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Assessment of Grain Preference Among Selected Rice Varieties by Field Rat, *Bandicota bengalensis* and House Rat, *Rattus rattus* in Sri Lanka

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ABSTRACT

Rice is the staple food in Sri Lanka, where significant grain losses in storage are one of the key factors affecting food security. Rodents cause the highest losses in rice, mainly by *Bandicota bengalensis* and *Rattus rattus* in the Sri Lankan context. Rodent damage depends on factors mainly on storage management and the type of rice varieties. However, there is no information on varietal and grain preference by rodents. Hence the experiment was conducted to determine the grain preference of rodents for available 45 rice varieties. The study was conducted in the screen house (1.5m x 9m x 1.5m), modified by providing hiding places to rodents. Three trays filled with 250g of paddy seeds of each variety were placed inside the screen house. One day starved 100 rats were released into the experimental setup and allowed to feed. The remaining grain quantities were measured at 3, 5, and 7 days after release. The same procedure was followed separately for both species. The study revealed that grain losses were dependent not only on the rice variety but also on the rat species. At311, Bg409, and Bg250 were the most preferred varieties, whereas At307, Bw312, At303, Bg379/2, and Bw351 were the least preferred by *B. bengalensis*. Meanwhile, Bw367 and Bw453 were the highest preference of *R. rattus,* whereas the lowest were At373, Bg300, Bw400, At362, Bw351, At354, At311, and Bg450. It may be due to the different grain sizes and physicochemical and nutritional composition. However, comprehensive studies are necessary before adopting the findings to minimize post-harvest losses by rodents.

INTRODUCTION

Rice (*Oryza sativa*) is the staple food of more than half of the world's population (Srujana *et al.,* 2017). In Sri Lanka, rice is the staple food and the highest priority crop. There are several constraints associated with rice cultivation and reaching the maximum yield potential. Among them, minimization of pest losses in storage is one of the most important approaches to increasing the productivity of the rice (Savary *et al*., 2000).

In recent years, the world food shortage problem has intensified and will continue to do so for the foreseeable future. This problem makes the protection of foodstuffs increasingly important during growth, storage, and processing. Rodents harm the crop during all the stages, taking a share farmers can ill afford to lose. Rodent control methods have changed little over the past several decades. In fact, due to environmental problems, the use of some effective toxicants is restricted. In turn, it has made rodent control in some areas difficult. The new safer toxicants are developed though the progress is slow due to the ever-rising costs of research, development, and testing (Smythe, 1976).

Rodents are a dominant group of mammals that cause serious damage to the rice grain during storage, and there are more than 2700 species of rodents reported worldwide (Aplin *et al*., 2003). Htwe *et al.,* 2019 reported that *Bandicota bengalensis* is the dominant rodent species in rice fields in Myanmar. In Sri Lanka, eight genera of rodents genera, *Bandicota, Mus, Golunda, Srilankamys, Rattus, Madromys, Millardia, and Vandeleuria, are identified*. Among them, Srilankamys, *Mus mayori, Mus fernandoni, Rattus montanus,* and *sub-species* of *Golunda ellioti ellioti* are endemic to Sri Lanka (Niroshini and Meegaskumbura, 2015). *Bandicota bengalensis,* a common pest in South Asia, is omnivorous and generalist (Kamal and Khan, 1977) and abundant in rice fields. *Rattus rattus* is considered the most destructive rodent for paddy grain under storage conditions.

Many people select chemical control methods to manage storage losses caused by rodents though it creates both health and environmental issues. Therefore, it is vital to develop and implement environmentally friendly efficient rodent control methods by observing their feeding behaviour, especially in rodent control programs. To achieve expected results from rodent control programs it is essential to know what type of grains, which type of variety, or which kind of characters (Physical, chemical, physiological or other characteristics) are preferred by rodents when feeding on grains. They may prefer to feed on different rice varieties according to their individual preference or due to special characteristics of rice varieties. So far, such characteristics are not well known, and preferable rice varieties of rodents are not documented. In this study, the feeding behaviors of *B. bengalensis* and *R. rattus* were investigated including the most popular rice varieties in Sri Lanka. This study may provide better insights into developing proper management strategies during storage facilities for different rice varieties.

