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Cleaning Reduces Grain Losses of Stored Rice

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Abstract
Rice in storage in Thailand is often infested with stored insect pests. Local rice milling factories in this region are unwalled employing a traditional open-air ventilation system and therefore insect pests easily attack the stored rice. The factories keep the rice for a few months to a year and do not usually clean the premises after the milling operation. The unclean environment becomes a suitable habitat for reproduction of insect pests, and consequently insect infestations on rice increase during storage. We set up two rooms (cleaned and uncleaned) to examine the effect of cleaning on stored rice grains. Bags of paddy, brown and milled rice were placed in the two kinds of rooms for one year to observe population dynamics of the insects and infestations caused by the pests on the rice. We found fewer insects in the milled rice than in paddy and brown rice but suggest that cleaning of the storage premises may decrease grain losses on all the types of rice.

Discipline: Insect pest
Additional key words: infestation, natural enemies, pest control

Introduction

Thailand has a hot and humid climate which is favourable for rapid growth of insect pests resulting in severe losses on stored rice[13]. Local rice milling factories are unwalled and use a traditional ventilation system of natural wind circulation which allows the stored rice to be easily attacked by freely moving insect pests. Moreover, the factories usually keep rice for a few months to a year to reduce the stickiness of rice[12,22] because non-sticky rice is favoured by Thai people. Rice husks and broken residues are left on the floors or in corners of the premises after daily milling operations and no cleaning is usually done. These uncleaned premises become a suitable habitat for reproduction of insect pests[11,19,21], and consequently this can increase the insect infestation on the stored grains.

To prevent insect infestations, the maintenance of pest-free milling premises through improvements in the structures and good storage conditions are recommended[18]. However, it is very difficult to follow these recommendations at unwalled rice milling factories employing traditional ventilation systems in Thailand. Although various measures have been applied to control insect infestations including using chemicals, most methods are expensive and therefore not economically viable given the low price of rice in the country. This study was undertaken to evaluate the effect of cleaning storage premises on reducing insect populations and their infestation of stored rice to find affordable and sustainable control measures for these pests.

Materials and methods

The experiment was conducted in a warehouse at Pathum Thani Rice Research Center (14˚ 01’ N; 100˚ 43’ E) in Thailand from December 2003 to December 2004.

Nine jute bags (100 kg per bag) each of paddy, milled or brown rice that had been newly-harvested were placed

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in a room of the warehouse to investigate population dynamics of insect pests and their natural enemies, and also to measure the damage caused by the pests. Three rice bags were piled up. One pile of the bags consisted of 3 different types of rice as one set, but piling order was random. The piles were placed as 3 rows and 3 columns (3 × 3) to make a total of 27 bags on a floor in one room and kept about 70 cm apart from each other. Wooden duckboards were set under the bottom of the piles which kept the piles 15 cm above the concrete floor. No chemical treatment was applied to the rice prior to storage, while the walls and the floor of the warehouse had been cleaned and swept with a broom before the experiment.

The investigations were conducted in two separate rooms that were located at opposite sides of a corridor in the warehouse. The rooms were the same size (6 m × 6 m × 4 m) each with 3 wooden doors (4 m^2 each in three directions of the rooms) which were left open during the day time (unable to be kept open at night because of security risks). In one room, the floor, ceiling, walls and the surface of the rice bags were cleaned by sweeping with a broom to remove residues, dust and spider webs just after the rice bags were brought in the room at the beginning of the experiment and once a month after sampling (see below), while in the other room no cleaning was done.

Once every month, three of the nine bags containing each type of rice were randomly selected. Then, 250 g of rice grains were collected from each of the three bags, therefore the total of 750 g of the grains were collected as a sample for each type of rice. Rice grain samples were brought to the laboratory to count the number of pests and kept for 30 days at room temperature to examine the number of natural enemies that emerged during this period. Five hundred rice grains from each sample were also randomly selected and the number of grains infested by the pests (grain losses) was examined just after sampling.

Temperature and relative humidity inside the rooms were measured every 1 h throughout the experiment using data loggers (TR-72S, T and D Corp., Nagano, Japan).

There is a possibility that ants could work as natural enemies of stored insect pests[23], and ants were sometimes observed carrying dead insects during the experiment. However, we did not count ants as natural enemies in this study, since in a previous study we could neither collect reliable data to estimate their efficiency as natural enemies of stored insect pests (unpublished data) nor confirm whether ants attacked and killed pests or just carried dead bodies.

