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Original Article

Effect of cylindrical cutting blades and travelling speeds on the performance of sweet sorghum harvesting equipment

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Abstract

This research aim sat developing harvesting equipment with cylindrical cutter for sweet sorghum harvesting. Vertical centrifugal blade mechanism is commonly used in forage harvesters. Such a mechanism would chop the plants into small pieces and transports the mout of the harvesting equipment. However, this research aims to develop such mechanism for harvesting equipment without the chopping process. The laboratory tests were done under simulation harvesting condition in the laboratory. An appropriate blade cutting speed was found. The efficiencies of the harvesting equipment with the varied blade speed and travelling speed were collected. The findings of the study were used to design and construct a harvester prototype that would harvest one row at a time. The field test was conducted to evaluate the functions of the prototype in a real field setting. The results showed that an increase of the blade speed between 6.28 and23.35 m/s did not affect the efficiency of the equipment, nor the cutting loss, but affects the height of the stump, which decreased by 4.82 mm/stump. By increasing the travelling speed from 2.00 to 3.50 km/hr, the efficiency of the equipment increased by 4.14 %, the cutting loss decreased by 6.86%, but the loss from the remaining stumps increased by 2.10%. The fuel consumption cost of this prototype is lower than the cost of the labor wage by 281.60 baht/ha.

Keywords: cylindrical cutter, sweet sorghum harvester

1.Introduction

Thailand is heavily reliant on its energy imports. In 2010, the net value of import increased by19.8% to 911 billion baht (Ministry of Energy, 2011).The government has been focusing on policies in the area of alternative energy, especially ethanol and gasoline mixtures. The current government is promoting to use of gasohol in stead of benzene and has permitted the construction of 54 ethanol plants in the country. The project will require huge amounts of resources, while the current raw material sin use are only molasses and cassava; but both sources are clearly insufficient to meet the demand of the ethanol plants. Moreover, because of its similar seasonal harvesting period, November to April (Wongpichet, 2008), the feeding time of these raw materials such as the cane(molasses) and cassava will not be constant for all ethanol plants.

Sweet sorghum is another viable option as a supplemental raw material to enhance ethanol production. Since the sweetness of the juice in its trunk is at a similar level of that in sugarcane, the sweet sorghum juice squeezed from the plant can directly produce ethanol with similar amounts of ethanol obtained from sugar cane at 70 liters/ton (Jaisil, 2005). Furthermore, the period of sweet sorghum reaping is only 100-120 days with the growing season between May and October that will fill the output gap between the harvesting season of sugar cane and cassava (Wongpichet, 2008). Sweet sorghum's harvesting process is similar to that of sugarcane. Research found that the reaping process of sweet sorghum, which includes harvesting, trimming, and transporting to

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trucks, requires 49.2 workers/hr/ha. The whole process requires 300 workers/hr/ha (Wongpichet, 2008) With labor costs just for harvesting process as high as 1,843.6 Baht/ha and the whole expenditure of 11,250 Baht/ha labor, at the wage of 300 Baht/worker/day, the idea was to reduce the cost of sweet sorghum harvest by developing harvesters that will serve as a substitute for labor work.

Referring to previous studies (Rain, 1993; Prai, 2008), the sweet sorghum harvesting machines were developed in three directions. First, single chop and double shop silage harvesters were applied to sweet sorghum harvesting without any machine modification. The sweet sorghum harvested by these machines was chopped into small pieces, which can be fermented easily. Consequently, the fermentation of chopped sweet sorghum resulted in 50% sugar loss in 24 hours after harvested. However, there was an effort to equip the milling system with the harvester to mill the chopped sweet sorghum, but the fermentation still resulted in 40% sugar loss. Thus, this direction of development became less utilized.

The second direction was an application of the sugarcane harvester without any modification as a sweet sorghum harvester. Prai (2008) reported the test results of the sugarcane harvester model Class cc1400 application. The tested machine cut three rows of the sweet sorghum at the same time. Then they chopped them into 320 mm length and conveyed them to the truck after leave separation by air. The field capacity was 0.77 ha/hr with a traveling speed during harvesting operation of 4.3 km/hr. As the sweet sorghum was chopped in large stalks, the loss of sweetness was low with 10% at seven days after harvest. This direction was popular among farmers in the southern part of the U.S.A. who own large farm areas. Nevertheless, many limitations of this harvester application were found by farmers in the central parts of the U.S.A and in Europe, who have small sized fields. Rain (1993) suggested that the field size should be larger than 10 ha for this kind of application.

