IMPROVING PEST CONTROL: RATS IN THE RICE FIELDS

EXPERIMENT RESULTS

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KOPERNIK

SUMMARY

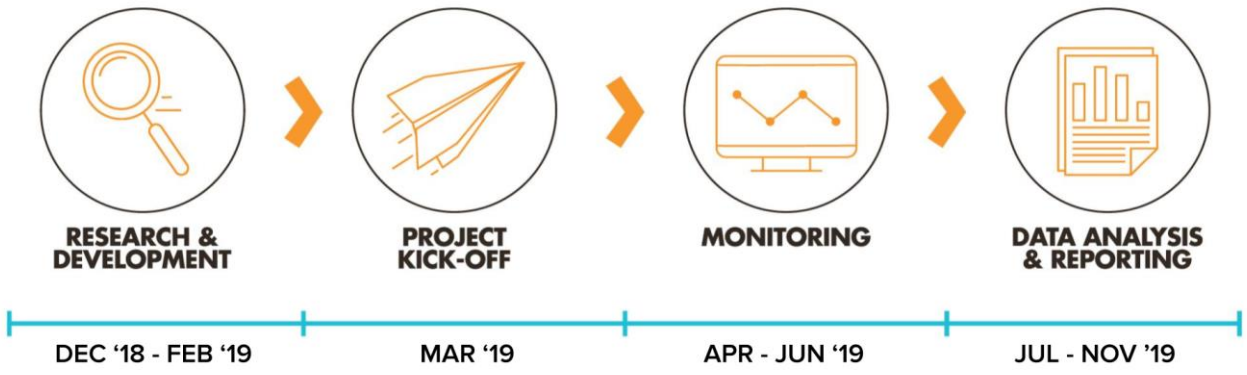
Rats have been identified as the most persistent pest for rice crops in Indonesia. Rats eat and damage rice during both the pre-harvest and post-harvest stages, causing crop losses amongst farmers In Indonesia of up to 17 percent.[1] The current rat control methods in Indonesia which include the use of rat poison (rodenticide), fumigation or smoking, or community-organized rat hunts (*gerobyokan tikus*) are still seen as unsatisfactory as rats have developed a resistance to these products and methods. Therefore, there is still a need for alternative ways to reduce rats damaging the rice field.

In collaboration with Forgotten Flavours, we created a homemade rat repellent using natural ingredients. The rat repellent is more ecological as it does not contain poisonous substances. We tested the efficiency of natural rodenticide (treatment group) compared to the common method with chemical rodenticide (control group) by measuring the stem damage and crop yield.

The results showed that:

- The natural rat repellent showed promise in reducing rat infestation, with 35 stems found to have been damaged in the treatment group as compared to 67 stems that had been damaged in the control group;
- The lower stem damage in the treatment group did not result directly to the higher crop yield in the group. The crop yield in the treatment group was 28 percent lower (175 kg) than the control group (244 kg) because the plants experienced rice blast disease and were left untreated.
- Compared to the total expense of all chemical treatments (IDR628,000 or US$44.63), the natural repellent (IDR196,900 or US$13.99) is 69 percent cheaper. However, when compared to the cost of only the chemical rodenticide (IDR45,000 or US$3.20), the cost of natural repellent is 77 percent higher.

TIMELINE



[1] International Rice Research Institute. (2003). *Impact of Rodents on rice production in Asia*.

CONTEXT

Rat outbreaks are one of the major constraints for achieving food security in Southeast Asia. In Indonesia, rats cause losses of 17 percent of the total rice production in the country.[2] Considering the total rice production in 2018 (34.42 million tonnes)[3], rat outbreaks contributed to 5.51 million tonnes of rice losses, which would be enough to feed 49.3 million people for a year.[4]

The current rat control methods in Indonesia primarily rely on chemical rodenticide, followed by fumigation or smoking and community-organized rat hunts (*gerobyokan tikus*). The efficiency and effectiveness of these methods are not optimal in reducing rat attacks due to farmers' limited knowledge in the rat's specific environment, living habits and the appropriate timing of these interventions.

