

Original paper

How high a fence can the nutria (*Myocastor coypus*) climb? – Climbing test of an anti-intrusion fence

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Abstract: We tested the height of fences that the nutria (*Myocastor coypus*) can climb when attempting to enter a farm field. The subject animals were four adult nutrias (two males and two females) from Akaiwa City, Okayama Prefecture, kept at Okayama University of Science. We performed repeated fence-climbing experiments on these animals and found that when the fences were fixed to the posts, the animals could climb heights approximately 1.5 times the body length. As the body length of the nutria is usually 50–60 cm, a fence with a height of approximately 90 cm is necessary in the field to prevent invasion. However, if the top of the fence is left unfixed, it warps when the nutria attempts to climb it and put their weight on it; the animals fail to climb over even a 60-cm-high fence. In this case, the width of the unfastened part is essential, and leaving approximately 15 cm unfastened was effective.

I. Introduction

The nutria, or alternately called coypu (*Myocastor coypus*), is an introduced species commonly occurring in Japan. It is a large semi-aquatic rodent that is native to South America. This species was introduced to Japan immediately after World War II and was widely bred mainly to mitigate food shortages. However, when the demand for this species decreased with improvements in food supply, most animals either escaped or were released. These escapees turned wild and have become agricultural pests in many areas (Kobayashi & Oda 2016).

In Okayama Prefecture, the nutria occurs throughout the prefecture (e.g., Kobayashi & Kawamura 2012), causing damage to crop and aquatic plants. Despite efforts to cull them, the amount of crop damage caused by nutrias in the prefecture has remained relatively stable at around 20 ± 10 million yen over the past 40 years (Kobayashi & Kawamura 2012). Their population in the prefecture is estimated to be as high as 90,000 (Natural Environment Division 2010).

Farmers, local communities, and municipalities have installed fences to control the damage; however, these have not been effective because the nutria climbs over or breaks the fences. Therefore, low-cost robust fences that can effectively prevent invasion are required.

To develop a low-cost and effective fence to prevent crop damage by nutrias, we examined (1) the method used by nutrias to climb over fences and (2) fence structures that are difficult for nutrias to climb over. Using captive nutrias, we evaluated for their climbing ability over two types of fences. The results showed that nutrias could climb over simple fences that were approximately 1.5 times high as their body length, but failed to do so with smaller fences if the top was not fixed and bent when grabbed.

II. Materials and Methods

1. Study subjects and captive environment

The study subjects were four captive adult nutrias (two males and two females) kept at the Okayama University of Science (Table 1). They were wild-born, that is, captured from Akaiwa City, Okayama Prefecture.

The subjects were kept together in a room (W380 × D580 cm) with no windows. The room temperature was set at 24°C in summer and 20°C in winter, with a light/dark cycle of 12L:12D. The subjects were housed individually in a steel

Table 1. Study subjects. See text for detail.

Individual ID	Name	Sex	Body length (cm)	Body weight (kg)
No.1	Lupin	Male	46.0	5.0
No.2	Niboshi	Male	50.0	5.8
No.3	Kitamura	Female	47.5	4.8
No.4	Chibita	Female	43.5	5.4

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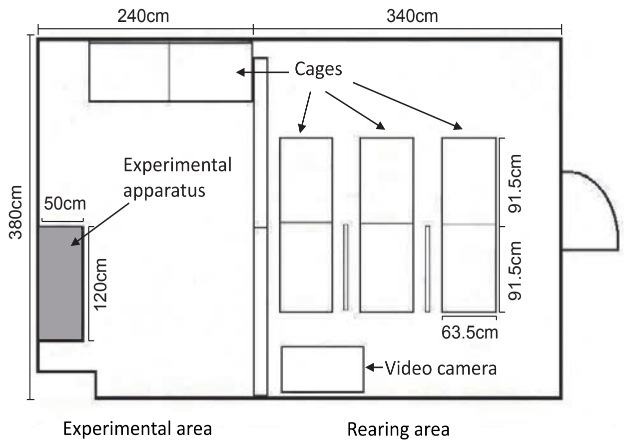

Fig. 1. Plan view of experimental apparatus arrangement in the breeding room of nutrias.

Fig. 2. Experimental apparatus in this study; fixed fence.

