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REVIEW
Rat Damage Control to Round-Baled Silage by Modifying Storage Layout

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Abstract

This self-review summarizes the prevention of rat damage to wrapping film when whole-crop forage containing cereals is preserved as round-baled silage (RBS). A trapping survey at the RBS stock yards showed that Large Japanese field mice (*Apodemus speciosus*), Japanese grass voles (*Microtus montebelli*), brown rats (*Rattus norvegicus*), and roof rats (*Rattus rattus*) were species with the potential to inflict damage. The features of the damage differed for each rat species. In particular, it was observed that brown rats and roof rats tended to cause extensive film-damage. RBSs are usually stacked in close proximity because they are produced in bulk. This usual storage layout was considered to provide rats with many narrow spaces between RBS, inaccessible to most of their predators, thereby exacerbating the rat damage to RBS. When modifying the storage layout to produce open spaces between RBS by separating them, the modified layout was effective in preventing damage caused by brown rats and roof rats because the predation hazard would be increased. However, the effect was lost when the spaces between RBS were covered with snow or when species such as Large Japanese field mice damaged RBS's bottom from underground burrows. It was suggested that these problems may be resolvable by providing sufficient open space between RBS and protecting the bottom with wire netting.

Discipline: Animal industry
Additional key words: whole crop, forage rice, corn, wrapping film

Introduction

In recent years, there has been increasing production of whole-crop forages processed in round-baled silage (RBS) such as corn and rice for feeding to dairy and beef cattle in Japan[7,18,22]. This cereal-rich RBS is an attractive food for wild animals because it is wrapped in thin polythene stretch-film and stored in fields until being fed to cattle. RBS is particularly susceptible to the breakage of the wrapping film, which results in air entering the bale. It was reported that fungal growth in RBS due to film-damage caused by birds or rats accounted for 40% of all spoiled RBS in several farms, with more than half the damage caused by rats[4]. There is concern that the loss of RBS due to rat damage will intensify with an increase in whole-crop RBS production.

Previous studies have reported that covering RBS by mesh netting is an effective means of protection against bird damage[6,15]. In contrast, little information is available on similar RBS protection against rat damage because this was not a serious problem for conventional grass RBS[14]. Although the use of rodenticide has been the main agricultural means of rodent control technique to date, several commonly used rodenticides pose the risk of primary and secondary poisoning of non-target species[23]. Such poisonous chemicals cannot be used, especially near livestock barns. The other rodent control techniques investigated include the application of repellents such as Siberian pine needle oil[23] and predator

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odor[3,5]. However, continual spraying of chemicals during long-term storage incurs considerable expense, and resistance to the repellent would build up with repeated daily exposure[5]. A capsaicin coating[13] for the breakable wrapping films is also ineffective[12], meaning a new form of rat damage control differing from the conventional method is required for RBS.

This self-review summarizes efforts to prevent rat film-damage of RBS which we addressed. Initially, we conducted a trapping survey to determine the kind of rat species causing the film-damage. In subsequent experiments, we proposed the modification of RBS storage layout to reduce the rat damage and evaluated the effectiveness of this method.

Trapping survey

Sherman traps were set in 5 stock yards for RBS, which had suffered considerable rat damage in Iwate Prefecture, located in the north of Honshu in Japan. The weight ratio of the discarded silage due to rat damage as a proportion of all stored silage was 34% in one of these stock yards[17]. In most stock yards, two or more species were captured (Table 1[10]), and all the species concerned were suspected of causing RBS damage. The features of the damage differed for each rat species. There were some burrows around all stock yards, near which Large Japanese field mice and Japanese grass voles were captured. Some RBSs near those burrows had small holes in their bottom (Fig. 1A), and the cereals had been raked into the tunnel underground (Fig. 1B). It is reported that Large Japanese field mice and Japanese grass voles dig complex underground tunnels[20,27], and tend to hoard food[24]. Thus it was suggested that these burrowing species damage the RBS bottom from such tunnels. Brown rats and roof rats were captured in the vicinity of the seriously damaged RBS groups. In these locations, many RBSs had sustained extensive film-damage whereby the silage was raked out from the damaged portion (Fig. 1C) and the rats had dug burrows into the raked silage between RBS (Fig. 1D). In particular, in the location where the roof rat was captured, even the upper stacked RBSs were damaged because this species possesses excellent climbing ability[25] (Fig. 2).