METHODOLOGY

Evaluation of the grain preferences for field rat (*B. bengalensis*) and house rat (*R. rattus*)

Measurements the study was conducted to evaluate the grain preference of *B. bengalensis* and *R. rattus* for available 45 rice varieties. The experiment was conducted in a modified screen house (1.5m x 9m x 1.5m) located in Rice Research and Development Institute at Bathalagoda. The experiment was conducted for *B. bengalensis* and *R. rattus* in two separate experimental arenas located on the same experimental site providing the same conditions. Forty-five commonly available rice varieties were tested to identify the most preferred varieties by rodents *i.e*. Bg250, Bg352, Bg370, Bg357, Bg409, Bg403, Bg379-2, Bg251, Bg360, Bg300, Bg374, Bg94-1, Bg359, Bg310, Bg450, Bg366, Bg34-8, Bg252, Bg358, Bg305, Bg455, Bg3-5, Bg745, Bg304, Bg354, Bg90-2, Bw400, Bw367, Bw452, Bw372, Bw364, Bw453, Bw312, Bw272-6b, Bw351, H-10, At311, At308, At362, At353, At307, At373, At354, At309, At303.

The quantity of grain eaten by rodents (g) = The quantity of grain used (250g) - The quantity of grain remained (g)

Three trays which were considered replicates, filled with 250g of paddy seeds from one variety were placed on the floor inside the screen house and arranged in a Completely Randomized Design. Both species of rats earlier collected from the field and maintained in rearing cages by providing artificial diets were used for the experiments. One day starved 100 rats from each species were released to each experimental set-up and allowed to feed on the rice varieties as per their choice without any disturbances. The grain amount that remained in each treatment (i.e. variety) was obtained after 3, 5, and 7 days from the release. The amount of grain consumed (kg) by each species was calculated using the following formula;

The data were analyzed using the Analysis of variance (ANOVA) of SAS statistical software (SAS Institute, 2002-2008) for both species. Means were compared using LSD at $p \leq 0.05$.

Figure 1: Experimental set up.

RESULTS AND DISCUSSION

Interestingly, *B. bengalensis had* a significantly higher preference for Bg250 ($F_{89, 45}$ =86.25, p<0.0001), followed by Bg409. Bg310, Bw400, and Bg450 with no significant difference among them (Figure 2), (Figure 3) and (Figure 4). However, the grain preference varied with time, and at the end of one week, it was following the sequence as At311 (212g), Bg409 (207g), and Bg250 (204g) ($F_{89, 45}$ =170.79, p<0.0001) but there was no significant difference between each other. During the first 3 days, the least preference was shown for At307 which showed non-significant difference between Bg305, Bg304, Bg3-5, At353, At354, Bw364, At303, Bw351, Bg352, Bw312, At362, H-10, Bw372, Bg34-8, Bg379-2, Bg455, Bg252 and Bg359 (Figure 2). However, there was no significant difference between At307 (18.5g), Bw312 (14.5g), At303 (14.5g), Bg379/2 (13.5g), and Bw351 (13.5g), which showed the lowest grain preference by *B. bengalensis* after one week (Figure 4).

Rattus rattus had a significantly higher preference for Bw453 ($F_{89, 45}$ =43.74, p<0.0001), followed by Bg455 (Figure 5), (Figure 6) and (Figure 7). At the end of the one week, the significantly higher grain preference ($F_{89, 45}$ =73.68, p<0.0001) was shown for Bw367 (193g) followed by Bw453 (192.5g), whereas no significant difference. A higher preference was shown for Bg352 (146.5g) and At353 (135.5g), without having a significant difference between them (Figure 7). The least preference was reported for At311 whereas no significant difference between At373, At354, Bg3-5, Bw312, Bw272-6b, At362, Bg300, Bw351, Bg450, Bw400, Bw452, Bg304, Bg379-2, Bw372, At303, Bg250, Bg305, Bw364, Bg370, H-10, Bg357 and Bg90-2 during first 3 days(Figure 5). After one-week same trend was observed without a non-significant difference between At373 (10.5g), Bg300 (9.5g), Bw400 (6.0g), At362 (5.5g), Bw351 (5.5g), At354 (5.0g), At311 (4.0g) and Bg450 (1.5g) which had the lowest grain preference by *R. rattus* after one week (Figure 7).