In 2018, Kopernik conducted Unmet Needs research to identify the needs and challenges faced by smallholder farmers in Papua, West Papua, and West Kalimantan. The study found that among four main commodities (palm, rubber, rice, and coconut) in West Kalimantan, rice smallholder farmers had the lowest income of the four commodities due to low yields. Farmers reported that harmful pests were tough to exterminate, causing farmers to use large quantities of chemical rodenticide (more than typically required) which negatively affected their crops, the soil and the water supply. They also said that the rodenticide was often ineffective due to the resistance that the rats had developed to the products.

In collaboration with Forgotten Flavours, we created a homemade rat repellent using natural ingredients. This experiment adopts a simple solution using natural ingredients to create natural rat repellent which was successfully implemented and widely applied in India.

In this experiment, we test the efficiency of natural rodenticide compared to the common method of using chemical rodenticide by measuring the stem damage and crop yield.

HYPOTHESIS

We hypothesized that by using natural rat repellent for a rice plantation, we will reduce the damage caused by rats, resulting in an increase in crop yield.

[2] Singleton, Grant (2003). Impact of Rodents on rice production in Asia. *IRRI Discussion Paper Series No. 45*, 30 pp, Los Baños, Philippines

[3] BPS Statistics Indonesia (2018). Executive Summary: 2018 Harvested Area and Rice Production in Indonesia. *BPS Statistics Indonesia Publication*.

[4] Based on BPS Statistics Indonesia data, the average rice consumption per capita in 2017 for Indonesian people was 111.58 kg / per capita / year

METHODOLOGY

Kopernik rapidly tests innovative solutions in order to determine their potential to reduce poverty effectively. In these experiments, Kopernik adopts a lean approach, collecting and analyzing small-scale data to learn about the effectiveness of the solutions.

Experiment location

This experiment took place in Sanggau district, West Kalimantan province, Indonesia. We tested the solution on a rice field owned by the local agricultural bureau and managed mainly by smallholder farmers.

Experiment design

The growth cycle of rice plants begins with sowing of the seeds, which is followed by tillering four to five weeks (28 to 35 days) later. In this study, we transplanted the seeds on week 3, and waited until five weeks before we applied the natural repellent. We then applied the treatment as the rice almost reached the panicle initiation stage (week 8) or when the stem began to grow more tillers. This is also the time that the rats typically start to arrive. The treatment ended in week 15, when the rice plants were almost ready to harvest (Figure 1).