Results

Cleaning and types of rice grains affected not only insect populations (Fig. 1) but also grain losses (Fig. 2).

Six species of pests and four species of their natural enemies were found in both the cleaned and uncleaned rooms (Table 1), and their niche and relationships are described in Fig. 3. Within these species, saw-toothed grain beetle, *Oryzaephilus surinamensis* (Linnaeus), a pteromalid, *Anisopteromalus calandrae* (Howard) and a chalcid, *Proconura minusa* Narendran were very rare, while five pest and two natural enemy species were relatively abundant, so that their population dynamics are described in Fig. 1.

Siamese grain beetle, *Lophocateres pusillus* (Klug) was collected only in the uncleaned room but not in the cleaned room. Weevil(s), *Sitophilus zeamais* Motschlsky and/or *S. orizae* (Linnaeus) were prominent in brown rice of the uncleaned room (Fig. 1 (e)), which showed the highest mean number per bag (207.5) 10 months after the experiment started (October). The density of Angoumois grain moth, *Sitotroga cerealella* (Olivier) in paddy of the uncleaned room rapidly increased within one month (January) of starting the experiment, peaked in 3 to 4 months (March and April) and decreased afterwards (Fig. 1 (d)).

The above mentioned insects were found mainly in the uncleaned room, while lesser grain borer, *Rhyzopertha dominica* (Fabricius) and red flour beetle, *Tribolium castaneum* (Herbst) were abundant in the cleaned room, except in milled rice.

Warehouse pirate bug, *Xylocoris flavipes* (Reuter) was recorded in all types of grains of both rooms (Fig. 1),

Table 1. Insect species found in the cleaned and uncleaned rooms

Pest		Natural enemy	
Lophocateres pusillus	(Coleoptera)	*Xylocoris flavipes*	(Hemiptera)
Oryzaephilus surinamensis	(Coleoptera)	*Anisopteromalus calandrae*	(Hymenoptera)
Rhyzopertha dominica	(Coleoptera)	*Proconura minusa*	(Hymenoptera)
Sitophilus spp.	(Coleoptera)	*Theocolax elegans*	(Hymenoptera)
Tribolium castaneum	(Coleoptera)		
Sitotroga cerealella	(Lepidoptera)		