In contrast, *B. bengalensis* showed the highest grain preference for At311 (212g), and it showed the lowest grain preference for *R.*

rattus. Similarly, the second-highest preference of *B. bengalensis* showed *for* Bw400 (192.5g), whereas it was the lowest preferred variety of *R. rattus.* But Bw351 showed the lowest grain preference by *B. bengalensis* and *R. rattus* species. Therefore, the grain preference depends on the species of the rats.

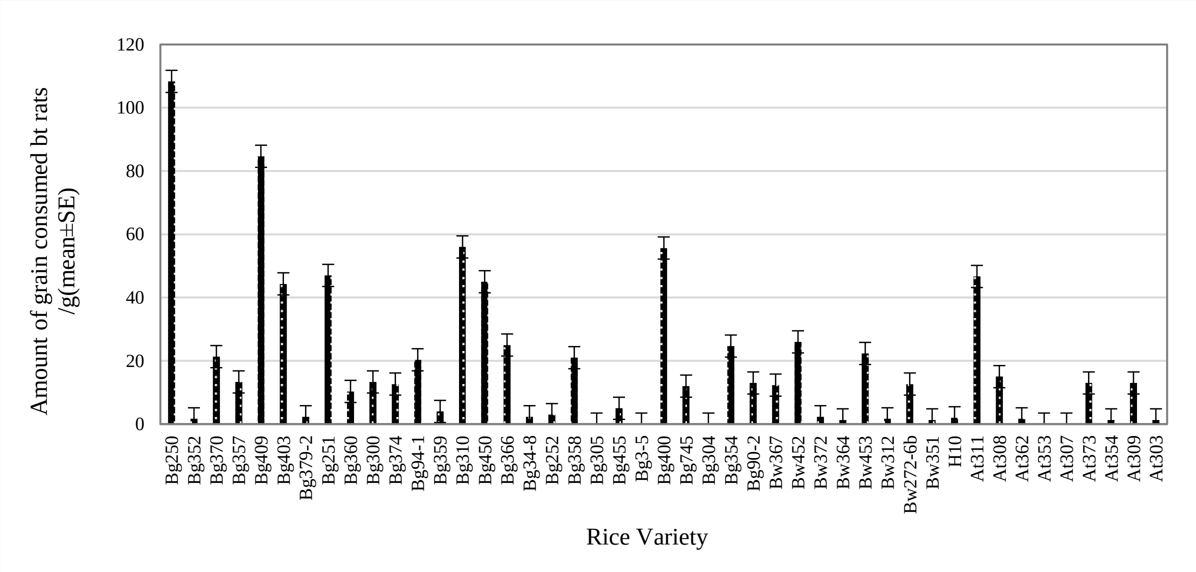

Figure 2: Quantity of grains consumed by *B. bengalensis* after 3 days of release.