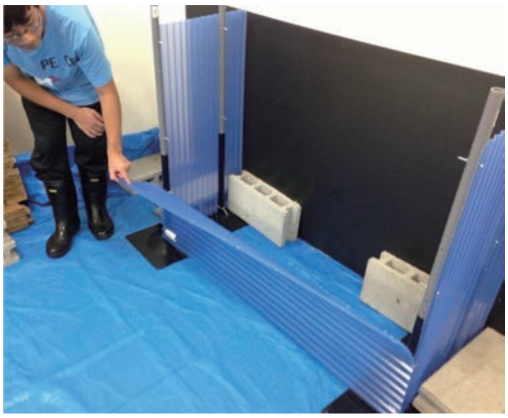

Fig. 3. Warping fence attached to the experimental apparatus. When nutrias hang on the fence, the top of the fence bends.

cage (W63.5 × D183 × H64 cm) with a plastic container (W40 × D28.5 × H24 cm) for bathing and drinking. Half of the cage was covered with black plastic cardboard to provide shelter. The cages were placed on a snowboard to prevent frostbite. An area of 380 × 240 cm separated by two wooden boards (W180 × H100 cm) at the back of the room was used as the experimental area (Fig. 1).

2. Experimental apparatus

Corrugated plastic boards were used as the fence boards. The boards were attached to four 100-cm-high PVC posts on a steel stand (W30 × D30 cm) with screws and wires. The experimental apparatus was U-shaped when viewed from above with the open part placed against the wall (Fig. 2). The width and height of the corrugated plate used on the side of the apparatus were 50 cm and 90 cm, respectively. The width of the fence was 120 cm, with heights ranging from 30 to 75 cm (see below). We secured the boards on both sides between concrete blocks weighing approximately 9 kg to prevent the device from collapsing.

Two types of fences were used. One was a fence fixed to the posts from the bottom to the top (fixed fence), and the other was a fence with the top 10 or 15 cm of the fence not fixed to the posts, so that it would flex when grabbed by nutria (warping fence, Fig. 3).

3. Experiments

The experiment was conducted between May 3 and November 29, 2013. One animal was tested per day. The duration of each experiment was 120 min. We started the experiment between 16:00 and 17:30, before feeding, so that the subjects were more likely to be attracted to the food behind the fence.

During the experiment, the cage of the target individual was moved to the experimental area for that day (Fig. 1). The food was then placed behind a fence and the cage of each subject was opened. To minimize the influence of observer presence on subject behavior, we set up a video camera in the room to monitor the subject from outside the room via video while simultaneously recording the scene for detailed behavioral analysis after the experiment.

Fixed fence sessions: We started with a fence height of 30 cm as a habituation session, and then gradually used higher fences. Three sessions were conducted at each height, and the animal was regarded as having succeeded if it could climb over the fence at least once. When the subjects succeeded quickly in all three sessions, the fence was increased by 10 cm. When the subject failed once or twice, or seemed to have struggled even though they successed in all three sessions, the height of the fence was increased by 5 cm, and the experiment continued until the animal failed all three times.

Warping fence sessions: Heights of 50 and 60 cm were used. Only individual No. 3 was additionally tested with a 40-cm fence. Similar to the fixed fence, three trials were conducted at each height.

If any physical changes were observed in the

Table 2. Summary of sessions with the fixed fence.

Individual	Fence height (cm)	Number of sessions	No. of successful sessions	Shortest time for first success*1 (s)	Average time for first success*2 (s)	Frequency of climbs (times/h) *3
No. 1	30	3	3	22	94.0	3.0
	40	3	3	22	45.3	1.3
	50	3	3	16	158.0	0.5
	60	3	3	22	43.0	0.5
	70	3	3	22	103.0	0.5
	75	3	0	-	-	0.0
No. 2	30	3	3	25	129.7	6.0
	40	3	3	24	30.7	3.3
	50	3	3	40	40.3	2.3
	60	3	3	55	147.7	1.2
	70	2	2	63	519.0	0.5
	75	3	0	-	-	0.0
No. 3	30	1	1	377	377	2.0
	40	1	1	221	221	1.0
	45	2	0	-	-	0.0
	50	5	3	25	383.3	0.8
	60	3	3	36	65.3	1.0
	65	3	1	65	65	0.3
	70	3	0	-	-	0.0
No. 4	30	1	1	579	579	2.0
	40	1	1	32	32	2.0
	45	2	1	785	785	1.0
	50	6	5	37	907.4	0.8
	55	3	0	-	-	0.0
	60	5	3	46	264.3	1.0
	65	3	3	46	264.3	0.8
	70	3	0	-	-	0.0

*1 Shortest time elapsed from the start of the session to the first climb over the fence.
*2 Average elapsed time from the start of the session to the first climb over the fence.
*3 Frequency of climbing over fences during the sessions. Either the entry to or exit from the apparatus was counted as a climbing event.