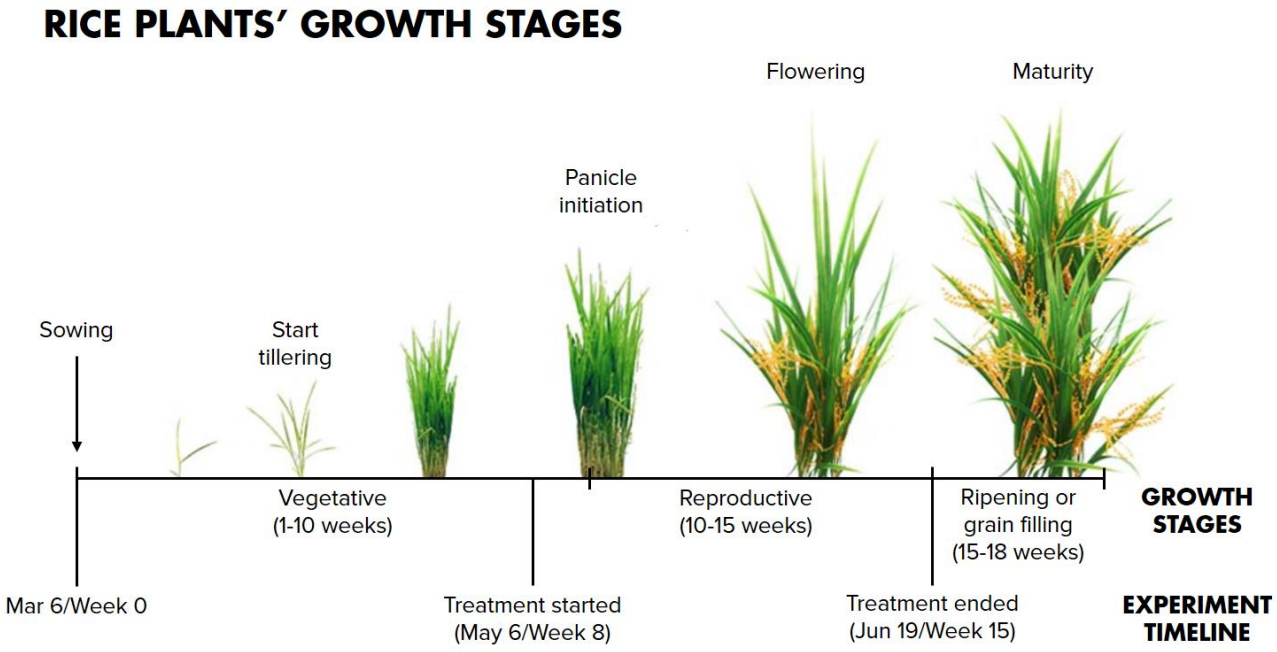


Figure 1: The growth stages of rice plants and experiment timeline

To be able to observe the difference between the homemade natural rat repellent and the chemical rodenticide currently used by farmers, we divided the land and differentiated the treatment in each group as follows:

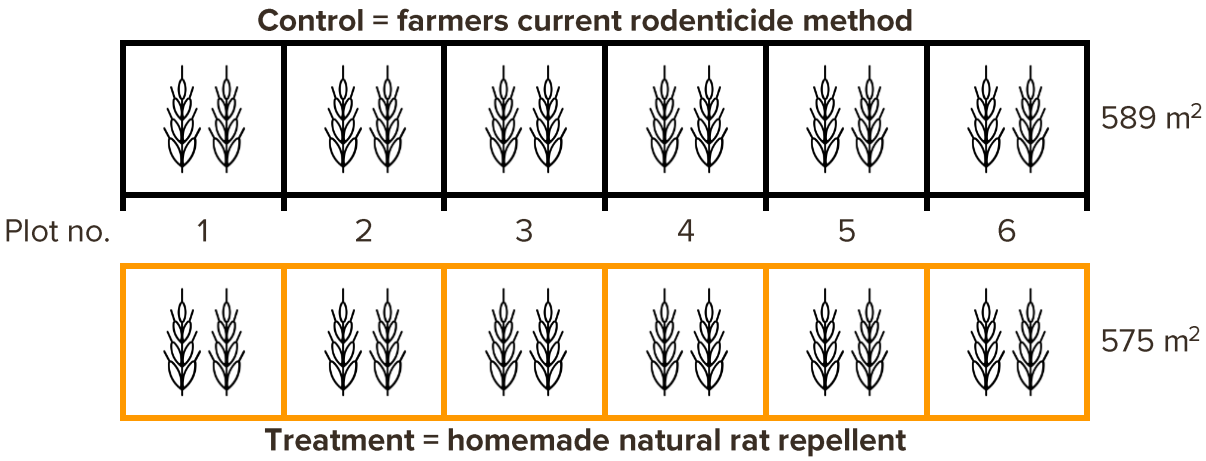


Figure 2: Experiment setup and treatment for the two groups

- **Control group**
  The rice plants in this group were treated with the chemical rodenticide that is commonly used by farmers. This product contains Brodifacoum, one of the most widely used pesticides globally. The farmer also continued his typical treatment by applying chemical fungicide, insecticide in line with his usual practice.

- **Treatment group**
  The rice plants in this group were treated with the homemade natural rat repellent. To create the repellent, we fermented locally available herbs that are known to have repellent properties such as ginger, chili, peppermint leaf and papaya leaf. We combined these with EM4 bacteria and palm sugar. The natural repellent was then diluted in water before application by spraying, with a ratio of 100ml of natural repellent per 10L of water per plot. The plot was sprayed twice per week for seven weeks.

Figure 3: Natural repellent ingredients (left); Fermentation process (right)

A detailed breakdown of the products used in the control group as well as the ingredients and instructions for the natural repellent can be found in Appendix 1.