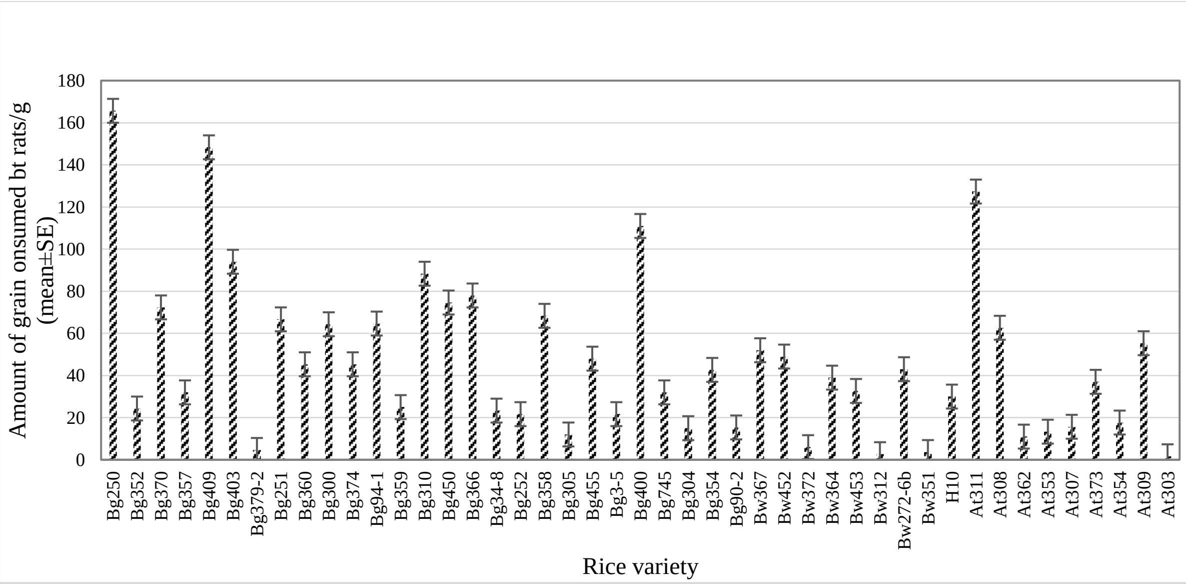

Figure 3: Quantity of grains consumed by *B. bengalensis* after 5 days of release.

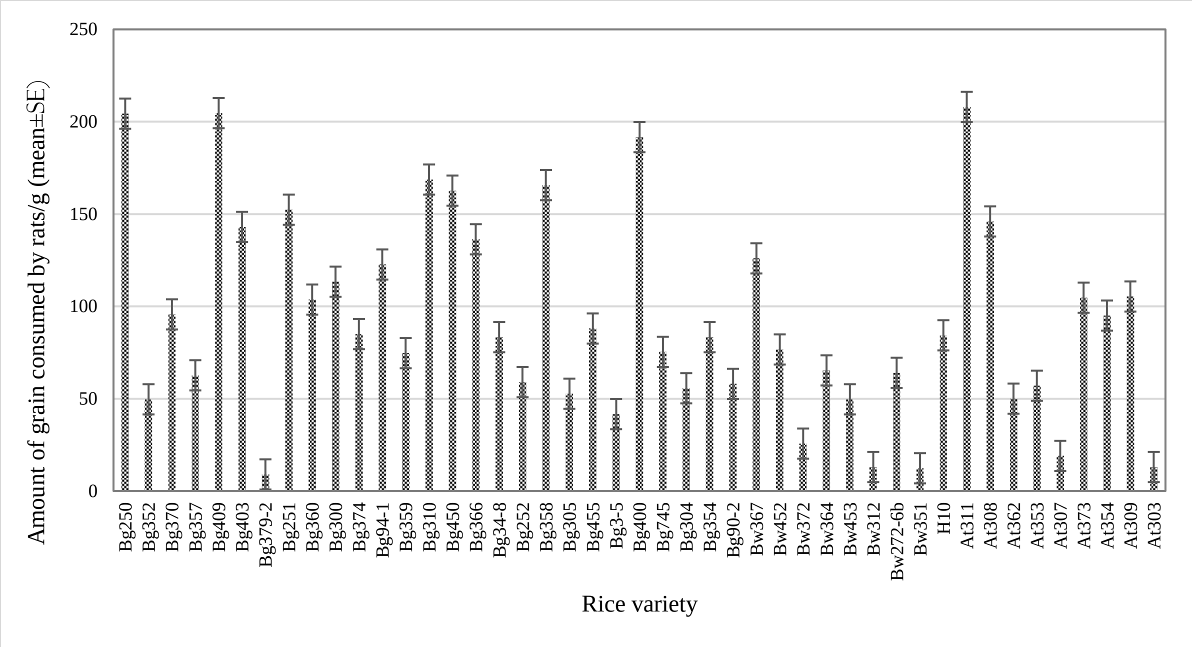

Figure 4: Quantity of grains in different rice varieties consumed by *B. bengalensis* after 7 days of release.

