

# Repellent Effect of The *Pandanus* (*Pandanus amaryllifolius* Roxb) and Neem (*Azadirachta indica*) Against Rice Weevil *Sitophilus oryzae* L. (*Coleoptera*, *Curculionidae*)

Slamet Fauzi, Sigit Prastowo\*

Department of Plant Protection, University of Jember, Jember, Indonesia

## ABSTRACT

The aim of this study was to determine the effect of *Pandanus* (*Pandanus amaryllifolius* Roxb.) and Neem (*Azadirachta indica*) leaves powder on the repellency, mortality, and weight loss of grains due to *Sitophilus oryzae*. The method of this study used a completely randomized design with 7 treatments and 4 replications. The results of this study showed the best treatment in terms of causing repellency was the treatment of 10 grams of *pandanus* with a percentage of 87.5%, while the best treatment in terms of causing pest mortality and was also able to reduce the risk of rice weight loss due to *Sitophilus oryzae* was treatment 10 gram of neem with a mortality percentage of 76.25% and weight loss of rice 3.14%. This research showed that neem leaf compounds are better in terms of causing mortality, while *Pandanus* compounds are better in terms of causing mortality of *Sitophilus oryzae*. The repellency effect is due to the volatile compounds produced by insecticides so that insects stay away from bioinsecticide sources. The mortality of insects due to volatile compounds that evaporate can interfere with the physiological function of insects through the entry of spiracles so that they interfere with breathing and cause death. The results of this research still need to be continued by other researchers by separating pure compounds from *pandanus* and neem leaves and formulating them in gas form (nanopesticides) so that it will become new products in the form of biodegradable fumigants.

**Keywords:** *Sitophilus oryzae*; Natural insecticides; *Pandanus amaryllifolius*; *Azadirachta indica*; Nanopesticides; Rice

## INTRODUCTION

Rice is the staple food for people in the most parts of Indonesia. Various disturbances from organisms that can reduce the quality and quantity of rice are always there. One of the pests that exist in rice and can cause the decline in quality and quantity of rice is the post-harvest pest *S. oryzae* [1-4]. The presence of *S. oryzae* in rice is extremely detrimental and causes damage. Management is necessary in order to avoid damage caused by *S. oryzae*, proper handling is needed when storing rice.

According to the Indonesian Central Statistics Agency, in 2019, Indonesia's rice production reached 54.60 million. The total production decreased by 7.76% from the total production in 2018 which reached 60.60 million tons. Food Agricultural Organization in 2017 stated that Indonesia as a Southeast Asian country has a risk of losing rice products after harvest reaching 10%-37%, so it is necessary to take control measures to minimize the risk of damage to rice during its storage period.

Rice stored in warehouses globally reduced 5%-10% in damaging in a relatively short time due to warehouse pests, especially *S. oryzae* [5].

The level of damage for each country varies depending on the region, type of rice, climate, and duration of storage [3]. For instance, rice damage in Ukraine can reach 25%-50%, Australia 0.7%, Pakistan 16%, India 20%-25% in 2010-2011, and Poland 3%-5% [5-7]. According to Phillips and Throne [8], the loss of storage products due to *S. oryzae* pest's ranges between 9% in developed countries and 20% in developing countries. This shows the importance of controlling *S. oryzae* to be carried out.

Using of synthetic fumigants causes a variety of serious problems, such as pest resistance, human health, the environment, natural enemies of pests, and pollution [9-11]. The synthetic fumigants commonly used to control *S. oryzae* are methyl bromide and phosphine [12]. The latest research by [13], stated that the *S. oryzae* in the quarantine of South Korea was resistant to Methyl Bromide (CH<sub>3</sub>Br) and Phosphine (PH<sub>3</sub>).

Hereby, it is important to control *S. oryzae* by using natural materials from plants used as bioinsecticide repellents so it will not cause negative effects on food safety. One of the alternative materials that can be used as bioinsecticides is Neem and *Pandanus* leaves. Neem leaves contain alkaloid compounds, nimbidine, tannins, resins, azadirachtin [14], and *Pandanus* leaves contain alkaloids, flavonoids, polyphenols,

**Correspondence to:** Sigit Prastowo, Department of Plant Protection, University of Jember, Jember, Indonesia, E-mail: prastowo\_hpt.faperta@unejac.id

**Received:** 02-Mar-2022, Manuscript No. EOHCR-21-15464; **Editor assigned:** 08-Mar-2022, PreQC No. EOHCR-21-15464 (PQ); **Reviewed:** 22-Mar-2022, QC No. EOHCR-21-15464; **Revised:** 28-Mar-2022, Manuscript No. EOHCR-21-15464 (R); **Published:** 04-Apr-2022, DOI: 10.35248/2161-0983.22.11.276

**Citation:** Fauzi S, Prastowo S (2022) Repellent Effect of The *Pandanus* (*Pandanus amaryllifolius* Roxb) and Neem (*Azadirachta indica*) Against Rice Weevil *Sitophilus oryzae* L. *Coleoptera*, *Curculionidae*. *Entomol Ornithol Herpetol*. 11: 276

**Copyright:** © 2022 Fauzi S, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

terpenoids, steroids, hydrocarbons, and aldehydes [15-17]. According to [18], stated that the bioactive compounds commonly used in plant pesticides are mostly steroids, alkaloids, tannins, terpenoids, phenols, flavonoids, and resins that have insecticidal properties. The content of these compounds is following accordance with the researchers chose to study the repellent effect of *Pandanus* leaves and neem bioinsecticide combination against *S.oryzae*.