From week eight (five weeks after rice transplanting) until week 15 (the end of the treatment), we measured the following across both the treatment and control groups:

- Mean stem damage, to identify the presence of rats;
- The presence of other pests;
- Crop yields.

FINDINGS

Stem Damage

Rats mostly eat the panicle of rice plants at the flowering stage and the grain when plants reach maturity. They normally feed at night with high activity at dusk and dawn. The damage caused by rats can be observed in many ways such as irregular cuts in stems, missing grains, missing panicles, tillers cut near their base at a 45 degree angle, delayed grain maturity, and missing plants.[5]

In this experiment, we measured the stem damage caused by rats, specifically by visual observation of the irregular cuts in stems and tillers that were cut near their base at a 45-degree angle. These aspects are defined by the farmers as the main characteristics of rice plants that have been damaged by rats in the area. We observed the stem damage twice per week to monitor the rats' activity throughout the experiment period.

From our seven-week observation, we found that the stem damage caused by rats in the treatment group was lower than in the control group. In fact, we saw hardly any stem damage by rats in the treatment group during the first three weeks of the experiment. As the panicle initiation stage started, the rat activity in both groups began to increase, with the control group experiencing more plant damage as compared to the treatment group. In total, the stem damage caused by rats in the control group was observed in 67 plants, which was more than twice the total damage observed in the treatment group (35 plants).

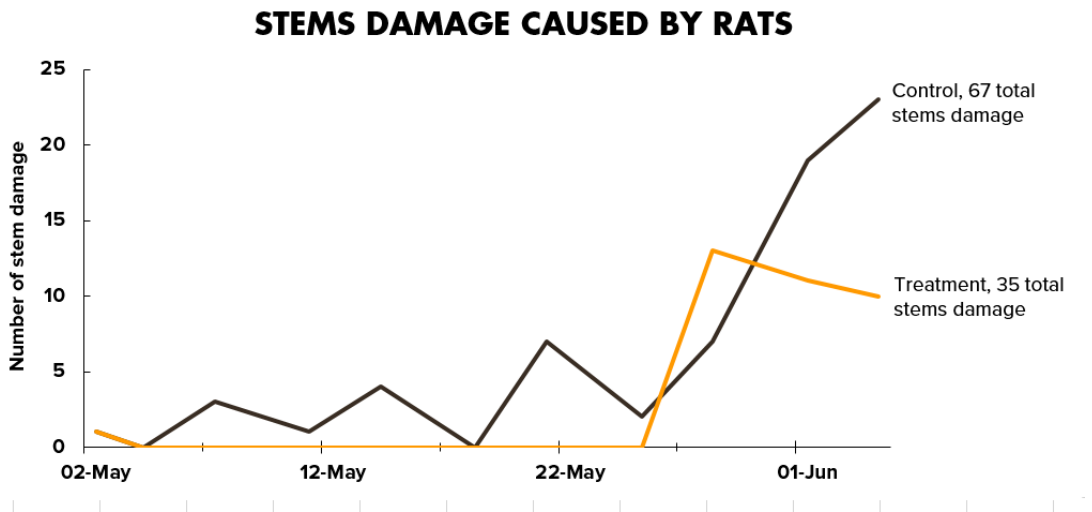


Figure 4: Number of plants with stem damage caused by rats during the experiment period

[5]Alex Stuart and G.R Singleton (2016). Rats. *IRRI Rice Knowledge Data Bank.* March 2016

The result shows promise that the natural repellent is effective as observed by the presence of less stem damage found in the treatment group (natural repellent) as compared to the control group (chemical rodenticide) during the tilering until flowering stage (week 8-13). This means that if the farmers continue to use the natural repellent, they could potentially reduce the amount of stem damage by rats.

Unfortunately, our study was compromised at the full maturity stage (week 16-17) when the farmer unintentionally put chemical rodenticide on the treatment group (which was supposed to only be treated with the natural repellent). Therefore, we do not know the effectiveness of the natural repellent at the full maturity stage and we have removed the data collected at full maturity period due to the study being compromised at week 16.

