residual is normal. The variance of the factors is uniform and there were no out-of-control signals for the data in the control charts. The results show that the responses are normal.

2. Analysis of variance. Based on the comparing of the Table 2 the statistical significance is as follows: Column 2 shows the analysis of variance of sugarcane loss from the base cutter operating process. It was found that the type of sugarcane and soil type are influenced by the losses of the base cutter and is statistically significant for both main factors and co-factors. It also found that planting and soil type had a significant influence on the amount of sugarcane losses in terms of the co-factors. Column 3 shows the analysis of variance of sugarcane loss from the feed rollers operating process. In terms of the main factors, the planting influences the amount of sugarcane losses significantly. The planting and soil type had a significant influence on the

amount of sugarcane losses in terms of the co-factors. Column 4 shows the variance analysis of sugarcane loss from the primary extractor operating process. It was found that the type of sugarcane, planting and soil type are

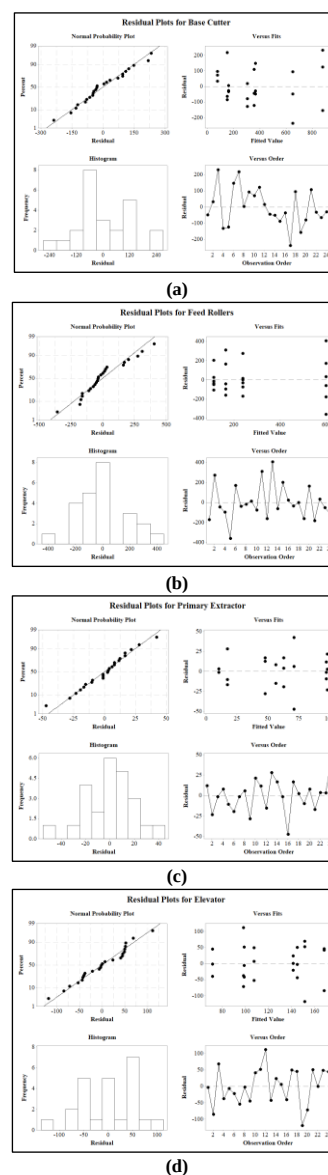


Figure 2. Model validation for the losses of harvested by sugarcane harvester: (a) base cutter, (b) Feed rollers, (c) primary extractor and (d) elevator

Table 1. Factors and levels of each factor used in the experiment

Factor	Level	
	-1	1
Sugarcane type	Planted sugarcane	Ratoon sugarcane
Planting	Single-row	Double-row
Soil type	Sand	Clay

Table 2. Shows the variance of the losses

Source	P-Value			
	BaseCutter	Roller	Extractor	Elevator
Model	0	0.001	0.002	0.626
Linear	0	0.002	0.002	0.394
sugarcane type	0		0.008	0.831
Planting	0.821	0.002	0.812	0.262
soil type	0.001	0.06	0.002	0.201
2-Way Interactions	0	0.015	0.04	0.551
sugarcane type*soil type	0		0.021	0.742
sugarcane type*planting			0.064	0.17
planting*soil type	0.001	0.015	0.869	0.984
3-Way Interactions			0.013	0.985
sugarcane type*planting*soil type			0.013	0.985
Error				
Lack-of-Fit	0.204	0.861		
Pure Error				
Total				

influenced by the amount of sugarcane losses sugar in terms of the co-factors. Additionally, column 5 shows the variance of sugarcane loss from the elevator operating process. It was found that there were no factors influencing sugarcane losses from this process.

