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Development of Kenaf Harvesting Technology Using a Modified Sugarcane Harvester

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Abstract

In this study, a kenaf harvester was developed and the optimum harvesting period and effective field capacity were determined. The kenaf harvester that was a modified sugarcane harvester had a 57 kW engine and ran with a crawler. To cut kenaf stems properly, a cutter equipment specific to kenaf was developed, to control the flow of harvested kenaf stems and prevent the basts of kenaf from winding around the cutter part of the drum. This machine enabled to cut kenaf stems with a length of about 22 cm each, regardless of the traveling speed, and harvest could take place from the period of flowering to the period of killing frost. In this machine, 2 types of carriers were developed for the harvested kenaf stems: a net bag type and a conveyor type. The net bag type consisted of a net bag container with a capacity of about 500 kg located behind the machine. With this type, although the field capacity efficiency was low because much time was spent on unloading the materials, the harvester could be handled with one operator. The effective field capacity was about 6.6 a/h. The conveyor type consisted of a belt conveyor system located behind the machine. Kenaf was conveyed to a wagon tractor by the conveyor system. In the conveyor type, the operations were slower (15%) than in the net bag type, but the effective field capacity was about 13.9 a/h.

Discipline: Agricultural machinery
Additional key words: kenaf harvester, optimum harvesting period, effective field capacity

Introduction

Kenaf is considered to be an alternative fiber crop in many countries[4–6] because of its ability to assimilate carbon dioxide[2,3], in addition to water purification[1] and fast growth characteristics. It could also be used for the manufacture of paper, fiberboard[7], etc. In Japan, kenaf may become a new material that could be used for building materials or the interior of cars. The fiberboard should be strong enough to withstand cracking forces even in areas where considerable bending may occur. Therefore, kenaf stems with a length of 10 cm and more are requested from the industry. Forage harvesters are generally used for the harvesting of kenaf, because of their high efficiency and low cost. However, forage harvesters cut kenaf stems into too short fragments.

In this study, a kenaf harvester was developed by using a small sugarcane harvester. This machine enabled to harvest kenaf while avoiding cutting stems into too short fragments.

Materials and methods

1. Study site

The study site was located at Tsukuba Science City, about 60 km Northeast of Tokyo. Mean temperature is 13.3ºC and annual precipitation is 1,240 mm. The rainy season occurs normally from early June to late July. Around Tsukuba, many crops and vegetables are cultivated, for example rice, soybean, sweet potato, tomato, lettuce, carrot, etc.

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2. Experimental harvester

In this study, the small sugarcane harvester HC-50N manufactured by BUNMEI Inc., Co. (Kagoshima, Japan) was used as the base machine. It has a 57 kW engine and it runs with a crawler. Fig. 1 shows the machine and Table 1 shows the specification of the machine. This machine (1) pushes down kenaf forward and cuts stems at the ground level, (2) removes leaves during transportation with rollers, (3) cuts stems with a chopper in the body, (4) blows out leaves and unripe stems with a fan and (5) drops off arranged stems.

To cut kenaf stems properly, a cutter equipment specific to kenaf was developed (Fig. 2). The diameter of the drum was increased from 14 to 20 cm and the lifter was lowered to 15 from 23 cm, compared with the conditions for the sugarcane harvester, to control the flow of harvested kenaf stems. The cutter had a scraper with sharp cutlery behind the drum to prevent the basts of kenaf from winding around the cutter part of the drum.

In this machine, 2 types of carriers were developed for the kenaf stems: A net bag type and a conveyor type. The net bag type consisted of a net bag container with a capacity of about 500 kg located behind the machine. The conveyor type consisted of a belt conveyor system located behind the machine. Kenaf stems were conveyed to a tractor-trailed wagon.

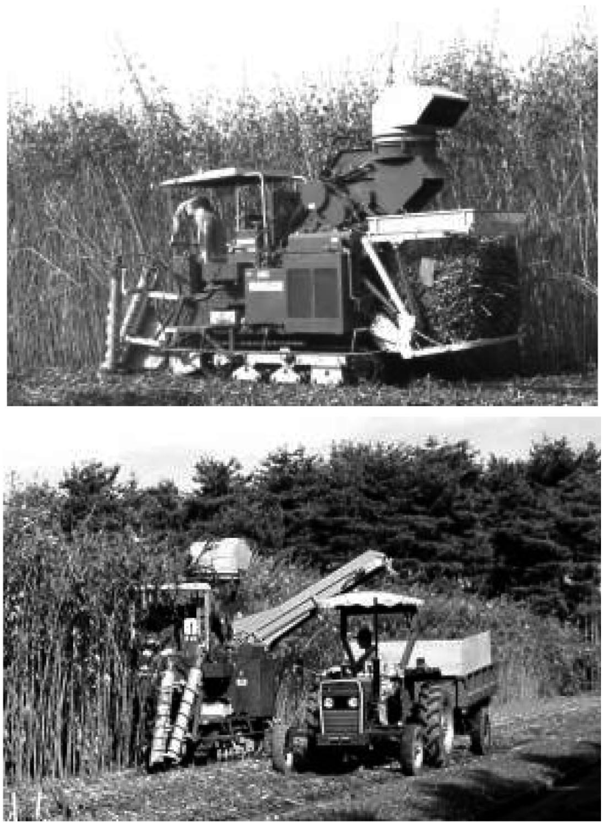

Fig. 1. Operation of the kenaf harvester
Upper, net bag type; bottom, conveyor type.

