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Basic Study of Leaf Cutting Mechanisms for Happy Trees

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Abstract: Happy trees have a potent anti-cancer material. Farmers have so far lacked a suitable machine to pluck the leaves. The purpose of this study was to find the best device for plucking leaves from happy trees. In this study, the reciprocating knife mechanism was chosen. Two types of reciprocating cutting devices were used. One is from a rice combine. It has a horizontal pattern and a serrated blade. The other is from a tea plucking machine that has an arc pattern and a smooth blade. The experiment tested the whole cutting mechanism at two different forward velocities (0.52 m/s and 0.63 m/s) and various knife speeds (230 rpm and 330 rpm for cutterbar from a rice combine, 750 rpm and 850 rpm for the cutterbar from a tea plucking machine) and recorded the torque and ratio of broken branches to determine which one is the best cutting mechanism. The result showed the ratio of broken branches for the reciprocating cutterbar from a rice combine at two different forward velocities and knife speeds was less than 5%. The ratio of broken branches for the reciprocating cutterbar from the tea plucking machine was less than 5% only at 0.52 m/s forward velocity. Another result showed that the torque required of the reciprocating cutterbar from a rice combine had an exponential relation with the velocities ratio. The conclusion from this study is that the reciprocating cutterbar from a rice combine is better for plucking happy tree's leaves.
Key words: Cutting device, ratio of broken branches, torque, velocity ratio, happy trees

INTRODUCTION

The formal name of happy tree is called Camptotheca acuminate Decne. Happy trees were imported from the mainland China between 1948 and 1952. Then they were domesticated by Taiwan Forestry Research Institute over a long period of time. Today they can be cultivated in the South of Taiwan successfully. A valuable material called camptothecin (CPT) is extracted from the xylem of happy trees. Two main derivatives of CPT are Irinotecan and Topothecan. In medicine it is proved that they have the function against some cancers (Yan et al., 2003). Therefore the need of CPT becomes more and more. There are some other plants that can also produce CPT, happy trees have the advantages of easy planting and fast growing, however. In Taiwan the main sources of CPT are the leaves from happy trees. Leaves can be plucked at least 20 times each year. Today farmers have so far lacked a suitable machine to pluck the leaves effectively. The most important device for a plucking machine is its cutter mechanism. Thus the purpose of this study is to find a best device for plucking leaves from happy trees.

MATERIALS and METHOD

Experiment Apparatus

For the sake of experiments to be carried out indoors and instruments to be installed easily, original moving chassis became stationary (Huang, 1989; Chen, 1981) and a mobile cart was developed to carry happy tree's leaves towards the cutting mechanism. Figure 1 shows the experiment apparatus used in this study. It consists of a cutting device and a mobile cart.

The cutting device included a cutterbar frame, a crank, a connecting rod and a measuring shaft. The power source for cutter was an eddy-current type motor with 3-Phase, 220V and 2hp. The rotating speeds could be changed by a speed regulator and the speed range was stepless between 0 and 1800 rpm. There were two strain gauges on the measuring shaft in order to determine the torques.

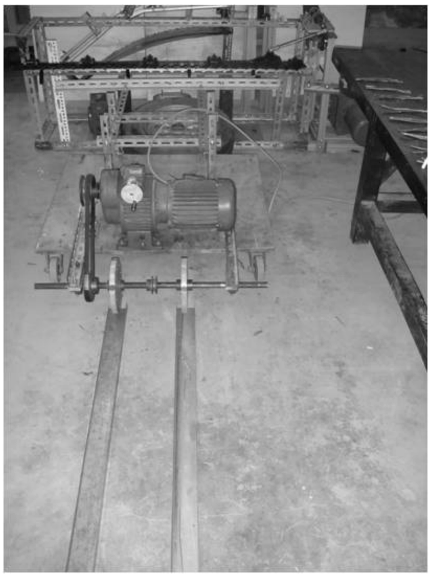

Figure 1. Experiment apparatus

A mobile cart was made by wooden plate with a dimension of 91.5cm x 79.5cm, angle steels, four pilot wheels and two driving wheels. Its power source was a three-phase 220V AC motor with 2hp. The speeds could also be adjusted by a stepless transmission and its speed ratio was between 1/7 and 1/42. There was a fixture with a width of 112cm which could clamp the leaves and branches of happy trees. Nine sets of sample could be mounted on the cart each time and the space between each sample was 11cm. The average length of leaves and branches of happy tree was cut to 15cm for test.