The third direction comprises many efforts to develop a sweet sorghum harvesting machine for small size fields. This direction can be divided into two categories. The first category was the development of a sweet sorghum cutting machine. Prai (2008) reported the operation of test result of a sweet sorghum cutting machine of Pasquli. Two rows of sweet sorghum were cut, then their leaves were split and the sweet sorghum stalks were laid down on the field. The field capacity is 0.11 ha/hr with an average speed of 0.9 km/hr. Moreover, Ghahraei *et al.* (2008) reported another test result of the sweet sorghum cutting machine. This machine cuts one row of the sweet sorghum and lays down the stalks on the field without leave separation. The field capacity was also 0.11 ha/hr with an average speed of 2 km/hr.

The second category of the third direction was the development of a small size combined harvester for sweet sorghum that has a similar operation technique than the sugarcane harvester. The operating process consists of leave splitting, base cutting, 300 mm chopping, leave separating by air, and conveying to a truck. Referring to the test result (Prai, 2008), the harvester cuts one row of sweet sorghum and hasa field capacity of 0.05 ha/ht with an average speed of 0.8 km/hr.

Even if the sweet sorghum has the capability to be used in ethanol production, research and development of a sweet sorghum harvesting machine is not available in Thailand at present. Accordingly, the development of a sweet sorghum harvesting machine should be considered in order to solve the labor shortage in the field of agriculture. This research considered a development in the second category of the third direction and focused on the base cutting part and conveying part to the next steps (such as chopping, leaves separating and conveying to the truck).

Similar to the sugarcane harvester and silage harvester, parts of the sweet sorghum harvesting machine were developed in former studies as mentioned in the second category of third direction, such as a counter rotating cutter (Figure 2A) that cut the base of stalk and then convey the stalk into a vertical feed rolls to be conveyed to the next part of machine. Even if the mechanism mentioned above has a good performance, it has a complex assembly and needs well maintenance. Thus, this research chose the cylindrical cutter (Figure2B) with a simple mechanism and easy maintenance. This mechanism was widely used in the single chop silage harvester, which Thai farmers are familiar with. In general, the cylindrical cutter will cut the base of the stalk, pick the stalk upward, chop the stalk and hurl the chopped sweet sorghum of the machine. This research aims to develop a cylindrical

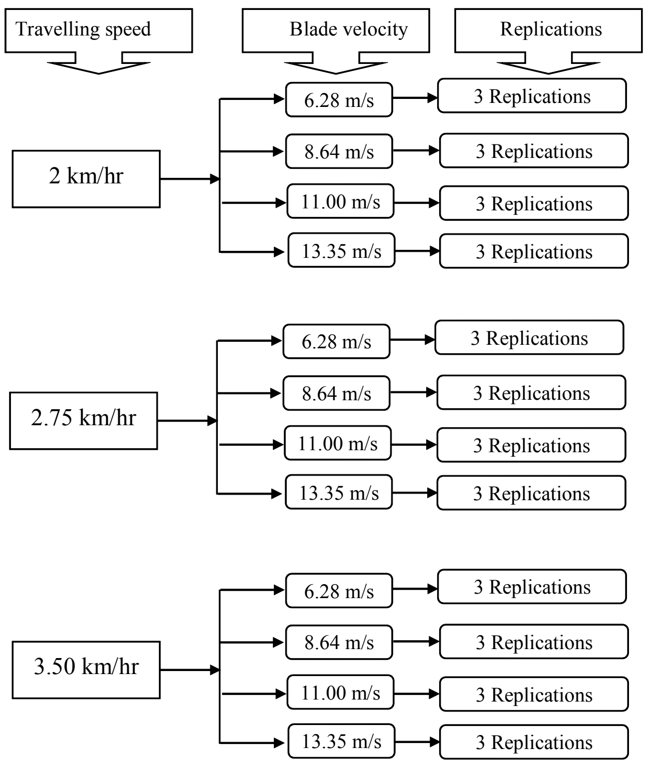
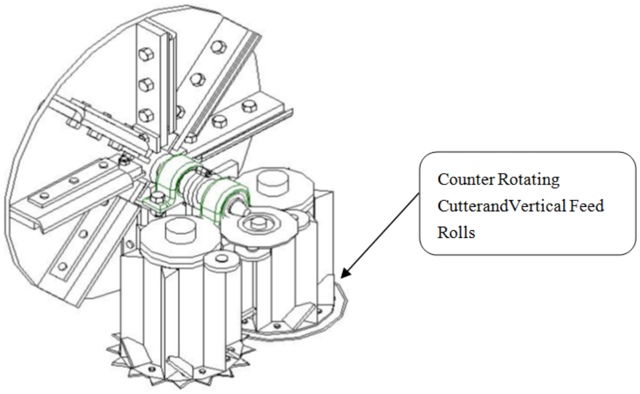
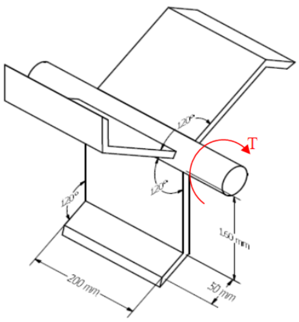


Figure 1. Test method Diagram



A: Counter Rotating Cutter (Homhual and Photong, 2005)



B: Cylindrical Cutter

Figure 2. Comparison of the blade between Counter Rotating Cutter (A)and Cylindrical Cutter(B).

cutter as a base cutter without chopping that is able to hurl the stalk of the machine and to convey the cut stalk to the next process step.