3. Analysis of the impact of factors influencing the response. The main factors influencing the amount of the losses of sugarcane are shown in Figures 3. By (a) shows the effect of the main factors affecting sugarcane loss from the cutting height stubble of the base cutter. It was found that if the sugarcane harvester is harvested by the type of sugarcane is planted sugarcane, there will be more sugarcane loss than harvesting in ratoon sugarcane. Also, if harvested by the sugarcane harvester on a double-row (planting), the loss of sugarcane will be more than that those harvested on single-row (planting). Additionally, when harvesting sugarcane, there will be more losses if the soil type is sand than if the soil type is clay. Because the sand soil is loose agglomeration of particles less than clay soil make the sugarcane stump rocking easy. When cutting the stalks, it makes the remaining part of the stump higher than. Results from Salvi, *et al.* (2007), indicated the use of the control device can be helpful to maintain a lower cutting height, but it is influenced by crop

conditions. (b) shows the effect of the main factors affecting sugarcane loss from the operation of feed rollers. It was found that in the operation of the sugarcane harvester, if the harvest planting is a single-row, there will be more sugarcane loss then the harvesting of double-row, because the sugarcane planted in a single-row will have less sugarcane stalks density than in double-row. Therefore, the nature of the stems depend on external stimuli. Furthermore, there will be more losses if the harvester operates on clay soil than sandy soil. (c) shows the effect of main factors affecting sugarcane loss from the operation of the primary extractor. It was found that if the sugarcane harvesters harvested ratoon sugarcane, there will be more sugarcane loss than harvesting planted sugarcane. Also, if the sugarcane harvesters is harvested on a double-row, the loss of sugarcane will be more then that those harvested on a single-row (planting). Furthermore, if the harvest is on sandy soil, there will be more the losses than on clay soil. And (d) shows the effect of the main factors affecting sugarcane loss from the operation of the elevator. Considering the type of sugarcane, it was found that in the operation of the sugarcane harvester. if the harvest sugarcane type is planted sugarcane, there will be more loss of sugarcane than the harvesting

of ratoon sugarcane. Furthermore, if the sugarcane harvester harvested on the planting is single-row, there will be more loss of sugarcane than harvesting in double-row. Additionally, the sugarcane harvester harvested on sandy soil, there will be more losses than harvesting on clay soil.

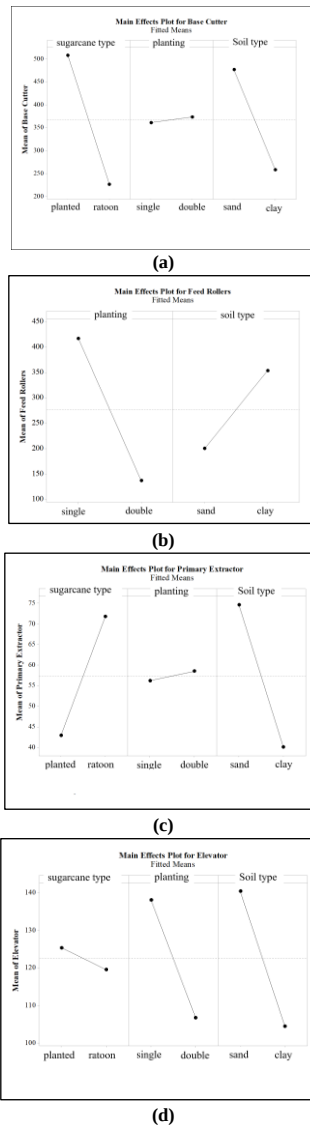


Figure 3. Shows the effect of the main factors influencing the losses of harvested by sugarcane harvester: (a) base cutter, (b) feed rollers, (c) primary extractor and (d) elevator