The Large Japanese field mouse and the Japanese grass vole are common species that inhabit forests and cultivated fields in Japan[1]. In this study, the burrows of these species were found everywhere in the stock yards. Brown rats and roof rats that cause serious damage to RBS are cosmopolite and commensal species[1]. In the A, C, and E points of Table 1, these species possibly moved from the livestock barn and house adjacent to the stock yard, meaning there is potential for rat-damage from RBS in various areas.

RBSs are usually stacked in close proximity because they are produced in bulk. In the entire surveyed stock yard, RBSs were placed by this layout and those damaged due to brown rats and roof rats were observed in internal positions within this storage layout. It was difficult to trap the brown rats and roof rats that had entered narrow spaces between RBSs, meaning few could be captured. In this trapping survey, the presence of rats' predators such as weasels and cats was also observed (Table 1). However, these predators would also find it difficult to capture rats that had entered the narrow spaces between the RBS groups. This common layout for RBS storage would provide rats with ample refuge from their predators, thereby exacerbating rat damage caused to RBS.

Table 1. The species and numbers of rat captured in five stock yards of round-baled silage

	A (Adjacent to livestock barns and woods)	B (Adjacent to livestock barns and grassland)	C (Adjacent to house and paddy fields)	D (Adjacent to woods and paddy fields)	E (Adjacent to livestock barns)
Large Japanese Field Mouse (*A.speciosus*)	28	0	7	21	5
Japanese Grass Vole (*M.montebelli*)	5	4	0	1	0
Brown Rat (*R.norvegicus*)	1	0	0	1	1
Roof rat (*R.rattus*)	0	0	1	0	0
Others[1)]	Weasel (*M.itatsi*), Cat				

[1)] It entered or broke the trap where the rat was captured.