2. Materials and Methods

The research procedure includes construction of a testing unit and simulatingan artificial harvesting test in a laboratory to find a suitable blade velocity. The test results will then be used to design and construct a prototype of a harvesting equipment to evaluate the performance in the field.

2.1 Laboratory test: Effect of the cylindrical cutting blades and travelling speed on the performance of sweet sorghum harvesting equipment

2.1.1 Testunit for a simulation of harvesting at laboratory scale

The sweet sorghum harvesting equipment used a cylindrical cutter (Figure 2B) to cut each row of sweet sorghum. When the harvesting equipment approaches the row of sweet sorghum, the sweet sorghum will be supported with the mechanism attached at the front of the blade. At the same time, the cylindrical cutter will rotate to cut at the base of the trunk (Figure 3A). After that, sweet sorghum with an average height of 2.5 m will be pulled and swung over the blade towards the back of the harvesting equipment (Figure 3B). As the equipment for the next process was not yet developed, in this research, the cut stalk was hurl off the machine to be laid down behind the developed harvesting equipment.

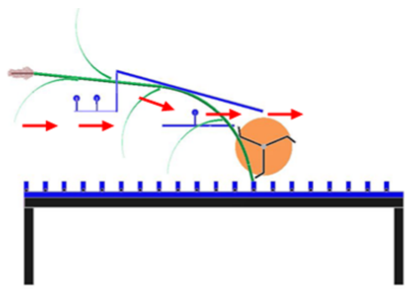
2.1.2 Test method and testing indicators

The study is aimed to find an appropriate blade and traveling speed for the harvesting process of sweet sorghum so that it can easily be transported across the blade to the back of the harvesting equipment.Referring to a preliminary test, the laboratory variation of cutting speed was limited between 6.28 and 25.13 m/s. The traveling speed was limited to the traveling speed of tractors at the 1st, 2nd, and 3rd gear position, respectively. Therefore, considering fourlevels of cutting speed (6.28, 8.64, 11.00, and 13.35 m/s) and three levels of traveling speed (2.0, 2.75, and 3.5 km/hr), the 3x4 factorial ina completely randomized design (CRD) with threereplications were arranged as shown in the following diagram (Figure 1).

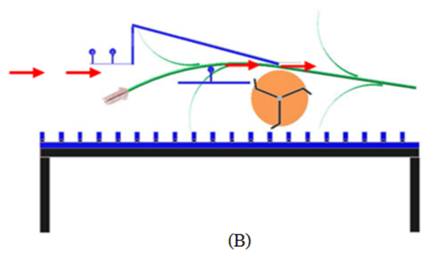
The indicating/dependent factors are harvesting efficiency (% wt), harvesting loss (% wt), height of remaining stumps (mm/stump) and the cutting loss (% wt) and cutting torque (N-m).

2.2 Fieldexperiment: Performance evaluation of the sweet sorghum harvesting prototype

The results from the laboratory test were used to design and construct a prototype of a sweet sorghum



(A)



(B)

Figure 3. Process of cutting the sweet sorghum (A) and transporting process (B).

harvesting equipment for a one-row harvest with a 33.6kW tractor. The prototype was tested in the field with a limitation of the gear set to rotate the blade. The blade velocity set in the study was set at 37.10 m/s at the four levels of travelling speed. The field test was done with two replications. Each replicationwas done in a 5.4x19 m^2 field.

The indicating/dependent factors are field capacity (ha/hr), field efficiency (%),harvesting efficiency (% wt), harvesting loss (% wt), height of remaining stumps (mm/stump) and the cutting loss (% wt) and cutting torque (N-m), and fuel consumption (l/ha)calculated by the following formula.

$$\text{Field capacity (ha/hr)} = \frac{\text{The areas of harvest, hectare}}{\text{Total time of harvest, hr}}$$

$$\text{Field efficiency (\%)} = \frac{\text{Time of harvest, hr}}{\text{Total time of harvest, hr}}$$

$$\text{Harvesting efficiency (\% wt)} = \frac{W_a \times 100}{W_a + W_b + W_c}$$

$$\text{Harvesting loss (\% wt)} = \frac{W_x + W_y + W_z \times 100}{W_a + W_b + W_c}$$

$$\text{The cutting loss (\% wt)} = \frac{W_b \times 100}{W_a + W_b + W_c}$$

where W_a = Weight of stem can be harvested (Figure 4),
W_b = Weight of stump after cutting (Figure 4),
W_c = Weight of stem cannot be harvested, with $W_c = W_x + W_y + W_z$
W_x = Weight of stem was cut off andcannot be transported across the blade to the back of the harvesting equipment (Figure 4),
W_y = Weight of stem was cut but not broken,
W_z = Weight of the trunk is not cut off due to not in wide harvest (Figure 2B, Harvesting width of 200 mm).

$$\text{Fuel consumption (l/ha)} = \frac{\text{The amount of fuel used during the operation, liter}}{\text{The areas of harvest, hectare}}$$

Cutting torque (T),(N-m) = Measurement the shaft of the blade (Figure 4).