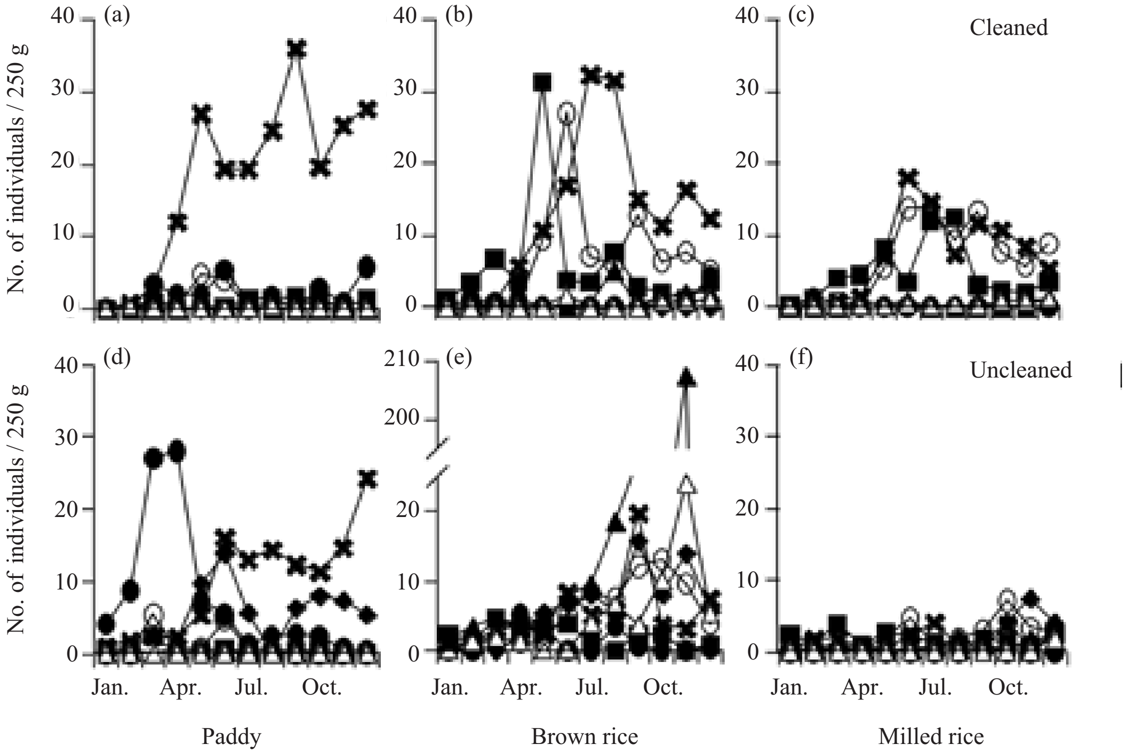

Fig. 1. Population dynamics of insect pests and their natural enemies in the paddy, brown or milled rice in cleaned or uncleaned storage rooms

The number of insects collected per 250 g sampled rice grains is indicated.
Solid and open symbols show pest and natural enemy species, respectively.
—◆—: *L.pusillus*, —✖—: *R. dominica*, —●—: *S. cerealella*, —▲—: *Sitophilus* spp., —■—: *T. castaneum*, —△—: *T.elegans*, —○—: *X.flavipes*.

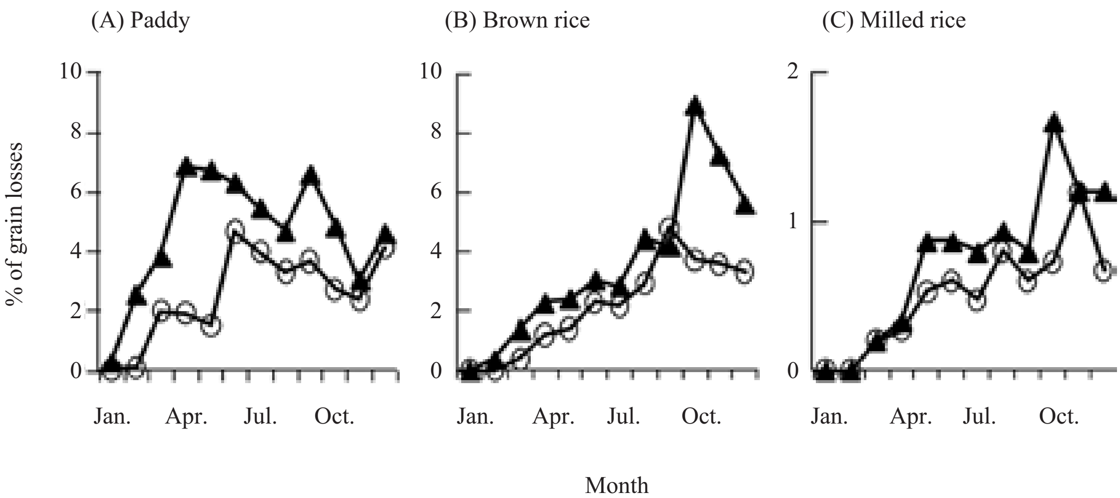

Fig. 2. Percentages of grain losses caused by insect infestations of paddy, brown or milled rice in cleaned or uncleaned storage rooms

Differences in grain losses were significant between the cleaned and uncleaned rooms for all the types of rice (Wilcoxon signed-rank test, $p < 0.01$).
—○—: Cleaned room, —▲—: Uncleaned room.

and showed similar tendencies to the population dynamics of *T. castaneum* and *L. pusillus* in brown and milled rice of both the rooms in particular. *Theocolax elegans* (Westwood) was relatively abundant in brown rice of the uncleaned room where there was an outbreak of *Sitophilus* spp. (Fig. 1 (e)). On the other hand, *A. calandrae* and *P. minusa* were hardly found in all the types of rice in both rooms.

Percentages (not in weight) of grain losses for all the types of rice in the cleaned room were less than those in the uncleaned room (Fig. 2, Wilcoxon signed-rank test, $p < 0.01$). Although the losses on the milled rice were less, the difference was significant between the two rooms (Fig. 2 (c), Wilcoxon signed-rank test, $p = 0.008$). In the paddy and brown rice, grain losses of less than 5.0% were recorded in the cleaned room, while losses more than 5.0% were found in some months in the uncleaned room (Fig. 2). In the paddy, cleaning affected grain losses from the beginning of the experiment, and losses occurred just after one month (= January, 0.33%) from the beginning in the uncleaned room, extending to 2.60% in the next month (February), which were significantly higher than those in the cleaned room (χ^2-test, $p<0.001$). On the other hand, losses in the cleaned room were 0.06% and 0.13% in January and February, respectively. In the brown rice, no loss was found in either room in January, and only the uncleaned room showed losses of 0.40% in February that increased to the highest grain loss (9.00%) in October. On the contrary, there was relatively less damage caused by the insect pests in the milled rice, and first losses of 0.20% were recorded in March in both rooms.