The previous research that also evaluated the repellent effect from the other botanical pesticides against *S. oryzae* was conducted by [2,19-23]. The results of a study by [19], explained that the fastest repellent effect on *S. oryzae* in just 5 minutes given by the methanol extract of *Duabanga grandiflora* at a concentration of 0.252 mg/cm<sup>2</sup> which resulted in a 63% response rate. After 4 hours, the repellency rate to *S.oryzae* was 100%, while the results of [3], showed a 98% repellent effect against *S.oryzae* after 5 hours of exposure to bioinsecticide from caraway essential oil with a concentration of 0.5%. [24], have also evaluated the fumigant toxicity and repellent activity of *Litsea cubeba* essential oil and its two main active ingredients against *S.oryzae*. The results showed that the repellency of *S.oryzae* is 81.83% at 4 hours after the start of the study. Different things were done by [25], through the use of bioinsecticides from *Olax zeylanica* leaf powder (a rural vegetable in Sri Lanka) at a dose of 7 gr and 1 gr per 50 gr of rice can provide a repellent effect against *S.oryzae* of 96% and 50%.

The repellency assessment of the insecticides of Neem and *Pandanus* leaves is highly necessary. The aim of this study was to test the repellency of the combination of neem leaves and *Pandanus*, and without the combination of the two being used as a powder to control *S.oryzae*. This research is expected to be able to control *S.oryzae* with an environmentally friendly manner, reduce the risk of product damage, and novel scientific development.

## MATERIALS AND METHODS

The study was conducted in the laboratory conditions at 28°C ± 1°C with 60 ± 5% relative humidity at the Department of Plant Protection in the University of Jember. The research design used a completely randomized design with 7 treatments and 4 replications, the treatments consisted of:

- P0: Rice
- P1: Rice with 10 g of neem leaves powder
- P2: Rice with 8 g of neem and 2 g of *Pandanus* leaves powder
- P3: Rice with 6 g of neem and 4 g of *Pandanus* leaves powder
- P4: Rice with 4 g of neem and 6 g of *Pandanus* leaves powder
- P5: Rice with 2 g of neem and 8 g of *Pandanus* leaves powder
- P6: Rice 10 g of *Pandanus* leaves powder

### Insects culture

*S. oryzae* adults reared was carried out according to the procedure and modification namely 50 (25 male and 25 female) *S. oryzae* were kept in a plastic jar filled with rice as a place to live and the food was then covered with a saffron cloth, and invested for 7 days and then all the pests were removed from the jar and waited for ± 35 days for the emerging of *S. oryzae* to come out of the rice. The method of obtaining adult female and male insects with a uniform number and size was then carried out by separating the young (virgin) with a slightly reddish brown color. The male and female insects could be distinguished by their body size, female insects are larger in size than male insects. Besides, it could also be seen in the

snout, where the snout length of the female of *S.oryzae* is longer than the male [26].

### Observations

The application methodology of neem and *Pandanus* leaves obtained was weighed according to the dosage in the treatment, namely 2 g, 4 g, 6 g, 8 g, and 10 g. The insecticide was put into a tea bag and then put into a plastic cup filled with 100 g of rice and 20 adapted *S. oryzae* covered with saffron cloth. This was done as a new way of applying insecticides by utilizing volatile compounds from the materials used or using the concept of inhalation poisons system. The Repellency observations were observed every 2 hours during the day and 4 hours at night for 48 hours. The calculation of repellency is seen from the insects that leave/move from the place that was given treatment to the outside of plastic cup in the jar. The evaluation of the repellency effects were based on the emigration index, calculated as a percentage proportion of individuals emigrating when compared with the total number of individuals in the population. The calculations were made using the following formula [3].

$$\text{Repellency effect} = \frac{\text{mean number of insects dead}}{\text{insects treated}} \times 100\%$$

The percentage of mortality was calculated by comparing the number of dead insects after application compared to the number of tested insects using the formula from [27]. The calculation of mortality at intervals of 3 days and until no more insects has died.

$$\text{Mortality index} = \frac{\text{mean number of insects dead}}{\text{insects treated}} \times 100\%$$

The percentage of weight loss was calculated after 30 days after insecticide application. The method used was by sifting with a size of 40 mesh, then the sieve in the form of flour from rice was weighed using a digital scale. The calculation used the formula from [28] as follows.

$$\text{Weight loss} = \frac{(\text{UND}) - (\text{DNU})}{U \times (\text{ND} + \text{NU})} \times 100\%$$

Where U is the weight of uninfested grains (g), NU is the number of uninfested grains (n), D is the weight of infested grains (g), and ND is the number of infested grains (n).

### Statistical analysis

We have investigated whether there were statistically significant differences in the repellent effect of different concentrations of neem and *Pandanus* leaves powder on *S. oryzae*. The dependent variable is the insect emigration rate. The analysis of variance (ANOVA) Kruskal-Wallis rank test was applied followed by the Duncan's Multiple Range Test (DMRT), in this case a multiple comparison test [29]. The test probability level "p" and the significance level were 0.05. The calculations were performed in the Excel's Statistics tool.

## RESULTS

The results of the application of insecticides from the *pandanus* and neem leaves powder, and the combination of the two had a highly significant effect on the control of the repellency of *S. oryzae*. Based on the results of the analysis of variance (ANOVA), the F count of 48 hours of response was 155.85 and was greater than the F crit of 5% and 1%, namely 2.57 and 3.81. The results of the Analysis of

Variance were very significantly different and continued with the Duncan's Multiple Range Test (DMRT) 5% which can be seen in the Table 1.