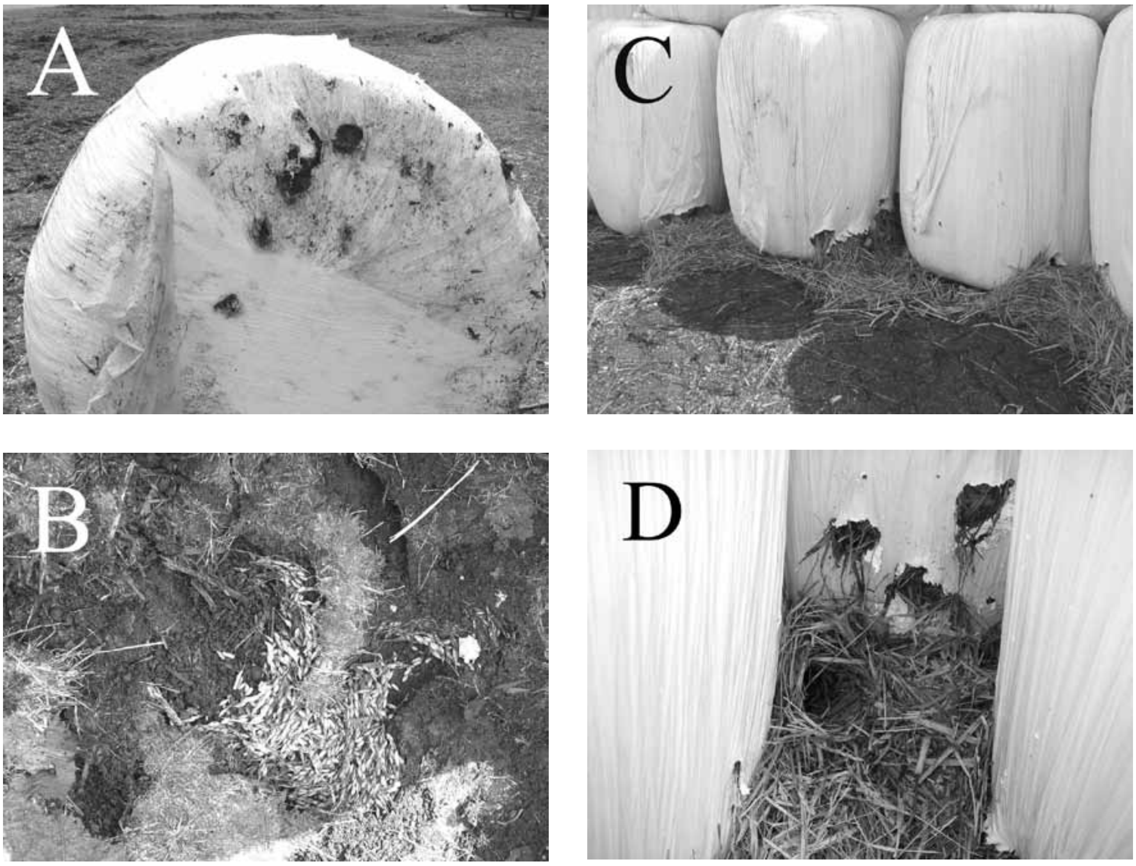

Fig. 1. The rat-damaged round-baled silages of forage-paddy rice
A: The burrows of the bottom of the bale.
B: The tunnel under the bale and the brown rice raked into the tunnel.
C: Considerable silage was raked out from the damaged portion.
D: The rat nest in the raked silage between bales.

Fig. 2. These round-baled silages of forage-paddy rice suffered rat damage despite being placed on top of the baled grass silage

Effects of modifying the storage layout (Experiments 1 & 2)

Based on the aforementioned observation, it was assumed that if the storage layout were modified such as to provide open spaces between the RBSs, fewer hiding places would be available for rats, and the damage caused by rats to these RBSs would be prevented or reduced. To confirm this, we compared two RBS storage layouts—one in which the RBS were placed according to the commonly used layout in close proximity and another in which they were placed apart leaving open spaces between them—to determine the extent of rat damage caused to the RBS. Two experiments were conducted at the C point (Exp. 1[9]) and A point (Exp. 2[11]) of Table 1. Twenty-three RBSs of the forage rice (diameter 50 cm) were used in Exp. 1. In Exp. 2, thirty-one RBSs of forage rice (diameter 100 cm) and 25 RBSs of corn (diameter 90