Height of remaining stumps (mm/stump) = Measurementthe height stump from ground surface to the top of stump (Figure 4).

3. Results and Discussion

3.1 Laboratorytest result: Effect of cylindrical cutting blades and travelling speed on the performance of sweet sorghum harvesting equipment

The Sweet Sorghum used in the study was KKU.40, 100 days old, planted using a Jab Planter tool. The average distance between each row and plot was 504 and 141 mm,respectively. Each plot had 1-2 trunks with average height of 2,484 mm, an average stump diameter of 13 mm (measured at 100 mm from soil surface, Figure 4), and a moisture content of 47.4% wb. The laboratory test results were shown in Table 1 and Figure 5 to 9.

3.1.1 Effect of blade and travelling speed on harvsting efficiency and harvesting loss

It was found thatthe change of blade speed between 6.28 and 13.35 m/s did not affect the harvesting efficiency and loss. Atravelling speed raisedfrom 2.00 to 3.50 km/hr, on the other hand, increased the harvesting efficiency with a statistical significance (P-value = 0.035). The cut sweet sorghum was increased by 4.14% byweight. Moreover, the harvesting loss was also reduced 6.86% with a statistic significance (P-value = 0.027). The findings can be illustrated with a linear correlation shown in Figure 5 and 6, respectively. From the study, it was found that when using a travelling speed at 3.50 km/hr, the hervesting tool was able to cultivate 85% of the sweet sorghum with only 5.29% harvesting loss.

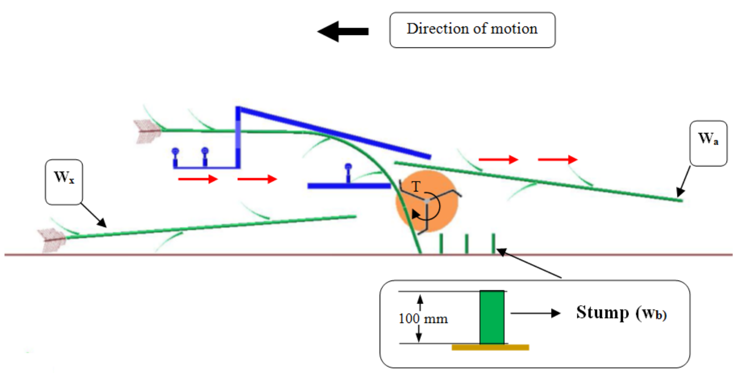


Figure 4. Sweet sorghum after harvested. The stem was cut off and cannot transported across the blade to the back of the harvesting equipment (W_x).The stem can be harvested (W_a). The stump after cutting (W_b).

Table 1. Harvesting efficiency and harvesting loss of prototype from sweet sorghum harvest in laboratory test.