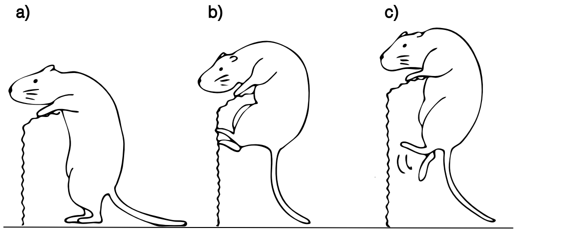

Fig. 4. Illustration of a nutria failing to climb over a warping fence. a) 50 cm, b) 60 cm with 10 cm unfixed part, and c) 60 cm with 15 cm unfixed part.

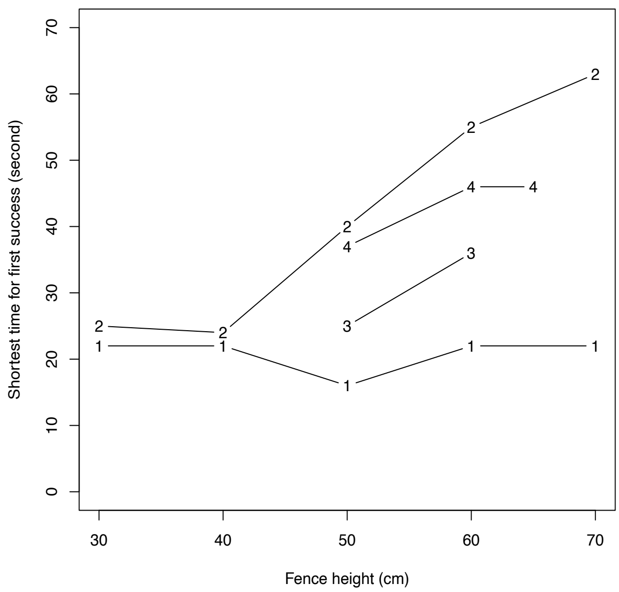

Fig. 5. Shortest time elapsed from the start of the session for each fence height to the first successful climb. The number on the plot represents the individual ID. Individuals with only one successful session are excluded.

subject during the experiment, we immediately suspended the experiment for both fixed and warping fences.

4. Behavioral analysis

The frequency and duration of "climbing behavior" and "exploratory behavior" were determined using video-recorded data. Standing up in front of a fence, grasping the top of a fence board, and climbing up were labelled as climbing behaviors. Exploring the space between the fence board and floor or wall was labelled exploratory behavior. Any other interesting behavior observed was recorded *ad libitum*.

III. Results

1. Height of fences for a successful climb and the manner, time required, and frequency of climbing over fences

The maximum climbing height of the fixed fence was 70 cm for individuals Nos. 1 and 2 and 65 cm for individuals Nos. 3 and 4 (Table 2), i.e., 1.52, 1.40, 1.37, and 1.49 times the body length of each subject. The height at which they failed to climb over was 75 cm for Nos. 1 and 2 and 70 cm for Nos. 3 and 4, corresponding to 1.63, 1.50, 1.47, and 1.61 times the body length. In the case of the fixed fences, the time required to climb over the fence for the first time from the start of the experiment tended to increase as the fence height increased (Fig. 4). The subjects climbed over the fence to enter and exit the interior and exterior several times during the experiment. However, the frequency of climbing over the fence tended to decrease as the height of the fence increased (Fig. 5).

In the case of warping fences, all individuals easily climbed over the 50- and 60-cm-high fences when the top 10 cm was not fixed. When the top 15 cm of the fence board was not fixed, all individuals successfully climbed a height of 50 cm but failed to climb over the 60-cm-high fence (Table 3).