Based on the results of the Duncan's Multiple Range Test at 2 hours to 48 hours of observation, there was a difference between treatments; the control was very significantly different from all other treatments. The Differences also occurred in the change and increase in the percentage of repellents in all treatments compared to controls. The control tended to have no increase in the percentage of repellents after exceeding the observation time of 4 hours and remained at 17.5% until the end of the observation. Treatments other than control continued to experience an increase in the percentage of response up to 22 hours of observation. Based on the Figure 1 that the highest increase in repellency was in the first 2 hours of observation with a percentage of 40% in the combination treatment of 8 grams of *pandanus* and 2 grams of neem (P5). However, the highest response from 10 hours to 48 hours was the treatment of 10 grams of *pandanus* (P6) (Figure 1).

$$\text{Mortality index} = \frac{\text{mean number of insects dead}}{\text{insects treated}} \times 100\%$$

In addition to the repellency rate, insect's mortality was also calculated based on the results of the analysis of variance (ANOVA), the F value of the insect's mortality count is 169.15 and is greater than the F crit of 5% and 1%, namely 2.57 and 3.81. The results of the analysis differed significantly so that it was continued with the Duncan's Multiples Range Test at 5% level further test which can be seen in the Table 2.

Based on the results of the Duncan's Multiples Range Test at 5% level, that is the observation of 3 to 21 days after application there were differences between treatments, namely the control was highly significantly different from all other treatments. In the control treatment, there was no increase in the percentage of mortality ranging from 3 till 21 days after application. The treatments other than controls continued to experience increased mortality up to 18 days after application. Based on the below figure, that the highest increase in mortality was observed 3 days after application

with a percentage of 27.5% in the 10 g neem treatment (P1). The treatment of 10 grams of neem remained the treatment that caused the highest mortality until the end of the observation up to 21 days after application, which was 76.25%. The combination treatment of 2 g of *pandanus* and 8 g of neem (P2) also had a fairly good mortality percentage of 62.5% up to 18 days after application. The treatment other than control that had the lowest percentage mortality value was the combination treatment of 6 g of *pandanus* and 4 g of neem with a mortality percentage value of 43.75% until the end of 21 days after application. The percentage value of mortality which was almost the same as the combination treatment of 6 g panda and 4 g of neem was in the combination treatment of 8 g of *pandanus* and 2 g of neem of 45% in Figure 2.

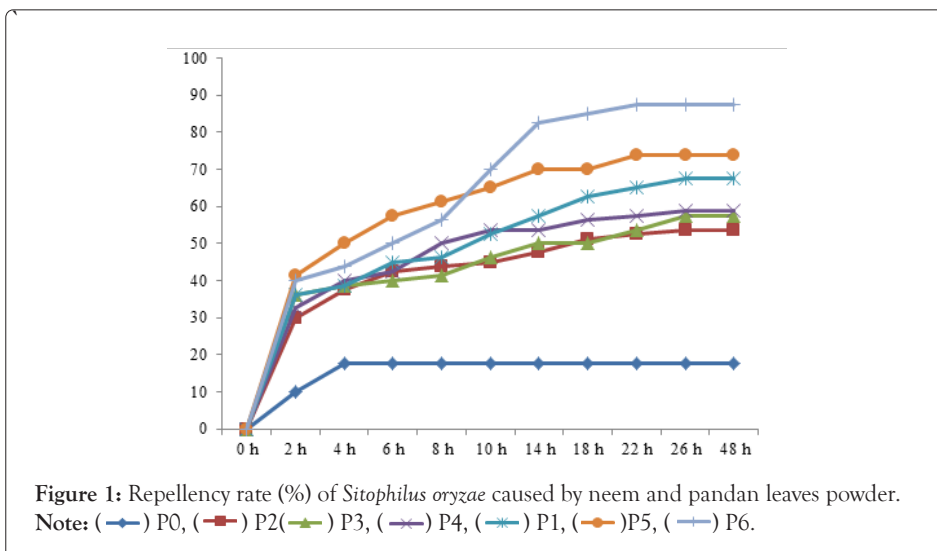
*S. oryzae* also causes weight loss of rice which becomes powdery like flour. The results of the research data were analyzed using descriptive analysis. The percentage of rice weight loss for 30 days from each treatment can be seen in the Table 3 and Figure 3.

Based on above, it showed that the control treatment with other treatments was very significantly different. The treatment of 10 g neem (P1) was significantly different from the combination treatment of 4 g *pandanus* and 6 g neem (P3), the combination of 6 g pandan and 4 g neem (P4), the combination of 8 g pandan and 2 g neem (P5), the 10 g treatment *pandanus* (P6), and control. However, the treatment of 10 g neem (P1) was not significantly different from the combination of 2 g pandan and 8 g neem (P2). The percentage of high and low weight loss can be seen. The percentage of rice weight loss as shown in the Figure 3 above is quite diverse. The highest percentage of loss occurred in the control at 6.55% or the equivalent of 6.55 grams of weight loss. The treatment that had the least weight loss was 10 g of neem (P1), which was only 3.14%. The combination treatment of 2 grams of *pandanus* and 8 grams of neem was the second-best treatment with a percentage of rice weight loss of only 3.40% of the initial rice weight and a percentage difference of 0.36% of 10 grams of neem. This indicates that the treatment of 10 grams of neem is the most effective in reducing or suppressing rice weight loss due to *S. oryzae*.