The co-factors influencing the amount of the losses of sugarcane, are shown in Figures 4. By (a) shows the effect of co-factors affecting sugarcane loss from cutting height stool of base cutter. It was found that if the sugarcane harvester is harvested on sandy soil, there was a wider range of sugarcane losses than on clay soil when changing the sugarcane harvester operation from planted sugarcane to ratoon sugarcane. Additionally, when comparing between sandy soil and clay soil for both single-row and double-row, it was found that clay is better, because of the high particles density. (b) shows the effect of the co-factors affecting sugarcane loss from the operation of the feed rollers. It was found that in the operation of the sugarcane harvester if harvested on clay, there was a wider range of sugarcane losses than in sandy soil when changing the operation of the harvester from sugarcane planted in single-row to double-row. (c) shows the effect of the co-factors affecting sugarcane loss from the operation of the primary extractor. When changing the operation of the sugarcane harvester from the sugarcane type of planted sugarcane to ratoon sugarcane, it was found that if the sugarcane harvester harvested on sugarcane planted in a single-row, there was a wider range of sugarcane losses than in double-row. Also, if the harvester is operating on clay, there was a wider range of sugarcane losses than in sandy soil. Additionally, changing the operation of the harvester from planting from double-row to single-row, it was found that if the harvester is harvested on sandy soil, there was a wider range of sugarcane losses than in clay. And (d) shows the effect of the co-factors affecting sugarcane loss from the operation of the elevator. When changing the operation of the sugarcane harvester from the sugarcane type of ratoon sugarcane to planted sugarcane, it was found that if the sugarcane harvester harvested on sugarcane planted in double-row, there was a wider range of sugarcane losses than in a single-row. Furthermore, if the harvester was operating on clay, there was a wider range of sugarcane losses than in sandy soil. Additionally, changing the operation of the harvester from planting in double-row to a

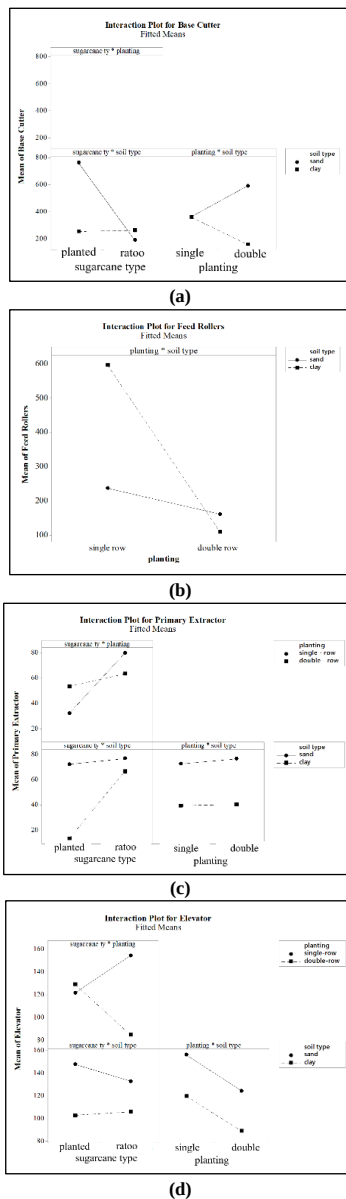


Figure 4. Shows the effect of the co-factors influencing the losses of harvested by sugarcane harvester: (a) base cutter, (b) feed rollers, (c) primary extractor and (d) elevator

single-row, it was found that if the sugarcane harvester harvested on sandy soil, there was a wider range of sugarcane losses than in clay soil.

Anonymous (1999) mentioned, many reasons related to field and crop conditions influence the sugarcane harvester performance including soil type, soil humidity, cane variety, crop yield and operator skill.

Conclusions

This research was designed using a 2k factorials design to determine the loss of sugarcane from the work process of the sugarcane harvester from the factors sugarcane type, planting and soil type. The results of the study found that all three factors influence the losses of sugarcane from the harvester operation. There is a loss of sugarcane from 1) cutting height stool of base cutter 49%, 2) the operation of feed rollers 26%, 3) the operation of elevator 17% and 4) the operation of primary extractor 8%. Additionally, when the variance analysis was done at a significance level of 0.05, it was found that sugarcane type and soil type had an influence on the amount of sugarcane loss from the operation of base cutter in terms of the main factors and co-factors. Planting and soil type had an influence on the amount of sugarcane loss from the operation of the feed rollers in terms of the main and co-factors. Sugarcane type, planting and soil type were the co-factor affecting the amount of sugarcane loss from the operation of the primary extractor.

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