Regardless of the fence type, the procedure for the nutria to climb over it was as follows: (1) standing up on their hind legs in front of the fence, (2) hooking their front legs over the top

Table 3. Summary of sessions with the warping fence. Column contents are the same as in Table 2.

Individual	Fence height (cm)	Number of sessions	No. of successful sessions	Shortest time for first success*1 (s)	Average time for first success*2 (s)	Frequency of climbs (times/h) *3
No. 1	50	3	3	20	104.3	2.0
	60	3	0	-	-	0.0
No. 2	50	3	3	20	23.0	5.0
	60	3	0	-	-	0.0
No. 3	40	3	3	36	130.3	2.7
	50	3	3	40	134.3	2.7
	60	3	0	-	-	0.0
No. 4	50	3	3	26	247.7	2.0
	60	3	1	51	51	0.3

Table 4. Summary of behavior during the unsuccessful sessions.

Individual ID	Climbing behavior		Exploratory behavior	
	Duration (s)	No. of times	Duration (s)	No. of times
(Fixed fence)				
1	450	29	1927	91
2	202	35	416	43
3	145	26	1068	85
4	106	13	1837	83
(Warping fence)				
1	865	31	532	33
2	825	44	1628	66
3	838	51	4128	126
4	2636	56	1794	78

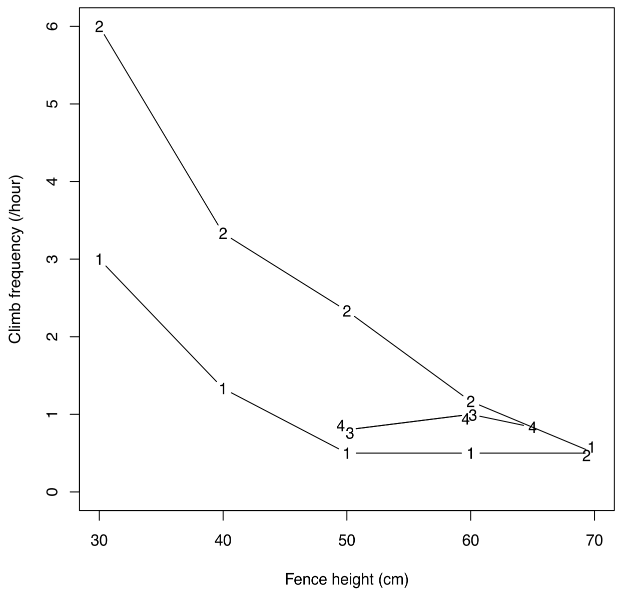

Fig. 6. Number of times the subject individual climbed over the fence at each height. Those with only one successful session are excluded.

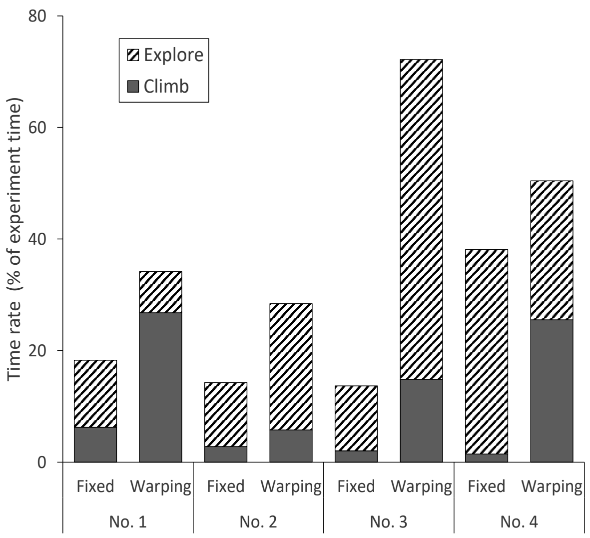

Fig. 7. Percentage (%) of the duration of climbing and exploratory behavior observed when the animal failed to climb over the fence in the experiment.

of the fence, (3) pulling their bodies up over the fence with their backs rounded, (4) placing their hind limbs on the top of the fence, and (5) jumping down from head first to the other side. The subjects failed to climb over the fixed fence when it was too high for their forelimbs to reach the top of the fence, or if they did, their trunk and forelimbs were too stretched to pull their bodies up. In contrast, in the case of the warping fence, the subjects could grasp the top of the fence with their forelimbs, but when they pulled themselves up, the fence warped, causing them to lose balance and fall (Fig. 6).