**Table 1:** Repellent effects of the Pandanus and neem leaves powder on the *Sitophilus oryzae*.

Treatment	Treatment details	Repellency rate (%) in hour after application (haa)									
		2	4	6	8	10	14	18	22	26	48
P0	Control	10 <sup>a</sup>	17,5 <sup>a</sup>	17,5 <sup>a</sup>	17,5 <sup>a</sup>	17,5 <sup>a</sup>	17,5 <sup>a</sup>	17,5 <sup>a</sup>	17,5 <sup>a</sup>	17,5 <sup>a</sup>	17,5 <sup>a</sup>
P2	2 g pandanus+8 g neem	30 <sup>b</sup>	37,5 <sup>b</sup>	42,5 <sup>b</sup>	43,75 <sup>b</sup>	45 <sup>b</sup>	47,5 <sup>b</sup>	51,25 <sup>b</sup>	52,5 <sup>b</sup>	53,75 <sup>b</sup>	53,75 <sup>b</sup>
P3	4 g pandanus+6 g neem	36,25 <sup>bc</sup>	38,75 <sup>b</sup>	40 <sup>b</sup>	41,25 <sup>b</sup>	46,45 <sup>b</sup>	50 <sup>bc</sup>	50 <sup>b</sup>	53,75 <sup>bc</sup>	57,5 <sup>b</sup>	57,5 <sup>b</sup>
P4	6 g pandanus+4 g neem	32,5 <sup>bc</sup>	40 <sup>b</sup>	42,5 <sup>b</sup>	50 <sup>c</sup>	53,75 <sup>c</sup>	53,75 <sup>cd</sup>	56,25 <sup>bc</sup>	57,5 <sup>c</sup>	58,75 <sup>b</sup>	58,75 <sup>b</sup>
P5	8 g pandanus+2 g neem	41,25 <sup>d</sup>	50 <sup>c</sup>	57,5 <sup>d</sup>	61,25 <sup>e</sup>	65 <sup>d</sup>	70 <sup>e</sup>	70 <sup>d</sup>	73,75 <sup>e</sup>	73,75 <sup>d</sup>	73,75 <sup>d</sup>
P6	10 g pandanus	40 <sup>cd</sup>	43,75 <sup>bc</sup>	50 <sup>c</sup>	56,25 <sup>de</sup>	70 <sup>e</sup>	82,5 <sup>f</sup>	85 <sup>e</sup>	87,5 <sup>f</sup>	87,5 <sup>e</sup>	87,5 <sup>e</sup>

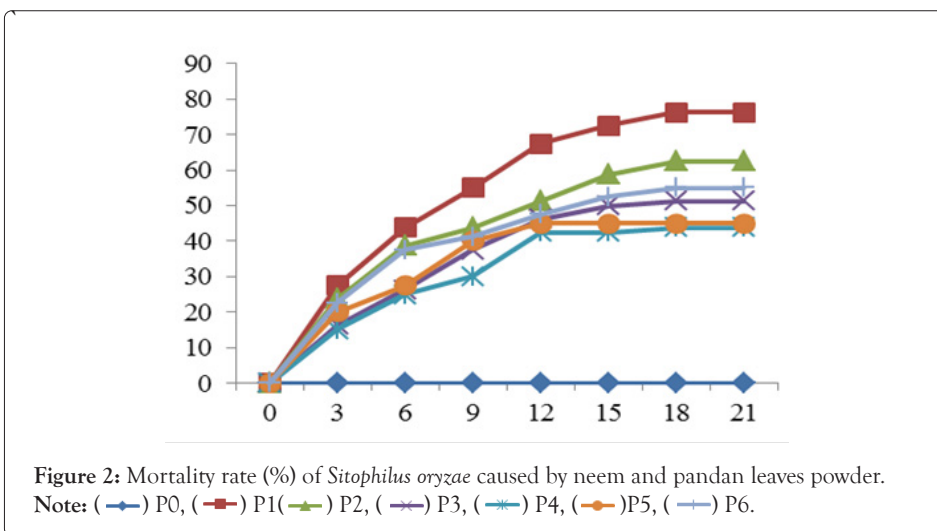
**Note:**The values followed by the same code are not significantly different in the same column



**Table 2:** Mortality effects of the Pandanus and neem leaves powder on the *Sitophilus oryzae*.

Treatment	Treatment details	Mortality rate (%) in day after application (daa)						
		3	6	9	12	15	18	21
P0	Control	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>
P1	10 g neem	27,5 <sup>e</sup>	43,75 <sup>e</sup>	55 <sup>e</sup>	67,5 <sup>e</sup>	72,5 <sup>e</sup>	76,25 <sup>e</sup>	76,25 <sup>e</sup>
P2	2 g pandanus+8 g neem	23,75 <sup>de</sup>	38,75 <sup>d</sup>	43,75 <sup>d</sup>	51,25 <sup>d</sup>	58,75 <sup>d</sup>	62,5 <sup>d</sup>	62,5 <sup>d</sup>
P3	4 g pandanus+6 g neem	16,25 <sup>bc</sup>	26,25 <sup>bc</sup>	37,5 <sup>c</sup>	46,25 <sup>bc</sup>	50 <sup>c</sup>	51,25 <sup>c</sup>	51,25 <sup>c</sup>
P4	6 g pandanus+4 g neem	15 <sup>b</sup>	25 <sup>b</sup>	30 <sup>b</sup>	42,5 <sup>b</sup>	42,5 <sup>b</sup>	43,75 <sup>b</sup>	43,75 <sup>b</sup>
P5	8 g pandanus+2 g neem	20 <sup>cd</sup>	27,5 <sup>c</sup>	40 <sup>cd</sup>	45 <sup>bc</sup>	45 <sup>b</sup>	45 <sup>b</sup>	45 <sup>b</sup>
P6	10 g pandanus	22,5 <sup>d</sup>	37,5 <sup>d</sup>	41,25 <sup>cd</sup>	47,5 <sup>cd</sup>	52,5 <sup>c</sup>	55 <sup>c</sup>	55 <sup>c</sup>