3. Kenaf planting

Kenaf seeds (*Chinpi3*) were planted to form a row pattern with hills arranged at an alternate spacing of 30 and 90 cm, in order to become adapted to the width of the disk cutter. The harvester was able to cut 2 rows of kenaf

Table 1. Specification of kenaf harvester

Length	6,070 mm
Width	3,900 mm
(Body)	2,200 mm
(Overhang part)	1,700 mm
Height	3,050 mm
Weight	4,900 kg
Running type	Rubber crawler
Engine	Diesel
Power	56.6 kW/2,500 rpm
Fan duct area	0.3 m^2
Net bag (volume)	1.95 m^3
Conveyor (width)	400 mm
(length)	3,400 mm
(height)	2,200 mm

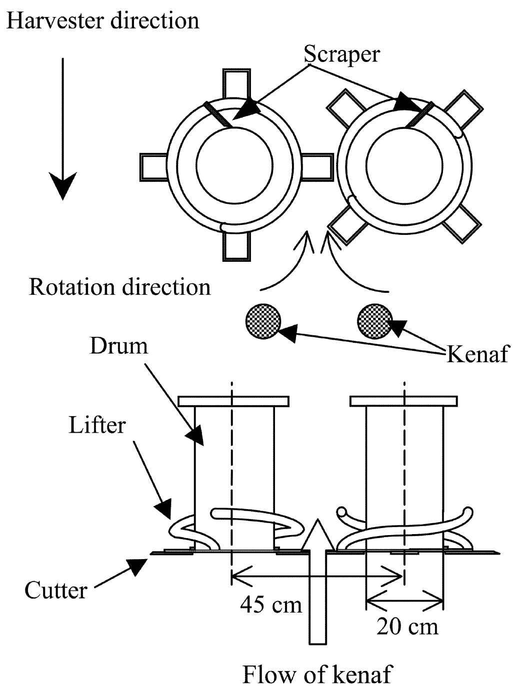

Fig. 2. Cutter specific to kenaf
Upper, plane view; bottom, lifting position.

at once. A sowing machine planted seeds at an inter-row spacing of 8 cm.

In 2000, kenaf was sowed on June 20, and in 2001, it was sowed on May 28, June 29 and July 23. To determine the growth stages, height, weight of leaves, moisture content, flowering date, etc. were recorded.

4. Experimental harvesting

The length of the cut kenaf stems was measured under different traveling speeds, 0.5 and 1.0 m/s.

In order to determine the optimum harvesting period, the harvester was tested from early October to late March, namely from the pre-flowering stage to the withering stage of kenaf.

After experimental harvesting, the loss was measured in a field 1.2 × 2 m in size with a rectangular shape. The loss could be classified into head loss, blowing out loss by the fan and falling loss from the inside of the body.

To determine the effective field capacity, a net bag type and a conveyor type were tested. For the net bag type, the harvesting performance was evaluated in a field 6 × 97.5 m in size with a rectangular shape. When the net bag became full, it returned so that the machine was able to unload the materials and the operator had to replace the bag with a new empty one at the end of the field and to go back and forth. For the conveyor type, the harvesting performance was evaluated in a field 2.4 × 100 m in size with a rectangular shape. This type required 2 operators for the harvester and wagon, respectively.

Results and discussion

1. Growth characteristics of kenaf

Fig. 3 shows the growth pattern of the kenaf plants sowed on June 20, 2000. At 16 weeks after sowing, flowering started and at 18 weeks after sowing, there were flowering plants in the picked-up samples. After flowering, the height of the kenaf plants did not change. The weight of the leaves increased by flowering and thereafter, the leaves fell gradually. At 4 weeks after flowering, the weight of the leaves was 1/5 of that of the maximum weight.

Kenaf was harvested at 20 weeks after sowing, when the average height was about 3.7 m and the weight was 6.9 t/10 a.

Fig. 4 shows the changes in the moisture content of the stems. The moisture content was stable at above 80%w.b. by mid-November when frost occurred. Though the moisture of the top of the kenaf stem decreased by frost, the moisture content of the bottom of the stem was as high as that before frost occurrence. The moisture content of the bottom of the stem decreased to 47.9%w.b. in late March.