2. Behaviors during unsuccessful climbing

The number and total duration of climbing and exploratory behaviors during unsuccessful sessions are summarized in Table 4. In all four individuals, these two types of behavior were observed for a longer period in the warping fence (60 cm high) than in the fixed fence (Fig. 7).

3. Other remarkable behaviors

(1) Individual No. 1

During the first session with the 30-cm-high fixed fence, the subject grabbed the fence board and pulled and gnawed on it before attempting to climb over it. It appeared as if the subject was trying to break the fence to penetrate it. This behavior was not observed in the subsequent sessions with fixed fences, but a similar behavior was observed after falling once in the first session with a 60-cm-high warping fence.

(2) Individual No. 2

In contrast to individual No. 1, no fence-breaking behavior was observed. It promptly attempted to climb over the fence from the first session, and succeeded with no problems up to a height of 70 cm.

(3) Individual No. 3

As this individual injured his forelimb in the cage during the experimental period, the experiment was suspended for approximately three months, ending with a 45-cm-high fixed fence session on June 30. The injury healed, and the experiment resumed on October 2. However, this interruption caused a significant deviation from the experimental schedule, and the order of sessions (type and height of the fences) was different from that of the other animals. In the warping fence experiment, sessions were also conducted with a 40-cm-high fence. However, the experimental results did not differ significantly from those of the other animals.

(4) Individual No. 4

From the first session at the fixed 30-cm-high fence, this animal did not immediately attempt to climb over the fence but instead engaged in exploratory behavior at the side and bottom of the fence. It seemed to be looking for a gap through which it could pass without climbing over the fence. At the 40-cm-high fixed fence, after the subject climbed over the fence to go inside the apparatus, it used a concrete block to climb over the fence to come out.

Exploratory behavior was frequently observed during the following sessions. With the 60-cm-high fixed fence, the animal succeeded in passing through the gap between the fence and floor. Finally, it did not attempt to climb the fence. Therefore, we attached a vinyl chloride post to the bottom of the fence board to prevent the subjects from entering the fence by passing under or beside it. In the session with the 50-cm-high fixed fence, the animal showed little interest in the food across the fence and would lie down under the fence.

IV. Discussion

1. Climbing ability of the nutria and effective fence structure for preventing intrusion

Our experiment revealed that nutrias could easily climb over a fixed fence with heights up to approximately 1.5 times their body length. The subject animals in this study were unable to climb over fences 70-75 cm in height. Given that the body length of a standard adult nutria is approximately 60 cm, a fence with a minimum height of 90 cm will be necessary to effectively prevent penetration by nutria into farmland. However, enclosing farmland with a fence of nearly one meter in height is labor-intensive and costly. In addition, a tall fence would disturb the landscape of the farmland and cause psychological pressure in farm workers, that is, a feeling of being enclosed during farm work. The width of the plastic corrugated plates used for the fence was set to 65.5 cm as a product standard. Thus, two commercially supplied corrugated sheets must be spliced together vertically to construct a 90-cm-high fixed fence.

In contrast, our experiment also indicated that by adding a structure that makes the fence warp when the nutria holds onto it, a considerable intrusion prevention effect can be achieved. Therefore, by using the warping structure, a fence constructed from a single layer of commercial corrugated sheets with a height of 65 cm is likely sufficient to prevent invasion by nutrias. This will be a significant advantage in terms of costs and labor.

The effectiveness of warping structures has been verified for wildlife other than nutrias. In addition to deer and wild boars, Japanese macaques are the third most damaging agricultural pests in Japan. Because of their arboreal nature and excellent climbing ability, electric fences are often used to prevent their intrusion into farmlands. However, electric fences are costly in terms of price and maintenance effort. Therefore, as an alternative, ordinary nets fixed to poles made of flexible materials have been developed. When monkeys attempt to climb the net, they bend back to the opposite side to prevent them from climbing (Muroyama & Oi 2000).