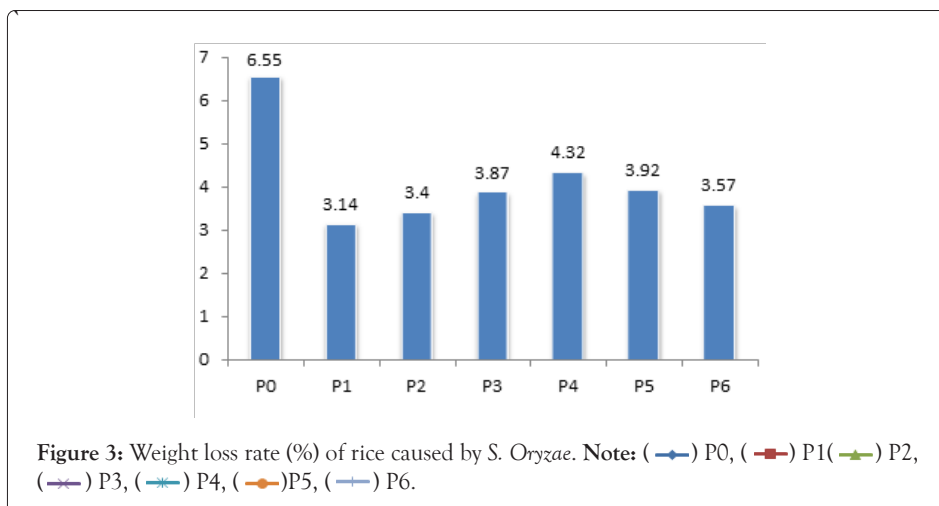
Note: The values followed by the same code are not significantly different in the same column



**Table 3:** Weight loss due to infestation of the *Sitophilus oryzae*.

Treatment	Treatment details	Weight loss (%) in day after application (daa) 30
P0	Control	6,55d
P1	10 g neem	3,14a
P2	2 g pandanus+8 g neem	3,40ab
P3	4 g pandanus+6 g neem	3,87bc
P4	6 g pandanus+4 g neem	4,32c
P5	8 g pandanus+2 g neem	3,92c
P6	10 g pandanus	3,57bc





## DISCUSSION

The results of this study showed that the highest percentage of repellency occurred in the insecticide combination treated with a combination of 8 g of *Pandanus* and 2 g of neem at 61.25% at 8 hours after application and was not significantly different from the treatment of 10 g of *Pandanus*. The percentage of repellency was still greater than the combination of 10 g of *Pandanus* treatment which causes repellent of 56.25%. This phenomenon is following the results of a similar study, that the insecticide combination from the combination of mahogani and neem was 66.67% greater resulting in repellency to *S. oryzae* than without the combination. In addition, the study from [27], state that the combination is carried out to increase the effectiveness of insecticides, including in terms of repellent to *S. oryzae*. Besides, the results of this study are in line with similar research but differ in the basic materials of insecticides, that the highest repellent effect occurs in the first 5 hours after application, such as research from [19], which explains that the fastest repellent effect on *S. oryzae* in just 5 minutes given by waste methanol extract at a concentration of 0.252 mg/cm<sup>2</sup> which resulted in a 63% repellency rate. After 4 hours, the repellency rate on *S. oryzae* was 100%. The results of the study by [3], showed a 98% response effect against *S. oryzae* after 5 hours of exposure to insecticides from caraway essential oil with a concentration of 0.5%. The repellency effect is due to the volatile compounds produced by insecticides so that insects stay away from bio insecticide sources [30]. The insects stay away from insecticide sources due to the volatile compound that produces a distinctive odor so that insects try to save themselves as shown in the results of this study.

The repellency of 10 g of *Pandanus* treatment was the highest at 70% when it entered 10 hours after application. The treatment which consisted of a smaller neem dose in the combination of 8 g pandan and 2 g neem had more high repellency than the larger neem dose combination. This study is different from the results of research by [25], which explain that the higher the dose, the greater the repellency. The results of his research explained that insecticides from the leaf powder of *olax zeylanica* (a rural vegetable in Sri Lanka) at a dose of 1 g and 7 g per 50 g of rice can provide 50% and 96% repellency effect against *S.oryzae* . However, the results of this study are following the results of the study by [3], that the repellent effect of insecticides is not always influenced by the larger the dose is given, it will produce a greater effect, sometimes low doses are more effective in controlling insects than using too high a dose. Based on the result of his research, the repellency effect

of caraway essential oil at a dose of 0.5% and 0.1% was 98% and 100%, respectively. According to [31], this phenomenon is caused by differences in the materials used which contain synergistic or antagonistic compounds, different formulations, and compounds.

The highest repellency in this study occurred in the first 2 hours after the application of insecticide in Figure 1. The information in the Figure 1 showed that *S.oryzae* are quite fast in responding to repellent sources of insecticides. The highest repellency value after 2 hours of application was the combination treatment of 8 g of *Pandanus* and 2 g of neem at 41.25%. This study proved that the use of a combination of insecticide-based materials is better at repellency effect of *S.oryzae* in the first 2 until 8 hours. The ability of the basic materials to be repellent between *Pandanus* and neem, so in this study it was seen to be greater in *Pandanus*. The repellency can be seen in the combination treatment of 8 g of *Pandanus* and 2 g of neem and treatment of 10 g of *pandanus*. The percentage produced is also greater than the 10 g neem treatment which produces a repellency effect at 2 hours after application is only 36.25%. This phenomenon may be due to the content of Terpenoid compounds which produce a stronger repellency effect on *S.oryzae* of *Pandanus* than neem [14,32].

The repellency effect tends to increase due to the increase in a certain time, but in this study, the increase in repellency did not occur after 26 hours of observation. This is following previous research [3,22,25,33], which reported that the repellency of insects of insecticides can still have an effect on 1 until 24 hours after application and after that time the effect will not be too high on repellency. This phenomenon is since insecticides can evaporate over time, thereby reducing their repellency to target insects, which is in this case are *S.oryzae* [34].

The lack of the repellency activity occurred 26 hours after the application of the insecticide in this study. In order the percentages were in the treatment of 10 g of *Pandanus* was 87.5%, a combination of 8 g of *Pandanus* and 2 g of neem was 73.75%, 10 g of neem treatment was 67.5%, the combination of treatment of 6 g of *Pandanus* and 4 g of neem was 58 75%, the treatment combination of 4 g of *Pandanus* and 6 g of neem was 57.5%, the combination of treatment of 2 g of *Pandanus* and 8 g of neem was 53.75%, and control was 17.5%. The interesting thing in this study was that the insecticide is still have repellent after 24 hours although there is less repellency than before 24 hours after application.