Traveling Speed km/hr	Cutting Speed m/s	rep	Wa kg	Wa %	Wb kg	Wb %	Wc kg	Wc %	Wx kg	Wx %	Total kg	Total %
2.00	6.28	1	13.78	85.94	1.42	8.86	0	0	0.83	5.20	16.04	100.00
2.00	6.28	2	13.38	80.97	1.46	8.86	0	0	1.68	10.17	16.52	100.00
2.00	6.28	3	11.38	73.50	1.37	8.86	0	0	2.73	17.64	15.48	100.00
2.00	8.64	1	10.02	71.04	0.53	3.74	0	0	3.56	25.22	14.10	100.00
2.00	8.64	2	12.98	85.94	1.34	8.86	0	0	0.78	5.20	15.10	100.00
2.00	8.64	3	11.62	71.02	1.45	8.86	0	0	3.29	20.12	16.36	100.00
2.00	11.00	1	13.59	83.46	0.61	3.74	0	0	2.09	12.81	16.28	100.00
2.00	11.00	2	13.79	88.43	0.58	3.74	0	0	1.22	7.83	15.59	100.00
2.00	11.00	3	13.71	85.94	1.75	10.98	0	0	0.49	3.07	15.96	100.00
2.00	13.35	1	11.78	80.97	0.54	3.74	0	0	2.23	15.30	14.55	100.00
2.00	13.35	2	13.73	83.46	1.04	6.30	0	0	1.69	10.25	16.45	100.00
2.00	13.35	3	10.98	75.99	0.54	3.74	0	0	2.93	20.27	14.45	100.00
2.75	6.28	1	12.73	88.43	1.44	9.98	0	0	0.23	1.59	14.39	100.00
2.75	6.28	2	11.85	83.46	1.62	11.42	0	0	0.73	5.12	14.20	100.00
2.75	6.28	3	13.66	83.46	0.61	3.74	0	0	2.10	12.81	16.37	100.00
2.75	8.64	1	12.84	88.43	1.29	8.86	0	0	0.39	2.71	14.53	100.00
2.75	8.64	2	13.70	85.94	1.41	8.86	0	0	0.83	5.20	15.94	100.00
2.75	8.64	3	13.16	88.43	1.32	8.86	0	0	0.40	2.71	14.88	100.00
2.75	11.00	1	12.55	88.43	0.59	4.17	0	0	1.05	7.39	14.19	100.00
2.75	11.00	2	13.31	88.43	1.50	9.98	0	0	0.24	1.59	15.05	100.00
2.75	11.00	3	11.14	78.48	0.53	3.74	0	0	2.52	17.78	14.19	100.00
2.75	13.35	1	12.89	83.46	0.58	3.74	0	0	1.98	12.81	15.45	100.00
2.75	13.35	2	12.86	83.46	0.97	6.30	0	0	1.58	10.25	15.41	100.00
2.75	13.35	3	13.16	83.46	0.99	6.30	0	0	1.62	10.25	15.77	100.00
3.50	6.28	1	13.56	88.43	1.59	10.34	0	0	0.19	1.23	15.34	100.00
3.50	6.28	2	13.03	85.94	1.38	9.12	0	0	0.75	4.94	15.16	100.00
3.50	6.28	3	12.59	85.94	1.88	12.85	0	0	0.18	1.21	14.65	100.00
3.50	8.64	1	11.74	83.46	1.61	11.42	0	0	0.72	5.12	14.07	100.00
3.50	8.64	2	13.85	83.46	1.47	8.86	0	0	1.28	7.69	16.59	100.00
3.50	8.64	3	13.67	83.46	2.22	13.54	0	0	0.49	3.00	16.39	100.00
3.50	11.00	1	12.78	78.48	1.03	6.30	0	0	2.48	15.22	16.29	100.00
3.50	11.00	2	12.72	80.97	1.79	11.42	0	0	1.20	7.61	15.71	100.00
3.50	11.00	3	13.38	88.43	1.53	10.11	0	0	0.22	1.46	15.13	100.00
3.50	13.35	1	13.59	90.92	1.32	8.86	0	0	0.03	0.22	14.94	100.00
3.50	13.35	2	12.91	78.48	0.61	3.74	0	0	2.93	17.78	16.45	100.00
3.50	13.35	3	12.89	88.43	0.92	6.30	0	0	0.77	5.27	14.58	100.00

Remarks: W_a = Weight of stem can be harvested. W_b = Weight of stump after cutting. W_c = Weight of stem cannot be harvested. W_x = Weight of stem was cut off and cannot transported across the blade to the back of the harvesting equipment.

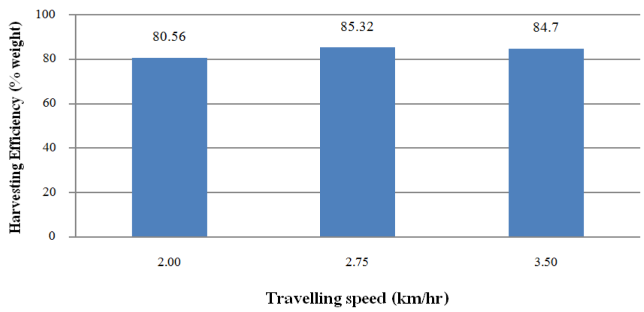


Figure 5. Harvesting efficiency at different travelling speed.

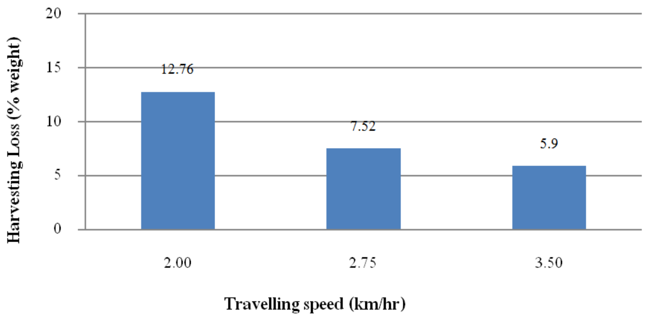


Figure 6. Harvesting loss at different travelling speed.