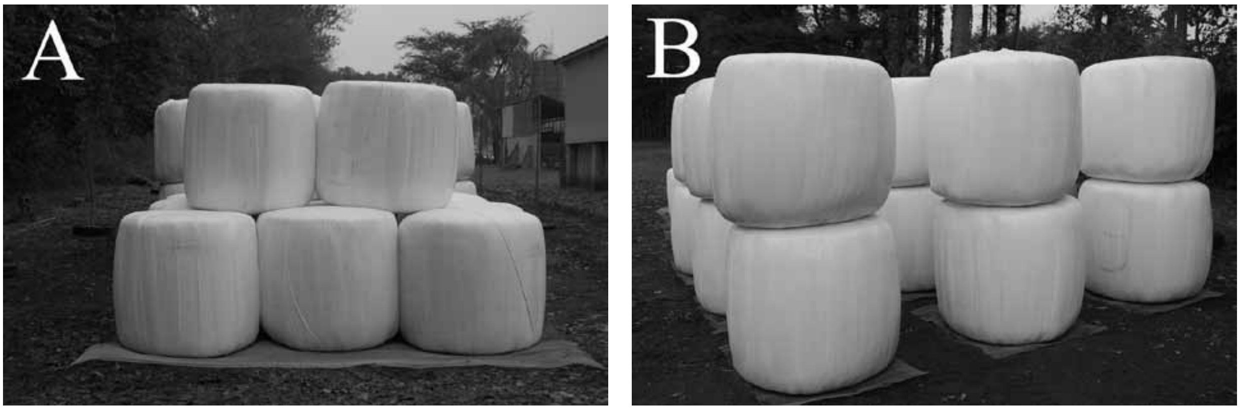

Fig. 3. The control layout (A) and spacious layout (B) of experiment 2

Table 2. The percentage of rat-damaged bales in the control and spacious layout (Experiments 1 & 2)

	Control layout	Spacious layout	Significant difference
Forage paddy rice (Exp.1)	80	7.1	**
Forage paddy rice (Exp. 2)	61.5	0	**
Corn (Exp .2)	46.2	0	*

**P<0.01, *P<0.05 (X^2 goodness-of-fit test).

cm) were used. These RBSs were divided into 2 groups, a control layout group and a spacious layout group, respectively. The RBSs of the control layout groups were positioned in close proximity (Fig. 3A). In the spacious layout group, RBSs were positioned maintaining a space of approximately half the distance of its diameter (20-30 cm for Exp. 1, 50 cm for Exp. 2) between each RBS (Fig. 3B). The film damage caused by rats was assessed by a crossover design; one term of which consisted of 29 days (Exp. 1) or assessed after 1-year storage (Exp. 2). The results were as follows; the percentage of RBSs with film damage by rats in the control layout group was 46 to 80% (Table 2). The percentage of damaged bales in the spacious layout was significantly lower (P < 0.01) than in the control layout in Exp. 1. In Exp. 2, no RBS-film damage was observed in any of the spacious layout groups. In terms of the rat species responsible for this damage, roof rats (Exp. 1) and brown rats (Exp. 2) were captured between RBSs of the control layout. Though these rats were readily able to damage the spacious layout groups adjacent to the control layout groups, the rat damage in the spacious layout groups tended to be avoided. Some rodents avoided foraging in open spaces because of the generally higher predation hazard in such places[2,16,19], and in this study, it was suggested that a similar phenomenon was observed in the spacious layout. The existence of predators during storage was not investigated in this study. However, predators such as weasels or snakes would definitely be present in agricultural sites where RBS is produced. Humans are also considered potential predators for rats. These results suggested that brown rats and roof rats can easily damage the RBS-films that were stacked in close proximity and that creating open spaces between the RBSs reduces this rat damage by increasing the predation hazard.

Effects of spacious layout in farm conditions (Experiment 3)

The effects of spacious layout in farm conditions were investigated[10]. Numerous RBSs of forage rice (diameter 50 cm) were stored at the C point (496 RBSs in 267 m^2) and D point (388 RBSs in 137 m^2) of Table 1. These RBSs were placed apart without stacking. There were so many harvested RBSs that the distance between them was almost less than 20 cm. The numbers of rat-damaged RBS were assessed once monthly during storage of 7 months. These areas were exposed to snow, and snowfall commenced at the end of November. The snow depth for the season soon peaked (26 cm). Total snowfall reached 120 cm up to the observation day in January. At the C point, the masking from the snow bridge was observed between RBSs during the observations in December and January (Fig. 4) and when such masking occurred, rat-damage to the RBSs was apparent (Fig. 5). The damaged situation was similar to the RBS of the control layout that had been damaged by the roof rat in the previous Exp. 1. Because the rat damage during the January observation was considerable, the snow and all the damaged RBSs were cleared away immediately. Subse-