Temperature and humidity in the two rooms were almost the same and stable through a year (Fig. 4), except for small peaks found in relative humidity of the two rooms in September.

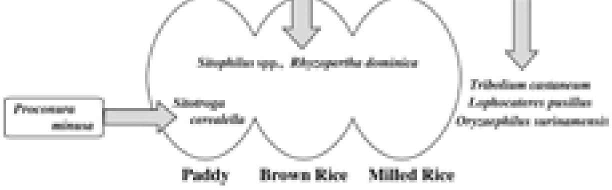

Fig. 3. Relationships among major pests and their natural enemies within and around rice kernels kept in storage

Ovals represent each type of rice kernels. Locations (inside or outside of the kernels) of the insects show their habitat. Squares and arrows indicate natural enemies attacking pest species.

Discussion

It is important to avoid introducing infested grains and pests to storage, to keep the storage environments clean, to maintain good storage conditions[1,18], and to clean storages before refilling with newly-harvested grains or after removing grains[11,19]. Although we could not set replications in this experiment to statistically verify "effect of cleaning storage" itself, we showed "the difference of grain losses between the two rooms" (Fig. 2). Since there were no considerable differences in temperatures, relative humidity (Fig. 4) and room structures between the rooms except for a cleaning treatment, these results show that cleaning the storage premises and around rice bags every month may reduce grain losses even in stores that are open to the outside environment. Grain losses should be accumulated and simply increase in total, but there were some decreases recorded at all the types of rice (Fig. 2). These decreases of grain losses were supposed to be caused by only sampling errors.

Nineteen species of stored-rice insect pests, 29 predator and 21 parasitoid species have been recorded at rice milling factories and warehouses throughout Thailand[5]. Among them, we found 6 pest species out of 7 important pest species indicated by Hayashi et al.[5], and also recorded 1 predator and 3 parasitoid species in this study (Table 1).

We did not conduct identification of *Sitophilus* species after identifying *S. zeamais* at the beginning of the experiment, but Nakakita[13] reported that the dominant *Sitophilus* species in rice storages in Thailand was *S. zeamais* except in the southern part of the country, so that we assumed *Sitophilus* species found in the experimental rooms in our study were possibly *S. zeamais*.

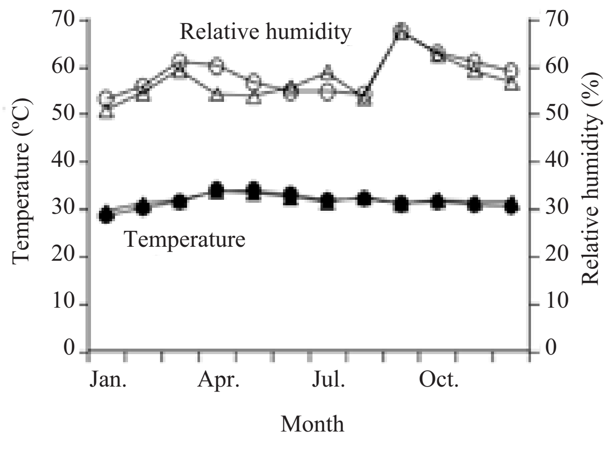

Fig. 4. Mean monthly temperature and relative humidity in cleaned or uncleaned storage rooms

○, ●: Cleaned room, △, ▲: Uncleaned room.

Cleaning seemed to intensely affect populations of *S. cerealella* in paddy and *S. zeamais* in brown rice. High densities of those species were found only in the uncleaned room (Fig. 1 (d) (e)).