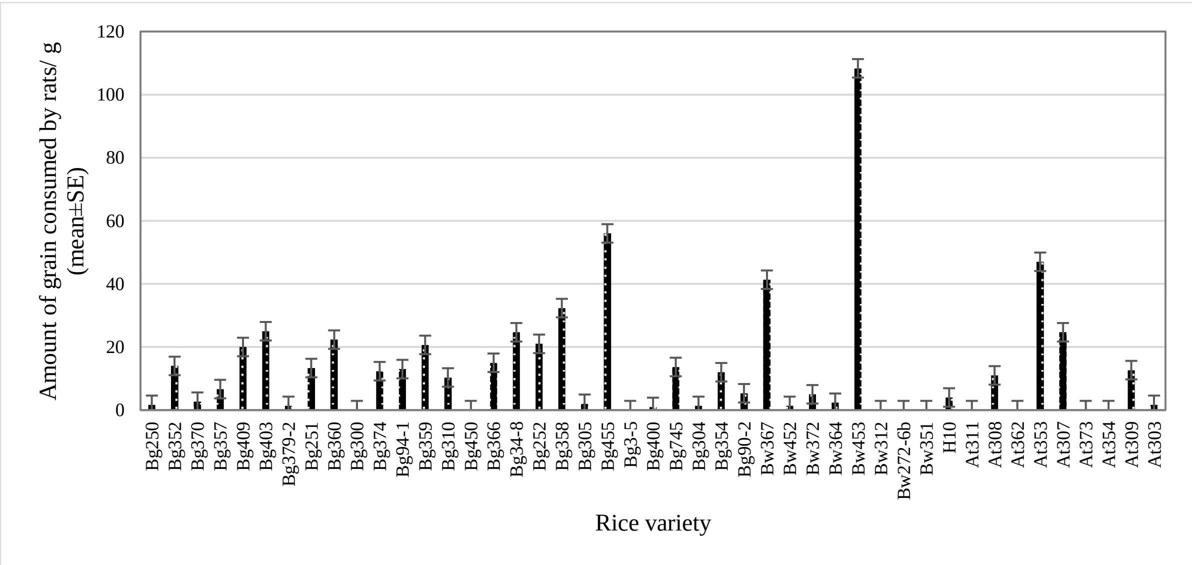

Figure 5: Quantity of grains consumed by *R. rattus* after 3 days of release.