Fig. 4. The masking situation caused by a snow bridge between bales

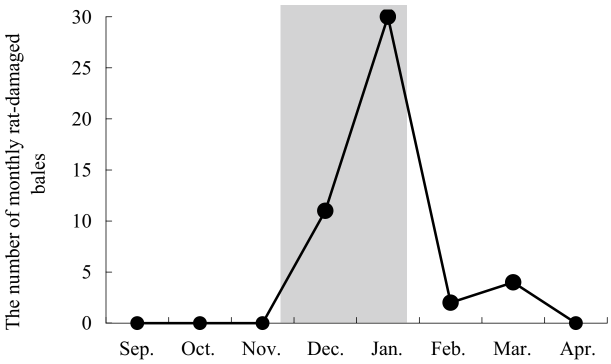

Fig. 5. The masking effect caused by snow on the number of rat-damaged bales stored at the C point (Experiment 3)

: Occurrence of masking by snow.

quently, the snow bridge disappeared, resulting in fewer rat-damaged RBSs. It was reported that the roof rat was less reproductive with falling temperature[21]. Since the roof rat is a commensal species, it tend to move from fields to homes after the harvest season[26]. Therefore, it was suggested that the cause of rat-damage in winter was not the rapidly proliferating number of rats in the stock yard but the masking situation by snow. In the previous Exp. 2, despite a snowfall condition almost similar to this C point (snow depth peaking at 27cm in Exp. 2), no snow bridge was formed since the RBS intervals were wider. In the snow zone in particular, it was suggested that providing sufficiently spaced RBS intervals and striving to preclude the masking situation posed by snow was necessary. To provide sufficient space to ensure a spacious layout, contrivances such as decentralization of the stock yards are required. Conversely, though the masking situation with the snow hardly occurred at the sunny D point, rat damage did occur when the storage period was extended (Fig. 6). The spacious layout meant the scope of the stored RBSs extended even to the border of the stock

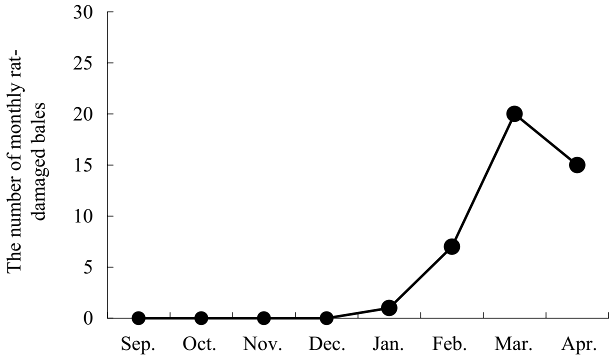

Fig. 6. The number of rat-damaged bales stored at the D point by burrowing species (Experiment 3)

yard, where the RBSs had not previously been placed. These RBSs were positioned over burrows of the Large Japanese field mouse, which damaged the bottom of these RBSs. Wire netting (diameter of wire 1.8 mm, reticulation 10 mm) was laid under the RBSs at the points of serious damage, and it was subsequently confirmed as preventing damage[8]. Therefore, in addition to the spacious layout, for RBSs which have to be stored long term within habitats of species with burrowing behavior, bottom protection is required, such as the use of wire netting.

These findings also revealed some considerations of the spacious layout. However, its beneficial effect is lost when the spaces between RBSs are covered in snow. There is the potential for a similar problem to be caused by weed infestation. During long term storage, the effect is minimal on rats causing damage to RBS's bottom from underground burrows. Sufficient open spaces must be provided, the rat species identified and countermeasures appropriate for the damage adopted to ensure the beneficial effect of the spacious layout can be exploited.

Conclusion

In preventing the RBS damage caused by rats, modifying the storage layout by creating open spaces between RBS was seen to be effective in reducing the rat refuges. When RBSs 1m in diameter were positioned to maintain a space of 50 cm between each unit, a good result was achieved for long term storage (Exp. 2). The open spaces of 50 cm ensured that even a human could pass through between the RBSs, and made it possible to repair the wrapping films immediately, even if rat damage occurred. Because a wider area is needed for this spacious storage layout, it may have limited applicability. However, this method is chemical-free, and prevents the unnecessary killing of any species, including rats.

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