Experiment methods

Two kinds of cutting mechanism were used in this study in order to find out which one was suitable for the plucking machine of happy tree's leaves. In this study, the reciprocating knife mechanism was chosen. Two types of reciprocating cutting devices were used. One was from a rice combine. It had a horizontal pattern and a serrated blade. The other was from a tea plucking machine that had an arc pattern and a smooth blade.

Two important indices were used to determine what kind of cutting mechanism is best for plucking leaves:

1. Ratio of broken branches after cutting

   In general new sprouts will be grown from the cutting section of branches after the leaves and branches are plucked. If the cutting section is not smooth (i.e. it is broken or torn), this section will become black and does not sprout anymore. Therefore, it is very important to avoid broken branches during cutting. The ratio of broken branches can be evaluated according to the following equation:

   $$R = \left(\frac{B}{A}\right) \times 100 \qquad (1)$$

   where R = Ratio of broken branches (%)
   B = No. of broken branches
   A = No. of total cutting branches

2. Torque required for cutting

   The strain gauges on the measuring shaft must be calibrated before the cutting torque experiments begin. The calibration equation obtained is (Huang, 2008):

   $$S = 1.59 \times T + 0.2 \qquad (2)$$

   where S = Strain (-)
   T = Torque (kg-cm)

   The power required can then be calculated from the following formula (Keneper, 1952):

   $$P = \left(\frac{N \times T}{726.43}\right) \qquad (3)$$

   where P = power (hp)
   N = Rotating speed (rpm)
   T = Cutting torque (kg-m)

The forward velocity of the mobile cart and the rotating speed of measuring shaft could be set by means of a tachometer and a stepless transmission on the cart. After the cart switched on, it would move toward the cutting device. When the leaves and branches of happy tree passed through the cutting device, the cart should stop to move immediately. The ratio of broken branches could then be calculated and the required cutting torques could be obtained further.

RESULTS and DISCUSSION

Ratio of broken branches after cutting

Table 1 shows the average ratios of broken branches after five tests under the same conditions. It is evident that all ratios of broken branches for the cutter from rice combine are less than 5%, no matter what the forward velocities of mobile cart (0.52 m/s or 0.63 m/s) or cutting speeds of knife (230 rpm or 330 rpm). This is the reason why a following developed machine uses this type of cutter for plucking leaves of happy trees. In addition, the assembly of cutterbar from rice combine is easier than that from tea plucking machine. Furthermore, the working width of cutter from rice combine is larger and more suitable than that from tea plucking machine.

Next, two knife cutting speeds (200 rpm and 420 rpm) and one forward velocity (0.84 m/s) were added in order to find an optimal condition for the cutter from rice combine. Table 2 shows a comparison of ratios of broken branches after the operation of cutter from a rice combine.

The data of Table 2 can be expressed by a diagram like Figure 2. From this figure it is obvious that the cutting mechanism from rice combine has a best cutting performance when the knife speed is 420 rpm and the velocities of cart are between 0.52 m/s and 0.84 m/s. The average ratio of broken branches is less than 3.7%. If the knife speeds are 200 rpm and 230 rpm, and the velocity of cart is 0.84 m/s, it is found that the ratio of broken branches increases rapidly. This means that the forward velocity of mobile cart has its limit in order to avoid the cutting sections of branches imperfectly. Besides, the cutting performances by knife speeds of 330 rpm and 420 rpm are better than that of 200 rpm and 230 rpm under all cart’s velocities and the ratios of broken branches are less than 5%.