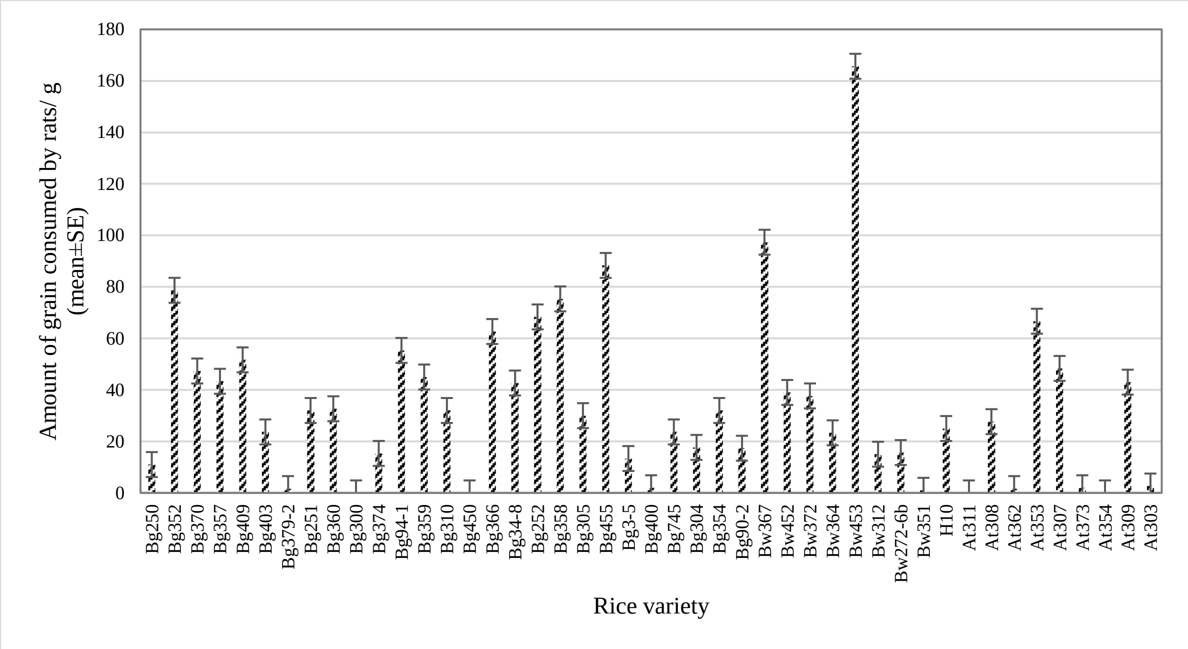

Figure 6: Quantity of grains consumed by *R. rattus* after 5 days of release.

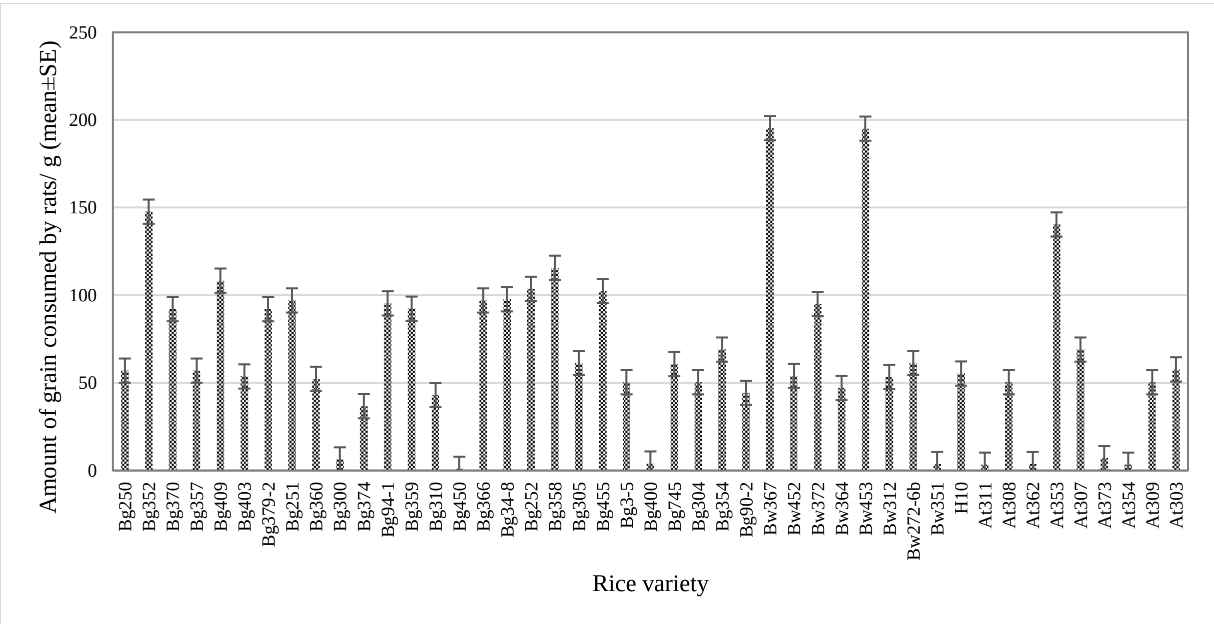

Figure 7: Quantity of grains consumed by *R. rattus* after 7 days of release.