These results indicate that the growth stages could be classified as follows. (1) Growing stage: Kenaf was growing and had many leaves. (2) Flowering stage: Kenaf had flowers and some leaves, and the height became stable. (3) Falling stage: Kenaf did not have leaves but the moisture content of the stems exceeded 80%. (4) Withering stage: The moisture content of the kenaf stems was lower than 50%.

2. Basic performance of kenaf harvester

Fig. 5 shows the length of the cut stems under different traveling speeds. The length of the cut stems was about 22 cm. The average length was 21.7 cm (S.D. 2.6) at a speed of 0.5 m/s and 21.5 cm (S.D. 3.0) at a speed of 1.0 m/s. Though kurtosis (Kw) amounted to 2.6 and 3.0, the distribution was limited to the center. The rate of stem cutting for a stem length between 21 and 24 cm was 71.2% at a speed of 0.5 m/s and 68.6% at a speed of 1.0

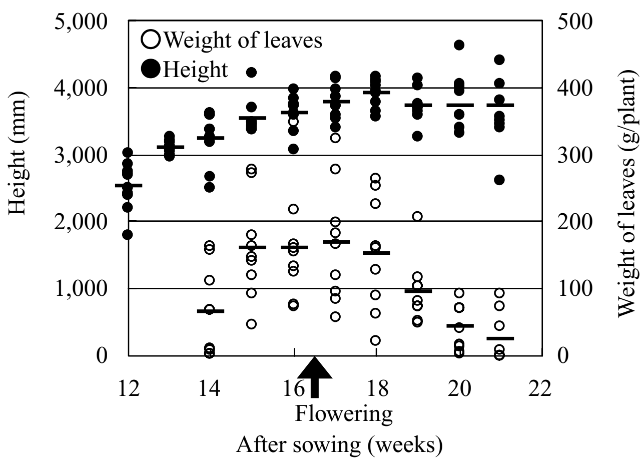

Fig. 3. Growth pattern of kenaf

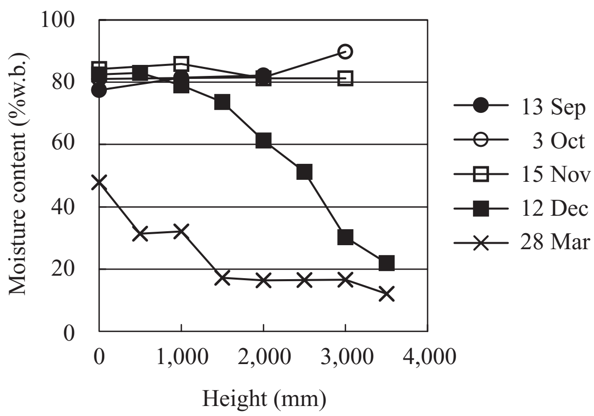

Fig. 4. Moisture content of kenaf stems
Sowed on June 29.

m/s. The length of the cut stems did not change with the traveling speed. Though the supply volume changed with the traveling speed, the length remained stable. It is essential that for further use as industrial products, the length of the fibers remain uniform.

3. Optimum harvesting period

Tests of kenaf harvesting were conducted at the 4 growth stages previously described. The results were as follows:

In the growing stage test, harvesting was difficult because of the large amount of leaves. At this stage, kenaf had many leaves and they tended to obstruct the fan duct. The harvester had to stop traveling to avoid the obstruction of the fan duct.

In the flowering stage test, harvesting was easily performed. At this stage, the revolution of the fan had to be controlled, because the rate of mixed leaves in the net bag and blown out stems changed. Fig. 6 shows the rate of blown out stems and mixed leaves in the net bag depending on the blowing power. The rate of the blown out stems was 7.2% at a 12 m/s speed and 10.2% at a 22 m/s speed.

In the falling stage test, harvesting was completely performed. At this stage, although kenaf plants still had a few leaves, the leaves did not interfere with the blow off fan. This was the optimum stage for harvesting with the machine.

In the withering stage test, the kenaf stems were broken by the cutter or within the drum, because the moisture content of the kenaf stems was low. The litter from kenaf, that could not be conveyed, obstructed some parts of the machine. Because the machine cut kenaf roots, the low moisture content of the roots impeded the harvesting operations. At this stage, 20.8% of the kenaf stems fell on the field, and the harvester could not pick them up.

The above results indicated that the effective harvesting period extended from the flowering period to root drying, i.e. from mid-October to late February, in the study area.

4. Effective field capacity and loss

Almost all of the loss consisted of blowing out loss by the fan, followed to a smaller extent by head loss, falling loss from inside of the body and the duct. The blowing out loss changed with the air velocity from the fan duct. In this test, the range of the blowing out loss was wide, 3–13%. To decrease the loss, the air velocity should decrease to reduce the volume of mixed leaves. Therefore, it is preferable to harvest kenaf at the falling stage.