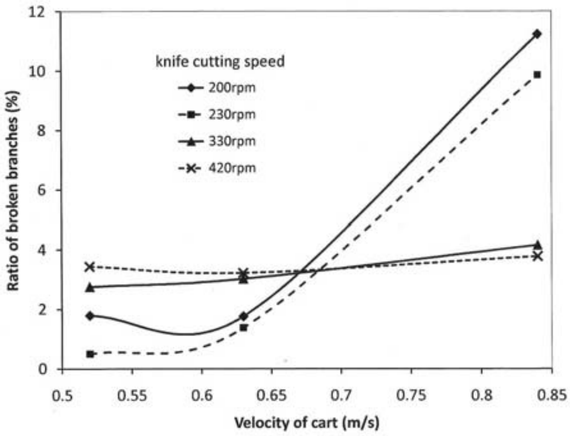

Figure 2. Relationship between ratio of broken branches and forward velocity of cart

Torque required for cutting

Table 3 shows the required torques by cutting under different knife velocities and forward velocities of cart for the cutting mechanism from rice combine. The definition of velocity ratio (k) is the knife velocity divides the forward velocity of cart (Kepener, 1952). This knife velocity can be converted from previous mentioned knife rotating speed.

Table 1. Ratio of broken branches with two different cutters

Forward velocity of cart (m/s)	Cutter from a rice combine		Cutter from a tea plucking machine	
	Knife speed (rpm)		Knife speed (rpm)	
	230	330	750	850
0.52	0.5%	2.76%	4.18%	0.625%
0.63	1.38%	3.026%	8.83%	6.045%

Table 2. Ratios of broken branches with the cutterbar from a rice combine

Forward velocity of cart (m/s)	Knife Cutting speed (rpm)			
	200	420	230	330
0.52	1.79%	3.44%	0.5%	2.76%
0.63	1.76%	3.22%	1.38%	3.026%
0.84	11.23%	3.78%	9.86%	4.16%

Table 3. Torque requirements of the cutterbar from a rice combine

Forward velocity of mobile cart (m/s)	Knife cutting velocity (m/s)	Velocity ratio k (-)	Torque required (kg-cm)
0.52	0.33	0.63	35.02
	0.38	0.73	44.44
	0.55	1.06	38.08
	0.7	1.35	44.90
0.63	0.33	0.52	30.30
	0.38	0.60	32.46
	0.55	0.87	33.58
	0.7	1.11	43.08
0.84	0.33	0.39	27.45
	0.38	0.45	27.87
	0.55	0.65	28.27
	0.7	0.83	35.92

If the regression analysis is applied to the above data, an exponential relationship between the cutting torque and the velocity ratio can be obtaioned (Figure 3). The exponential function is:

$$T = 23.41 \times \exp(0.51 \times k) \quad (4)$$

where T = torque (kg-cm)

k = velocity ratio (-)

and the coefficient of determination R^2 = 0.67.

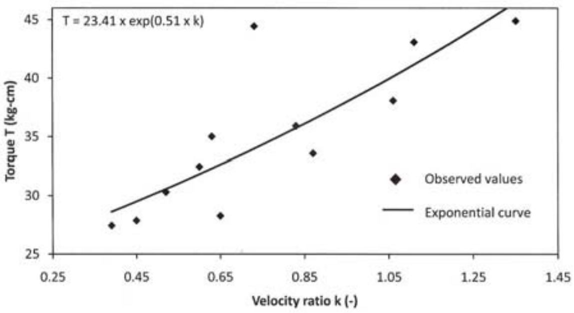

Figure 3. Relationship between torque requirment and velocity ratio

In addition, if the forward velocity of mobile cart increases, the torque required will reduce. If the knife cutting velocity increases, the torque required will also raise, however. Figure 4 describes these results.

According to equation (3), the power required can be calculated. Table 4 shows the required power for the cutting mechanism from rice combine.