In mortality rate, the mortality of *S. oryzae* in this study began to

occur at 3 days after application with the age of *S. oryzae* was 42 days. The highest mortality at 3 days after application occurred in 10 g of neem treatment with a percentage of 27.5%. *S. oryzae* has not experienced mortality at 1 to 2 days after application. This result was different from previous studies, such as [35], in that the *S. oryzae* died in 100% after 72 hours of insecticide application from extracts of materials containing neem. Differences in toxicity that cause mortality may be influenced by differences in the way the insecticides work. Previous studies used contact poison or insecticide mixed with rice which is the food of *S. oryzae* so that the toxicity tends to be faster. The difference in this study was the use of neurotoxins by utilizing the distinctive odor of volatile compounds from insecticides so that the toxicity may tend to be longer in causing mortality in insects.

The phenomenon is because most of the toxic fumigant action of insecticides is made to penetrate the insect's body through the respiratory system or the inhalation system [36]. In addition, the same thing was conveyed by [25], that volatile compounds that evaporate can interfere with the physiological function of insects through the entry of spiracles so that they interfere with breathing and cause death. This is also due to the differential response of insects to insecticides that block octopamine receptors in insect so that they experience interference with their bodies which results in an abnormal respiratory system and causes death [37-39]. Insects that experienced mortality were in a lying position with their legs bent stiffly.

The highest mortality percentage until the last observation in this study was still in the combination treatment of 10 g neem, which was 76.25% at 18 and 21 days after insecticide application, followed by the combination treatment of 2 g *Pandanus* and 8 g neem which had a mortality value of 62.25%, treatment of 10 g of *Pandanus* was 55%, a combination of 4 g of *Pandanus* and 6 g of neem was 51.25%, a combination of 8 g of *Pandanus* and 2 g of neem was 45%, and a combination treatment of 6 g of *Pandanus* and 4 g of neem has a percentage of 43.75%, and 0% control (Figure 2). This result was almost the same as the research by [40], that insecticide with neem as the base material causes 76.10% mortality against *S. oryzae* with a concentration of 0.5% per 100 g of rice. The results of this study may be because the compounds in neem are more deadly to *S. oryzae* (alkaloids, resins) than the compounds in *Pandanus* leaves [41]. Insecticide with neem composition causes higher mortality than pandan or a combination of the both. According to [31], the efficacy of pesticides used depends on the content of compounds that are synergistic or antagonistic, differences in formulation, temperature, and origin of the plant.

Based on the Figure 2, it was known that in addition to control, the effect of insecticides on *S. oryzae*'s mortality will tend to increase from 3 until 18 days after application of insecticide. However, when entering 15 days after application, the increase in effect on mortality tended to be slight and stable. This is different from the previous percentage of repellent effect, that insecticides with more pandan-based ingredients will cause higher repellent than neem, while on insect's mortality effects; insecticides with more neem composition produce higher mortality than *Pandanus* or a combination of both. The insects that died from the insecticides showed stiff bodies with bent legs and the body lying sideways. This may be due to the insecticidal effect exposed. According to [42], that the volatile organosulfur constituents of insecticides can enter through the cuticle or through the spiracles and disrupt gas exchange in respiration or shortness of breath, resulting in death.

This is also due to the differential response of insects to insecticides that block Octopamine receptors in insects so that they experience interference in their bodies which results in an abnormal respiratory system and causes death [37-39]. *S. oryzae* can experience death due to exposure to volatile compounds from the insecticides used.

In weight loss rate due to *S. oryzae*, the results showed that the use of insecticides can reduce the risk of weight loss in rice. Based on the Figure 3, it can be seen that in the control treatment without the use of insecticides had the highest percentage of rice weight loss was 6.55%. This study is following the research of [43], that *S. oryzae* cause 5%-25% weight loss starting from 30 days of it infected rice.

The percentage of rice weight loss depends on the length of time the rice is infested by *S. oryzae*. According to [44], so far no rice is resistant to *S. oryzae*. This is based on the results of his research, that of the 10 types of rice (royale stallion, mama royale, parboiled rice, mama gold, white rice, super eagle, indian rice, champion rice, abakiliki rice, and mama africa) none of them are resistant and permanent, experienced weight loss with an average of 19%. According to [45], also reported on the results of their research that the *S. oryzae* caused a weight loss of 35.4% in wheat for 50 days of infestation. The large weight loss is due to the absence of special treatment for *S. oryzae*, such as the use of pesticides to control them.

The percentage of rice weight loss was quite different between the controls and those treated with insecticide. The lowest percentage of rice weight loss was in the treatment of 10 g of neem (P1) which only experienced a weight loss of 3.14%. The decreasing weight loss of rice indicates that the material or insecticide used is effective. This is because great insecticides affect appetite, disrupt metabolism, and block pest spiracles, causing pests to die [46]. The high insect's mortality will cause a small risk of rice weight loss. Based on the results of this study, if sorted from the treatment that caused weight loss from the least to the most, namely the treatment of 10 g neem was 3,14%, the combination of 2 g of *Pandanus* and 8 g of neem was 3,40%, treatment of 10 g pandan neem resulted in a weight loss of 3,57%, the combination of 4 g of *Pandanus* and 6 g of neem was 3.87%, the combination of 8 g of *Pandanus* and 2 g of neem was 3,92%, and the combination of 6 g of *Pandanus* and 4 g of neem was 4,32%.

The different effectiveness is caused by differences in the composition of the insecticide used [31]. The results of this study provided information that the effect of the compounds contained in neem is better in terms of preserving rice as evidenced by the least of weight loss than in *Pandanus*, a mixture of both, and controls. According to [41,47,48], neem has alkaloid and resin compounds that give a more lethal effect on *S. oryzae* than the terpenoid content contained in *Pandanus* leaves.