Table 2 shows the effective field capacity obtained in the experimental harvesting test. In the case of the net bag type, the traveling speed was 0.49 m/s. When the net bag behind the machine became full, it returned so that the machine was able to unload the materials and the operator had to replace the net bag with a new empty one. The effective field capacity was 6.6 a/h because much time was spent on unloading the materials at the end of the field and on going back and forth. Actually, 30.8% of the total time was spent on harvesting. In this test, a 2,970 kg load of kenaf was harvested and the operator changed the net bag 7 times. Although the machine could carry about 500 kg in the net bag, a load of kenaf of

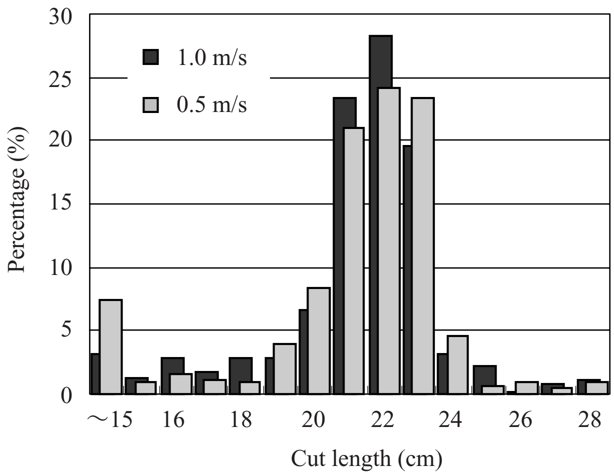

Fig. 5. Relationship between the cut length of stems and the running speed of the harvester

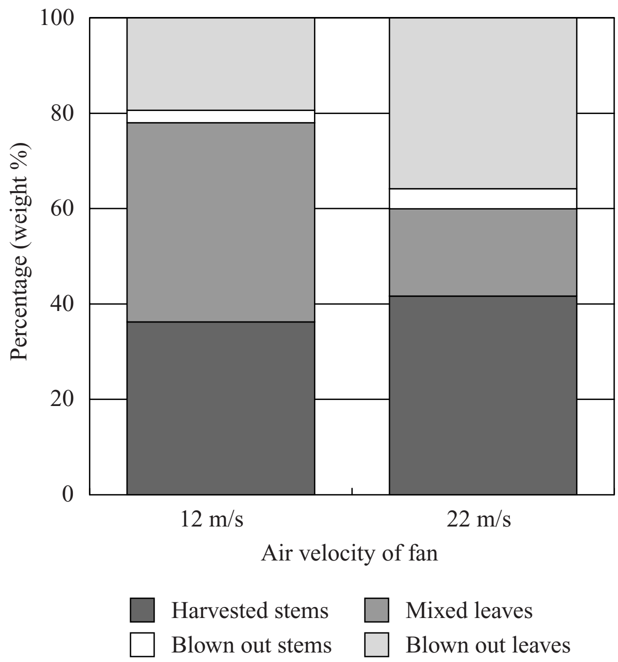

Fig. 6. Relationship between loss and air velocity

Table 2. Efficiency of kenaf harvester

	Net bag type		Conveyor type	
	(min/10 a)	(%)	(min/10 a)	(%)
Harvest	28.2	30.8	37.5	86.8
Move 1	14.9	16.3	–	–
Move 2	15.2	16.6	–	–
Replacement of the net bag	33.3	36.3	–	–
Round to next path	–	–	5.7	13.2
Sum	91.6	100	43.2	100
Effective field capacity (a/h)	6.6		13.9	

Move 1: The harvester moved from the unloading point to the harvesting point.
Move 2: The harvester moved from the harvesting point to the unloading point.

approximately 600 kg was harvested on a path. The volume of the net bag did not correspond to the yield of a path. In the case of the conveyor type, the traveling speed was 0.42 m/s, being lower by 15% than in the case of the net bag type. The effective field capacity was 13.9 a/h. Compared with the efficiency of about one person, the effective field capacity was 6.95 a/h.

Conclusions

To harvest kenaf mechanically, a sugarcane harvester that was modified in some parts could be used. Field tests enabled to elucidate the basic performance, the period when the machine could be used for harvesting and the effective field capacity of the machine. The results were as follows:

(1) A modified sugarcane harvester with the development of a cutter specific to kenaf was able to harvest kenaf stems.
(2) The machine cut kenaf stems 22 cm long each, regardless of the traveling speed.
(3) The machine could be used for harvesting from the flowering stage to the withering stage of kenaf, i.e. from mid-October to late February, in this study area.
(4) The effective field capacity of the net bag type was 6.6 a/h, and that of the conveyor type was 13.9 a/h.

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