Grains in storage are attacked by primary insect pests capable of piercing the seed coat and by secondary insects that feed on powdery remains left by the primary pests. *S. cerealella*, *Sitophilus* spp. and *R. dominica* are called primary insect pests, or internal feeders, while *L. pusillus* and *T. castaneum* are secondary pests. The latter alone cannot be a main factor to cause grain losses unlike the former[3,5]. Some reports have described competition between the primary insect pests[6,8,14]. However, two or more species of these primary insects did not simultaneously exist at high densities in this study (Fig. 1). *R. dominica* increased in density after *S. cerealella* decreased in paddy of the uncleaned room (Fig. 1 (d)), and *R. dominica* decreased when *S. zeamais* increased in brown rice of the uncleaned room (Fig. 1 (e)). A rapid increase in the population of *S. cerealella* in paddy of the uncleaned room (Fig. 1(d)) probably caused early grain losses (Fig. 2 (a)). Increasing grain losses in brown rice of the uncleaned room (Fig. 2 (b)) was a similar trend observed in the population dynamics of *S. zeamais* (Fig. 1 (e)) that could be a main factor of losses.

On the other hand, there were no noticeable increases of pest populations in the cleaned room except for those of *R. dominica* and *T. castaneum*. In paddy of the cleaned room only the former increased (Fig. 1 (a)) and in brown and milled rice of the cleaned room both of the pests were recorded (Fig. 1 (b) (c)). Reed et al.[19] had an experiment with wheat stored in upright concrete bins and compared pest densities between cleaned and uncleaned bins before filling with newly-harvested wheat. They reported that all pest insects combined were significantly lower when bins had been cleaned, but *R. dominica* itself did not show any difference with cleaning. There might be a common reason to explain why cleaning did not affect populations of *R. dominica* in both of the experiments, even though there was a difference between Reed et al.[19] and our experiment that the former cleaned storage premises only before introducing grains, but the latter cleaned them before and after introducing grains. *R. dominica* is also reported to be less mobile and to require a longer period of time to establish a colony in a new environment[4]. On the other hand, *S. cerealella* has greater mobility and arrives at a new place for establishing a colony before *S. zeamais*[8]. Therefore the percentage of grain losses in the cleaned room where *R. dominica* was dominant probably increased slowly compared with that in the uncleaned room where *S. cerealella* showed an unexpectedly high density within 4 months after starting the experiment (Fig. 2).

There are reports that *X. flavipes* attacks[2,9,10,16,17,20] and secretes toxic compounds[15] to *T. castaneum* and *O. surinamensis*. *X. flavipes* was recorded in high densities in brown and milled rice of the cleaned room in particular, and its population appeared to increase after a lag of about one month when the density of *T. castaneum* increased (Fig. 1 (b) (c)) so that we assumed *X. flavipes* controlled populations of *T. castaneum* in these cases.

Among parasitoids, *T. elegans* parasitizing *S. zeamais* and *R. dominica* (Fig. 3), was collected only in brown rice of the uncleaned room where very high population densities of *S. zeamais* were recorded (Fig. 1 (e)). As Reed et al.[19] reported that parasitoids of insect pests in stores were found only when the density of the insect pests was really high, a similar phenomenon might also have happened in this study. However, it was uncertain why *A. calandrae*, parasitizing the same host species as *T. elegans* (Fig. 3), and *P. minusa*, an important natural enemy of *S. cerealella*[7], were rarely recorded.

Some reports[11,19,21] state that rice husks and broken residues in the premises become a suitable habitat for reproduction of insect pests. In the uncleaned room, there were residues left during samplings as well as dust and spider webs found in the room and surfaces of the rice bags. A number of insect pests and their natural enemies were trapped in the spider webs, but we could not exactly identify the species or count the number of those insects without disturbing the webs and therefore we did not record them. However, there is a possibility that those spider webs affected more on the natural enemies (parasitoids in particular) that were relatively small and powerless, rather than on the pests. Therefore, there would be high populations of *S. cerealella* and *S. zeamais* found in paddy and brown rice, respectively. It is necessary to investigate the effects of spiders on the pests and their natural enemies in the near future.

Mean monthly temperature and relative humidity of the two rooms were almost the same, but did not show any particular tendency or fluctuation through a year except for a slight peak of relative humidity in September. We assume temperature and relative humidity would not be key factors for population dynamics of the pests and natural enemies in this experiment.

The importance of keeping storage premises clean and excluding sources of infestation was often pronounced in the practical control of stored-products insects[1,11,18,19], which was determined by the number of the pests found in storage but not by grain losses. Cleaning the surroundings of stored rice resulted in significantly-reduced grain losses in this study. Therefore, cleaning could be an efficient and important part of the practical control methods for insect pests at traditional storages employing open-air ventilation systems in Thailand, and we can recommend regular cleaning at rice milling factories and warehouses to reduce the insect infestations.

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