## CONCLUSION

Based on the results of research that had been carried out, the best treatment in terms of causing repellent was the treatment of 10 grams of *Pandanus* with a percentage of 87.5%, while the best treatment in terms of causing mortality and reducing the risk of rice weight loss due to *S. oryzae* was the treatment of 10 grams of neem with a mortality percentage of 76.25 and weight loss of rice was 3.14%. The results of this research still need to be continued by other researchers by separating pure compounds from *pandanus* and neem leaves and formulating them in gas form so that they will become new products in the form of biodegradable fumigants. All

of these efforts are expected to help reduce the risk of rice damage caused by *S. oryzae*.

## ACKNOWLEDGEMENT

The authors are thankful to the Department of Plant Protection, University of Jember, and the entire faculty for providing necessary facilities for conducting the investigation and valuable suggestions during the course of the investigation.

## CONFLICT OF INTEREST

The authors declare that they have no competing interests.

## REFERENCES

- Sawicka B. Post-harvest losses of agricultural produce. Spri Nat Swi. 2019; 1: 1-16.
- Akhtar M, Raza AM, Iram N, Chaudhry MI, Azeem W. Effect of infestation of *Sitophilus oryzae* L.(Coleoptera: Curculionidae) on protein quality of rice under storage conditions. Int J Agric Appl Sci. 2015;7(1): 43-45.
- Klys M, Izdebska A, Malejky-Klusek N. Repellent of the caraway carum carvi l. on the rice weevil *Sitophilus oryzae* L. (Coleoptera, Dryophthoridae). Insects 2020;836: 1-11.
- Park IK, Lee SG, Choi DH, Park JD, Ahn YJ. Insecticidal activities of constituents identified in the essential oil from leaves of *Chamaecyparis obtusa* against *Callosobruchus chinensis* (L.) and *Sitophilus oryzae* (L.). J Stored Prod Res.. 2003;39(4): 375-384.
- Fox, T. Global Food: Waste Not, Want Not; Institution of Mechanical Engineers: London, UK, 2013; pp. 1-31.
- Nattudurai G, Irudayaraj SS, Paulraj MG, Baskar K, Ignacimuthu S. Insecticidal and repellent activities of *Toddalia asiatica* (L.) Lam. extracts against three major stored product pests. Entomol, Ornithol & Herpetol. 2015;4(2): 1.
- Nawrot J, Harmatha J. Phytochemical feeding deterrents for stored product insect pests. Phytochemistry reviews. 2012;11(4):543-566.
- Phillips TW, Throne JE. Biorational approaches to managing stored-product insects. Annu Rev Entomol. 2010;55:375-397.
- Lengai GM, Muthomi JW, Mbega ER. Phytochemical activity and role of botanical pesticides in pest management for sustainable agricultural crop production. Scientific African. 2020;7:e00239.
- Sande D, Mullen J, Wetzstein M, Houston J. Environmental impacts from pesticide use: a case study of soil fumigation in Florida tomato production. Int J Environ Res public health. 2011;8(12):4649-4661.
- Wimalawansa SA, Wimalawansa SJ. Agrochemical-related environmental pollution: effects on human health. Glob j biol agric health sci. 2014;3(3):72-83.
- Zettler JL, Arthur FH. Chemical control of stored product insects with fumigants and residual treatments. Crop Protection. 2000;19(10):577-582.
- Kim B, Song JE, Park JS, Park Y, Shin EM, Yang J. Insecticidal effects of fumigants (EF, MB, and PH3) towards phosphine-susceptible and-resistant *Sitophilus oryzae* (Coleoptera: Curculionidae). Insects. 2019;10(10): 327.
- Girish K, Shankara BS. Neem—a green treasure. Electronic journal of Biology. 2008;4(3):102-111.
- Lopez DC, Nonato MG. Alkaloids from *Pandanus amaryllifolius* collected from Marikina, Philippines. Philippine Journal of Science. 2005 ;134(1):39.
- Faras AF, Wadkar SS, Ghosh JS. Effect of leaf extract of *Pandanus amaryllifolius* (Roxb.) on growth of *Escherichia coli* and *Micrococcus* (*Staphylococcus*) *aureus*. Int Food Res. 2014;21(1): 421.
- Md Akhir R, Umbaidillah SZ, Abdullah NA, Alrokayan SA, Khan HA, Soga T, Rusop M, Khusaimi Z. The potential of *pandanus amaryllifolius* leaves extract in fabrication of dense and uniform ZnO microrods. Micromachines.2020;11(3):299.
- Ahmad W, Singh S, Kumar S. Phytochemical screening and antimicrobial study of *Euphorbia hirta* extracts. J Med Plants Stud. 2017;5: 183-186.
- Auamcharoen W, Chandrapatya A, Kijjoa A, Kainoh Y. Toxicity and repellency activities of the crude methanol extract of *Duabanga grandiflora* (Lythraceae) against *Sitophilus oryzae* (Coleoptera: Curculionidae). J Zool. 2012;44(1).
- Yankanchi SR, Jadhav AD, Patil PM. Insecticidal and repellent activities of *Clerodendrum serratum* L. leaf extract against rice weevil, *Sitophilus oryzae* L. Asian J Exp Biol Sci.2014;3(1):35-39.
- Aref SP, Valizadegan O. Fumigant toxicity and repellent effect of three Iranian Eucalyptus species against the lesser grain beetle, *Rhyzopertha dominica* (F.)(Col.: Bostrichidae). J Entomol Zool Stud. 2015;3(2):198-202.
- Das S, Rayhan MZ, Kamal MM, Sarkar R, Gharami RK, Adhikary SK. Assessment of toxic and repellent effect of natural bio pesticides on rice weevil (*Sitophilus Oryzae* L.). J Agr Vet Sci.. 2015;8:16-23.
- Khyš M, Malejky N, Nowak-Chmura M. The repellent effect of plants and their active substances against the beetle storage pests. J Stored Prod Res. 2017;74:66-77.
- KH EK, El-Shewy AM, Morsy AR. Evaluation of Essential Oil and its Main Active Ingredients of Chinese *Litsea cubeba* Against Two Stored-Grain Insects. Academic Journal of Entomology. 2019;12(2): 29-39.
- Fernando HS, Karunaratne MM. Mella (*Ola x zeylanica*) Leaves as an Eco-friendly Repellent for Storage Insect Pest Management. Journal of Tropical Forestry and Environment. 2013;3(1).
- Wilhelm G, Handschuh S, Plant J, Nemeschkal HL. Sexual dimorphism in head structures of the weevil *Rhopalapion longirostre* (Olivier 1807) (Coleoptera: Curculionoidea): a response to ecological demands of egg deposition. Biol J Linn Soc. 2011 ;104(3):642-660.
- Abdelatti ZA, Hartbauer M. Plant oil mixtures as a novel botanical pesticide to control gregarious locusts. J Pest Sci. 2020;93(1): 341-353.
- Mehta V, Kumar S. Influence of different plant powders as grain protectants on *Sitophilus oryzae* (L.)(Coleoptera: Curculionidae) in stored wheat. J Food Prot.. 2020;83(12): 2167-2172.
- Sokal etF RR, Rohlf J. Biometry. The Principles and Practice of Statistics in Biological Research". 887p.
- Hamza AF, El-Orabi MN, Gharieb OH, El-Saeedy AH, Hussein AR. Response of *Sitophilus granarius* L. to fumigant toxicity of some plant volatile oils. J Radiat Res Appl Sci. 2016;9(1): 8-14.
- Dhakshinamoorthy G, Selvanarayanan V. Evaluation of certain natural products against pulse beetle, *Callosobruchus maculatus* (Fab.) infesting stored green gram. Insect Environment. 2002;8(1): 29-30.
- Nerio LS, Olivero-Verbel J, Stashenko E. Repellent activity of essential oils: a review. Bioresour Technol. 2010;101(1):372-378.
- Abteu A, Subramanian S, Cheseto X, Kreiter S, Garzia GT, Martin T. Repellency of plant extracts against the legume flower thrips *Megalurothrips sjostedti* (Thysanoptera: Thripidae). Insects. 2015;6(3): 608-625.
- Suteu D, Rusu L, Zaharia C, Badeanu M, Daraban GM. Challenge of utilization vegetal extracts as natural plant protection products. Applied Sciences. 2020;10(24):8913.