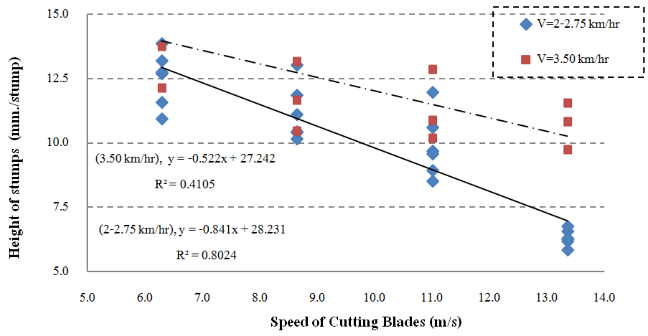


Figure 7. Relation between the speed of cutting blade and the heigh of stumps.

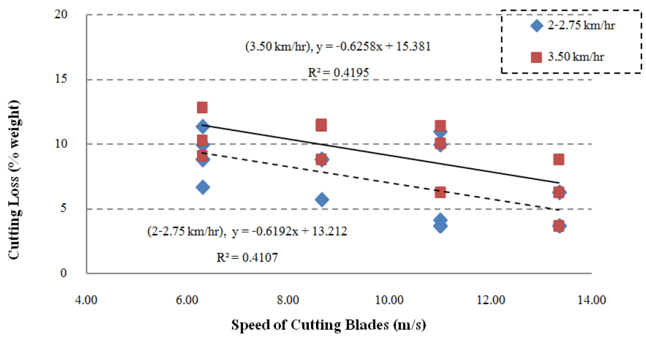


Figure 8. Relation between the speed of cutting blade and cutting loss.

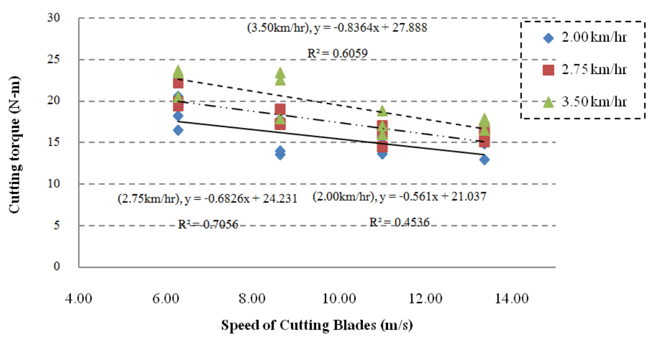


Figure 9. Relation between the speed of cutting blade and the cutting torque.

3.1.2 Effect of the blade and the travelling speed on the height of the remaining stumps and its cutting loss

During the study, the harvester's blade was set to be 5 mm above the soil surface. It was found that the blade speed raisedfrom 6.28 to13.35 m/s reduced the height of the remaining stumps with a statistical significance (P-value = 0.000). On average, the height decreased by 4.82 mm. Araising travelling speed from 2.00 to3.50 km/hr increased the height of the remaining stumps with a statistic significance (P-value = 0.001).Nonetheless, theraisingtravelling speed between 2.00-2.75 km/hr did not lead to any change in the height of the remaining stumps. All of these finindings can be illustrated in a linear correlation shown in Figure 6. At ablade speed of 13.35 m/s, if the travelling speed was at 2.00-2.75 km/hr, the height of the remaining stumps would be on average 7 mm, but if the travelling speed was at 3.50 km/hr, the height of remaining stumps would be on average 10 mm. It can be concluded that at different travelling speed, cutting with high speed blade will result in a lower height of the remaining stumps, closer to the value adjusted before the study at 5 mm.

The remaining stumps were weighed to calculate the cutting loss. Figure 8 shows the correlation between the blade speed and the cutting loss. It was found that when the travelling speed was at 2.00-3.50 km/hr, an increase of blade speed reduced the cutting loss on average by 4.40%. When the blade speed was at 13.35 m/s, a travelling speed at 2.00-2.75 and 3.50 km/hr would result in a lower cutting loss on average by 4.95% and 7.04%, respectively.

3.1.3 Effect of blade and travelling speed on the sweet sorghum cutting torque

The ananlysis of the results showed that when the blade speed increased from 6.28 to13.35 m/s a reduction in the sweet sorghum cutting torque was obsereved with a statistical significance (P-value = 0.000). A raise in the travelling speed from 2.00 to 3.50 km/hrled to an increase in the cutting torque with a statistical significance (P-value = 0.000). The findings can be shown as a linear correlation illustrated in Figure 9. When the blade speed was at 13.35 m/s and the travelling speed was at 2.00 km/hr, the cutting torque was at 13.54 Nm; when the travelling speed was at 3.50 km/hr the cutting torque increased to 16.72 Nm.