The different grain preferences shown by different rodent species may be due to physical, chemical, or any other characteristics of grains of different rice varieties. Different studies have reported that rats (*Rattus norvegicus* Berkenhout, *Rattus rattus* L.) have a preference for different tissues or sub-fractions of grains and seeds (e.g., germ vs. endosperm), meals vs. whole grains, differences due to particle size, and different plant species (e.g., millet vs. maize) (Carlson and Hoelzel, 1949; Barnett and Spencer, 1953; Khan, 1974; Bhardwaj and Khan, 1979).

The texture appears to be a significant factor in food selection. Carlson and Hoelzel, 1949 showed that soaking maize seeds in water removed all preferences of rats, and soaking wheat in water increased consumption (Khan, 1974). In addition to that, food consumption by rats mainly depends on the hardness of the diet pellets, their consumption decreased when the hardness of diet pellets increases (Ford, 1977). The same idea was revealed by Robards and Saunders, (1998) that mice showed a marked preference for the grain of soft wheat varieties compared with grain from hard varieties. However, closer examination of their results indicated that although one variety or grain lot was preferred over others, the preference for soft vs. hard was not absolute. Some researchers found seed palatability of some rodents mainly depends on their olfactory cues, and some buried seeds can be found due to odours reflected by seeds (Howard and Cole, 1967; Howard et al., 1968). According to the Morris *et al*., 2012, there was a strong preference for soft white and a 5-fold preference for soft white over hard red, indicating that kernel texture (i.e., "hardness"), or bran colour, flavour, etc., could be the primary discrimination criterion (criteria) for the mice. In addition to that, this study revealed that texture might play a role. Similarly, taste or olfactory cues could play a role in grain preference by mice. Lawhon and Hafner (1981) reported the feeding behaviour of kangaroo rats (*Dipodomys* sp.) and pocket mice (*Perognathus* sp.). Each potential food item was handled beneath the head (out of sight), but olfactory cues were not primarily involved. They concluded tactile perception to be the primary means of selecting or rejecting potential food objects. Barnett and Spencer (1953) observed learning behaviour; prior exposure had some influence. Rats would often eat the less preferred food. Spencer (1953) described how mice eat wheat: "Mice typically holds a grain at right angles to the long axis of the body, as a man holds corn on the cob. They also rotate the grain around its long axis while eating it." Both rat and mouse produced "kibbled" grains where only a portion of the grain was consumed. The feeding behaviour of the house mouse is influenced by both inter-generic through intra-specific differences among cereal grains, including texture (hardness), morphology, composition, grain color, the presence/absence of hulls (lemma and palea), and ultimately taste and nutrition. As a hypothesis, the rice kernel traits such as hardness, bran color, presence of hulls, and other yet-to-be-identified factors (e.g., smell or taste) influence the food selection of the house mouse. The first comparison trial involved examining an anecdotal observation that one idea based on the statement of Spencer, (1953) might speculatively be that mice prefer to eat foods that can be held in their forepaws. Mechanical treatment of grains may enhance their acceptability to rodents. Bait tests have indicated a definite particle-size preference among rodents. As stated earlier in this paper, rodents are grain feeders. This does not mean that they would not eat anything in sight, but rather that they do have basic feeding habits. While some rodents are primarily fruit, root, or fodder feeders, grains and combination baits can still be used for their control. Tests conducted by some authors for Monsanto using wild Norway rats, *Rattus norvegicus,* indicated a particle-size preference for adult Norway rats of 0.4 to 0.7 mm in diameter. This seemed to be a size suitable for holding in the forepaws while eating. There seemed to be a supra-normal stimulus for bait particles of 2x to 3x, but a significant portion of the feeding was in the optimum range. The size was proportionally smaller for the smaller rats, and with rodents that have a hoarding reflex, the larger bait pieces may be hoarded. It was also noted that the fines and flour-like dust were then last to be consumed. According to the bait preference, related research revealed that the particle size has a greater impact on their feeding behaviour. Similarly, can conclude that the size of grains has an impact on their feeding behaviour. The current study showed similar results may be *R. rattus* which has a smaller body size and prefer to feed smaller size grains their preferred varieties were "Samba" varieties. In the case of *B. bengalensis*, their preference moved towards the long grains that were "Nadu" varieties. Not only particle size, but hardness also plays a part in bait preference, too. Again, rodents will gnaw on anything. Baits with a hardness between that of soft wheat and water-soaked corn are near optimum. Accessing the pellets required gnawing the pellet, Robards, and