Similarly, by means of regression analysis a statistical curve can be found (Figure 5).

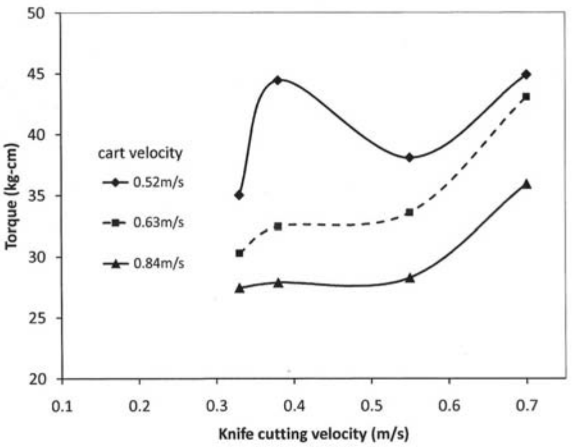

Figure 4. Relationship between torque requirment and knife cutting velocity

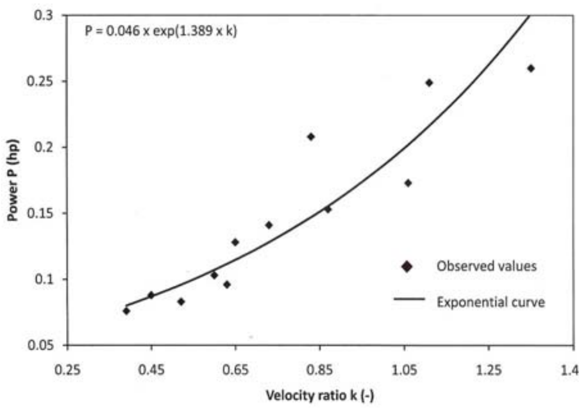

Figure 5. Relationship between power requirment and velocity ratio

Table 4. Power requirments of the cutterbar from a rice combine

Cart's forward velocity (m/s)	Knife velocity (m/s)	Cutting torque (kg-cm)	Power required (hp)
0.52	0.33	35.02	0.096
	0.38	44.44	0.141
	0.55	38.08	0.173
	0.7	44.90	0.260
0.63	0.33	30.30	0.083
	0.38	32.46	0.103
	0.55	33.58	0.153
	0.7	43.08	0.249
0.84	0.33	27.45	0.076
	0.38	27.87	0.088
	0.55	28.27	0.128
	0.7	35.92	0.208

In Figure 5 it is obvious that the relationship between power and velocity ratio is also exponential and the function is:

$$P = 0.046 \times \exp(1.389 \times k) \qquad (5)$$

where P = power (hp)
k = velocity ratio (-)
and the coefficient of determination R^2 = 0.876.

CONCLUSIONS

The followings were concluded from the study:

- Two reciprocating cutters used in this study were originally mounted on a rice combine and a tea plucking machine respectively. The cutting speeds chosen for cutter from rice combine were 230 rpm and 330 rpm; the cutting speeds chosen for cutter from tea plucking machine were 750 rpm and 850 rpm. The forward velocity of mobile cart were 0.52 m/s and 0.63 m/s. Comparison of ratio of broken branches from these two types of cutters, it is obvious that the cutter mechanism from rice combine is more suitable to pluck leaves and branches of happy trees than that from tea plucking machine. All the ratios of broken branches were less than 5%.
- Also under the knife speeds of 420 rpm and 330 rpm and three forward velocities of cart (0.52 m/s, 0.63 m/s and 0.84 m/s) the cutter from rice combine still had a good cutting performance. Except cart velocity of 0.84 m/s, this type of cutter had also satisfied results under the knife speeds of 200 rpm and 230 rpm.
- The torque and power required for the cutter from rice combine were dependent on the cutting velocity ratio k and had an exponential relationship. The corresponding equations were: Torque = $23.41xe^{(0.51xk)}$ [unit:kg-cm] and Power = $0.046xe^{(1.389xk)}$ [unit:hp].

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