However, although experiments with captive monkeys have demonstrated the effectiveness of warping nets for monkeys, reports from the field show that they are not always practical in real farmlands. Kibe et al. (2000) reported monkeys successfully climbing over the warping net and entering the farmland. The monkeys used a scaffolding structure near the net. In the current study, individual No. 4 used a concrete block as a foothold when escaping from the fence once it had entered. All subjects easily climbed over a 50-cm-high warping fence as they could stand up with their hind limbs in contact with the ground and grasp the top of the fence with their forelimbs. In the presence of scaffolding, even if the fence is sufficiently high, the effect of height is diminished, and the fence becomes ineffective. In addition, as shown by individual No. 4, loose joints through the side and bottom of the fence would allow easy intrusion. Therefore, it is essential to ensure that there are no gaps at the joints or at the bottom of the fence.

2. Possible limitations of warping fences owing to behavioral characteristics of nutrias

Avoiding scaffolding and gaps in the fence are common problems for both fixed and warping fences. Here, we discuss the unique challenges of warping fences based on behavioral observations.

For all subjects, the frequency and duration of climbing and exploratory behaviors were higher for the warping fences than for the fixed fences. In addition, regardless of the fence type, the animals attempted to climb fences with lower heights more intensively. This suggests that the height of the fence is crucial for decision-making in nutrias on whether to attempt climbing over the fence. If so, for example, a 65-cm-high warping fence and a 90-cm-high fixed fence can be equally difficult for nutrias to climb, but the former likely encourages more nutrias to climb.

The more often a nutria attempts to climb, the more likely it is to succeed. Such accidental success in climbing is likely to have a negative effect on crop damage control. A successful climb and entry into farmland would provide an opportunity for nutria to learn that there is an attractive food resource inside the fence. This would motivate the nutria to make further climbing efforts.

3. Future tasks in implementing nutria control fences

Based on the analysis and discussion above, we summarize the issues that need to be addressed to implement fences against nutrias. To effectively prevent nutrias from entering a fixed fence, the height of the fence must be at least 1.5 times the body length of an adult animal, which is costly. A warping fence, in which the upper part of the fence is not fixed but warped, makes it possible to reduce the height of the fence with a reduction in costs. However, the nutria is assumed to use the height of the fence as a criterion for deciding whether to attempt an invasion, and a low warping fence is more likely to encourage the nutria than a high fixed fence. Therefore, the next task is to conduct comparative field experiments by installing fixed fences and warping fences of various heights on farmlands to determine the optimal structure and height in terms of cost and effectiveness.

4. Behavioral diversity in nutrias

Finally, apart from preventing crop raids by nutrias, the behavioral diversity of nutrias is discussed. Occasionally, the same individual and test conditions produced entirely different results. For example, individual No. 1 attempted to break the fence when it failed at climbing, whereas No. 2 always attempted to climb the fence without hesitation. In contrast, No. 4 searched for a gap on the side or at the bottom of the fence, even if it was short enough to climb over.

A good understanding of the behavioral, sensory, and physiological characteristics of pest animals is essential to prevent crop damage and other disturbances by wild animals to human activities. Although information on individual variation in behavior is sometimes dismissed as experimental noise, the accumulation of such information will indirectly contribute to future damage control.

Acknowledgements

We express our sincere gratitude to all the people who worked hard every day to maintain nutrias in the breeding room on the first floor of Building D3, Okayama University of Science, for their cooperation and support over a long period.

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竹ノ下祐二・柳原綾佳・八神未知弘・小林秀司：ヌートリアはどのくらいの高さの柵をよじ登れるのか？－侵入防止柵の登攀試験

要約

ヌートリアが圃場に侵入しようとする際，どのくらいの高さの柵まで乗り越えられるのか試験を行った．試験個体は，岡山理科大学で飼育中の岡山県赤磐市産成獣雄雌２頭ずつである．これらについて柵越えの試験を繰り返しおこなったところ，頭胴長の約1.5倍程度の柵を乗り越えられることが分かった．ヌートリアの頭胴長は50 cmから60 cm 程度のことが多いので，圃場に侵入防止柵を設置する場合は90 cm 程度の高さが必要となる．ただし，柵の上部をあえて固定せず，ヌートリアがよじ登ろうとして体重をかけると折れ曲がるようにしておくと，60 cm の高さの柵でも乗り越えに失敗することが分かった．この時重要なのは非固定部分の幅であり，15 cm 程度固定せずにおくと効果的なことが判明した．

(Accepted 16 December 2022)