3.2 Field experiment result: Performance evaluation of the prototype of the sweet sorghum harvesting equipment

From the findings in the laboratory tests, a prototype of the sweet sorghum harvesting equipment was developed to evaluate its performance at actual farming conditions (Figure 10 and 11). For a one-row harvest, the speed of the blade was adjusted to 37.10 m/s; a higher speed than in the laboratory tests. The adjustment was made due to limitation of gear used in the prototype model. However, the increased speed could give a better result in terms of height of the chopped stump, which is now lower. In addition to that, the blade was adjusted to be 80 mm above the soil surface to reduce the problem with chopping into the soil surface. The prototype was tested under the real harvesting condition with a 33.6 kW tractor as power source. The results are shown in the Table 2 to 4.

It was found that when the travelling speed exceeded 3.09km/hr, the performance of the prototype clearly reduced (Table3). Because of the speed increase, more sweet sorghum was harvested with a total volume of trunks and leaves

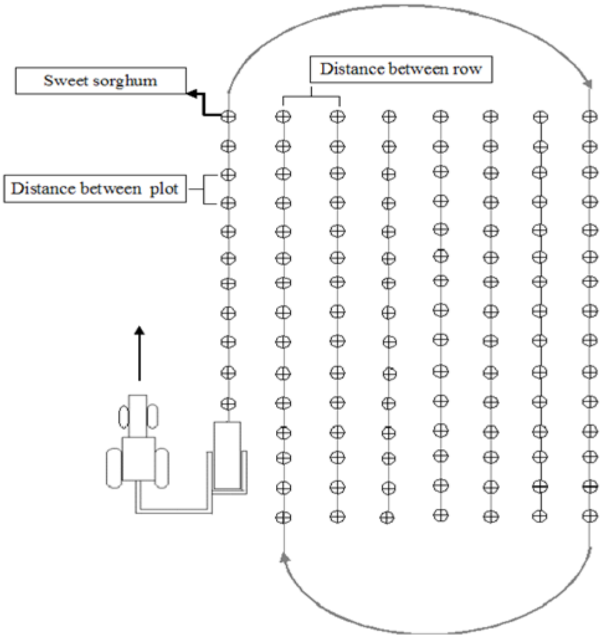


Figure 10. Distance between row and plot.

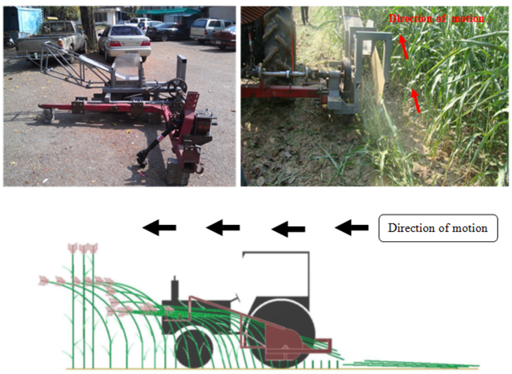


Figure11. Sweet sorghum harvesting equipment one row with a tractor while sweet sorghum harvesting.

larger than the input canal which was designed for only 0.02 m^2. Hence, this caused congestion with in the prototype, obstructed the conveyerbelt, and hamppered the harvesting process. It was concluded that the prototype could not work under the condition where the travelling speed exceeds 3.1 km/hr.

When comparing the results of the travelling speed from 1.91 to 3.09 km/hr (Table 3 and 4) it was found that an increase in the travelling speed resulted in a higher field capacity but barely changed the field efficiency, the harvesting efficiency, the harvesting loss, and the cutting loss from remaining stumps. It can be concluded that the prototype had the field capacity at 0.15 ha/hror1,895 kg/hr and the average field efficiency was at 74.04%. An average harvesting efficiency was 88.00% while the average harvesting loss was 4.82%. Anaverage cutting loss from the remaining stumps was 7.19% and the prototype needed average torque of 28.00 Nm. Fuel consumption was at 52.1 l/hr or 1,562 baht/ha at the fuel price of 30 baht/l. The cost of using the sweet sorghum harvester is lower than that of using human labour by 1,843 baht/ha. It can be concluded that the sweet sorghum harvesting with cylindrical cutter equipment has the potential to be researched to further development.

4. Conclusions

The laboratory results have shown that by increasing blade speed from 6.28 to 13.35 m/s the harvesting efficiency was barely affected, but it has reduced the height of the remaining stumps by 4.82 mm each. By increasing the travelling speed from 2.00 to 3.50 km/hr the harvesting efficiency was raised by 4.14%, the harvesting loss was reduced by 6.86%, but the loss from the remaining stumps increased by 2.10%.

The prototype for a one-row harvest was then constructed from the laboratory findings to evaluate the performance under actual farming condition. The results show that the cost from fuel consumption was lower than

Table 2. Harvesting efficiency and harvesting loss of prototype from sweet sorghum harvest in field test.