Saunders, (1998) similarly reported house mice to have a preference for soft wheat over hard. Preference by rats and mice for a softer texture and selective eating of the grains have been reported (Carlson and Hoelzel, 1949; Khan, 1974; Ford, 1977). Beyond this "selective" feeding, no kibbling was observed (Spencer, 1953).

Further, the studies on baits or bait materials stored may become tainted by chemical smells and become unattractive to rodents. Similarly, the grains contaminated with chemicals may repel rodents while reducing their feeding behavior. In addition to that, rodents do not like grains contaminated by rodents, dirty, old, stale, or musty. If grains have a previous contaminated history with rodents, such grains may be rejected by rodents with no rodent infestation. According to some findings, rodents demonstrate selective feeding preferences among different seed-based foods. Rats seem to have a taste preference like men. Rodents may seem to prefer sugars and fall between 1 and 5% by weight in the bait. Sucrose is well accepted, but inverted sugars like maltose, dextrose, fructose, and laevulose are also acceptable. Therefore, the preference of rats for rice varieties may also depend on the sugar composition of rice as well. This hypothesis is to be investigated in the future to get a proper idea about its impact on grain preference by rats. Most newly improved rice varieties consist of higher protein content than previously accepted standard rice varieties. Therefore, rodents may prefer to feed rice varieties that are high in proteins for their proper growth. Not only protein, but they may also prefer nutrient-rich rice varieties. According to the bait-related findings, grain preference by rodents may also depend on the chemical composition of grains. However, in the present study, such properties were not investigated. The previous findings can predict that the grain preference of rodents may depend on the chemical, physical or other properties of different rice varieties and some special characteristics of rodent species. However, such preferences may change due to individual properties of the same species as well. Therefore, further investigations are needed to prove such predictions.

Paddy can be stored separately based on their grain type and size generally as long medium or long slender-grain ("Nadu") and short round-grain ("Samba") types to reduce losses from rodent damages. Further, "Keeri samba" /Bg360 and "Suwanda samba" /At373 should be stored separately to reduce losses during storage conditions. Therefore, it is important to observe the level of preference by rodent species for different rice varieties before storing paddy.

However, the present study may help to develop special prevention methods during storage conditions while protecting them from rodent infestation. After conducting this study, people can give special attention to rice varieties that are highly preferable to rodents while protecting them from rodent infestation by implementing special precautions. In addition, this study provided better insight for further development of baits, and such findings can be used in future rodent control programs.

CONCLUSIONS

Different rodent species show differences in grain preference, and the best choice of *B. bengalensis* was for Bg250 grains, and they preferred mostly grains of At311, Bg409, and Bg250 varieties, where they are long grains. The least preferable varieties were At307, Bw312, At303, Bg379/2, and Bw351. However, the best preference of *R. rattus* was for "Samba" varieties, *i.e*. Bw453 and followed by Bw367 and Bw453, whereas the lowest preference was for At373, Bg300, Bw400, At362, Bw351, At354, At311, and Bg450.

Although At311 was the highest preferred grain for *B. bengalensis,* it showed the lowest preferred grain for *R. rattus.* Further, the study provided primary information on grain preference of rodents depending on the rodent species, and the grain characteristics such as variety, size, other physicochemical characteristics, and the nutritional composition are affecting the rodent damage, and such factors could be considered for proper rice grain storage to minimize the post-harvest losses by rodents.

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