35. Akter A, Talukder S, Tahmina A, Munjuri A, Mohammad JU. Assessment of neem products for management of rice weevil (*Sitophilus oryzae* L.) in stored rice grain. *Int Jou of Res & Rev.* 2015; 2: 543-545.
36. Rani S, Gailce LJ, Sheeba JR. Evaluation of plant extracts against rice weevil, *Sitophilus oryzae* (Coleoptera: Curculionidae) in stored sorghum seeds. *The Phar Inn Journal.* 2019;8: 154-159.
37. Enan EE. Molecular and pharmacological analysis of an octopamine receptor from American cockroach and fruit fly in response to plant essential oils. *Arch Insect Biochem Physiol.* 2005;59(3):161-171.
38. Kostyukovsky M, Rafaeli A, Gileadi C, Demchenko N, Shaaya E. Activation of octopaminergic receptors by essential oil constituents isolated from aromatic plants: possible mode of action against insect pests. *Pest Manag Sci.* 2002;58(11): 1101-1106.
39. Priestley CM, Burgess IF, Williamson EM. Lethality of essential oil constituents towards the human louse, *Pediculus humanus*, and its eggs. *Fitoterapia.* 2006;77(4):303-309.
40. Singh BK. Study on the life cycle of *Sitophilus Oryzae* on rice cultivar Pusa 2-21 in laboratory condition. *Int J Educ Res.* 2017;4(2):37-42.
41. Shannag HK, Capinera JL, Freihat NM. Effects of neem-based insecticides on consumption and utilization of food in larvae of *Spodoptera eridania* (Lepidoptera: Noctuidae). *Int J Insect Sci.* 2015;15(1):152.
42. Dhar R, Dawar H, Garg S, Basir SF, Talwar GP. Effect of volatiles from neem and other natural products on gonotrophic cycle and oviposition of *Anopheles stephensi* and *An. culicifacies* (Diptera: Culicidae). *J Med Entomol.* 1996;33(2): 195-201.
43. Prakash A, Rao J. Insect pest management in stored-rice ecosystems. *Stored-grain ecosystems.* 1995:709-736.
44. Okpile C, Zakka U, Nwosu LC. Susceptibility of ten rice brands to weevil, *Sitophilus oryzae* L. (Coleoptera: Curculionidae), and their influence on the insect and infestation rate. *Bull Natl Res Cent.* 2021;45(1): 1-10.
45. Gvozdenc S, Tanasković S, Vukajlović F, Prvulović D, Ovuka J, Viacki V, et al. Host and ovipositional preference of rice weevil (*Sitophilus oryzae*) depending on feeding experience. *Appl Ecol Environ Res.* 2020;18(5):6663-6673.
46. Sokker RF, Hussein MA, Ahmed S, Hamed RK. Effect of katel-sous dust and clove powder and their mixtures on the cowpea seed beetle, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). *Egypt Acad J Biol Sci.* 2012 ;4(1):23-33.
47. Flower Thrips *Megalurothrips sjostedti* (Thysanoptera: Thripidae). *Insects* 2015; 6: 609-625.
48. Peter KV. *Handbook of Herbs and Spices: Volume 3.* Woodhead publishing; 2006;453-459.