Traveling Speed km/hr	rep	Wa kg	Wa %	Wb kg	Wb %	Wx kg	Wx %	Wy kg	Wy %	Wz kg	Wz %	total kg	total %
2.00	1	52.00	86.06	4.72	7.81	1.50	2.48	1.70	2.81	0.50	0.83	60.42	100.00
	2	51.30	89.01	3.84	6.65	1.20	2.08	1.30	2.26	0.00	0.00	57.64	100.00
2.50	1	57.00	89.55	2.95	4.63	1.50	2.36	2.20	3.46	0.00	0.00	63.65	100.00
	2	53.70	89.74	3.54	5.92	0.70	1.17	1.90	3.18	0.00	0.00	59.84	100.00
3.00	1	46.30	86.04	5.31	9.87	1.50	2.79	0.00	0.00	0.70	1.30	53.81	100.00
	2	56.40	87.56	5.31	8.24	0.00	0.00	2.70	4.19	0.00	0.00	64.41	100.00
3.50	1	28.00	52.52	5.31	9.96	13.50	25.32	5.10	9.57	1.40	2.63	53.31	100.00
	2	40.00	69.58	6.49	11.29	8.50	14.79	2.50	4.35	0.00	0.00	57.49	100.00

Remarks: W_a= Weight of stem can be harvested. W_b= Weight of stump after cutting. W_c= Weight of stem cannot be harvested. W_x = Weight of stem was cut off and cannot transported across the blade to the back of the harvesting equipment. W_y= Weight of stem was cut but not broken. W_z= Weight of the trunk is not cut off due to not in wide harvest.

Table 3. Performance of the sweet sorghum harvester prototype in a field[1)].

Travelling Speed (km/hr)	Field Capacity (ha/hr)[2)]	FieldEfficiency (%)[2)]	CuttingTorque (N-m)	FuelConsumption (l/ha)
1.91	0.10 a	74.65 a	20.85	67.7
2.34	0.12 b	74.56 a	23.64	57.3
3.09	0.15 c	72.91 a	28.80	52.1
3.64	0.13 d	53.76 b	27.16	49.5

Remarks: 1) Sweet sorghum cultivated was KKU 0.40, 93 days old, grown using a row-planting tool. The average distance between each row and plot was 678 and 181 mm, respectively. Each plot had 1-3 trunks with moisture content average of 48.9% wb and yield of 24,194 1 kg/ha. 2) In each column, the average was derived from two repeated tests. There is no difference between average values followed by the same letter when compared the average values against the least significant difference (LSD) at level of significance of 0.05.

Table 4. Performance of prototype from sweet sorghum harvest.

Travelling Speed (km./hr)	Average Harvesting eff.[1)] (% wt)	Average Harvesting loss (% wt)				Average Cutting Loss from Remaining Stumps[1)] (% wt)	Total
		successfully cut but not fed into the harvester	partially cut	remained uncut	total[1)]		
1.91	87.54 a	2.28	2.53	0.41	5.23 a	7.23 a	100.0
2.34	89.65a	1.76	3.32	0.00	5.08 a	5.28 a	100.0
3.09	86.80 a	1.39	2.10	0.65	4.14 a	9.06 a	100.0
3.64	61.05 b	20.05	6.96	1.31	28.33 b	10.62 b	100.0

Remark: 1) In each column, the average was derived from two repeated tests. There is no difference between average values followed by the same letter when compared the average values against the least significant difference (LSD) at level of significance of 0.05.

that of human labor by 281.60 baht/ha. It may be concluded that the method of sweet sorghum harvesting with a cylindrical cutter has great potential to be researched for further development.

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References

Ghahraei O., Khoshtaghaza, M.H. and Bin Ahmad, D. 2008. Design and development special cutting system for sweet sorgum harvester. Janal Center Europane Fo Agricoltura. 3, 469-474.

Homhual, S. and Photong, W. 2005. Single row forage harvester driven by small tractor. Kamphaengsaen Academic Journal. 3(3), 62-69.

Jaisil, P. 2005. Potential of using sweet sorghum as an additional raw material for commercial ethanol production. Proceedings of the 32nd Thai National Corn and Sorghum Research Conference, Bangkok, Thailand, p. 49-50.

Ministry of Energy. 2011. Annual Report 2010. Ministry of Energy.

Pari, L. 2008. State of the areart: Harvesting, storage and logistic of the sweet sorghum. Proceedings of the 16th European Biomass conference and Exhibition, June 2-6, 2008, 174-177.

Rains G.C., Cundiff, J.S. and Welbaum, G.E. 1993. Sweet sorghum for a piedmont ethanol industryp. Proceedings of the 2nd National Symposium. 394-399. Available source http://www.hort.purdue.edu/newcrop/proceedings1993/v2-394.html, 15/09/2012 [February 1st, 2014].

Wongpichet, S. 2008. Development of the sweet sorghum crusher for agricultural group. Research report, Khon Kaen University. p. 17