Besides the stem damage caused by rats, we also observed damage caused by other pests such as rice caterpillars, rice bugs (*Leptocorisa acuta*), and birds. According to farmers, these are the most common rice pests in Sanggau, West Kalimantan, the location of this experiment. We found that while the stem damage caused by rats is lower in the treatment group, the damage caused by other pests is similar across both the treatment group (275 stems damaged) and the control group (278 stems damaged). The main damage found was as a result of rice caterpillars.

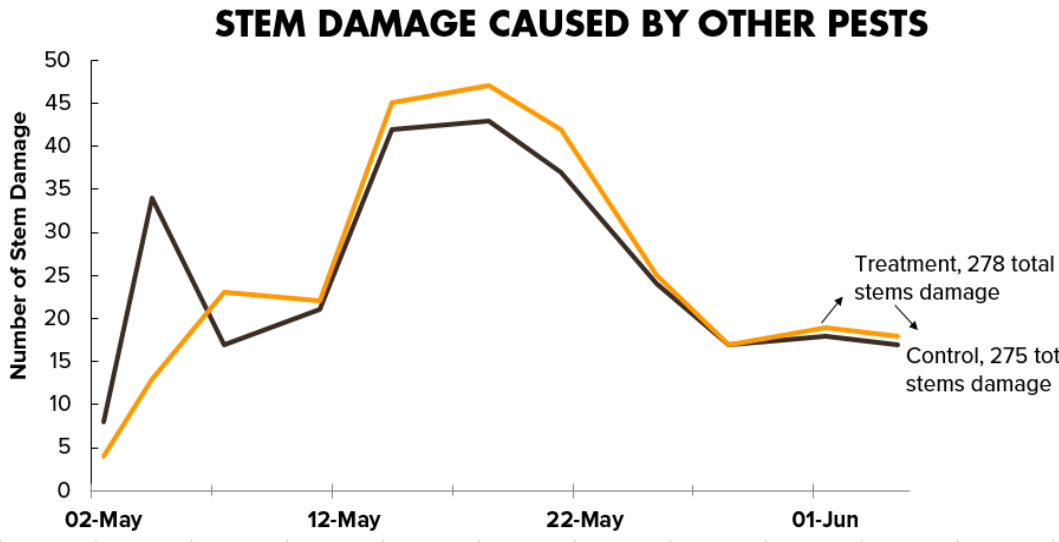


Figure 5: Stem damage caused by other pests during the experiment period

Final Yield

On week 16, we visited the location to harvest the rice plants and to calculate the final yield by measuring the weight of the rice husks in both groups. We found that the total yield in the control group (chemical rodenticide) was 28 percent higher than the treatment group (natural repellent), with the control group yielding 244 kg, while the treatment group yielded 175 kg (Figure 6).

To check the yield of other farmers with the same size of land, we interviewed three other farmers and found that the average yield for a similar size of land (580 m^2) ranges between 174 kg and 348 kg.

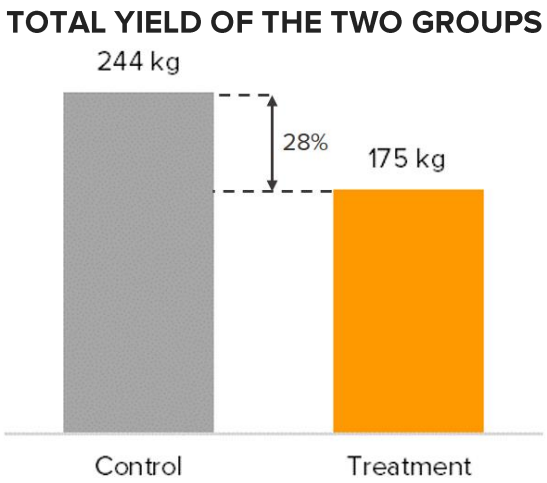


Figure 6: Comparison of the total agricultural yield between control and treatment group

We found that there were a number of other contributing factors that we were not able to control and directly affected the final yield. In this experiment, our farmers reported that the rice plants in both groups experienced rice blast disease. Rice blast is a disease caused by the fungus *Magnaporthe oryzae* and is considered as the worst disease of rice worldwide because of its extensive coverage and destructiveness (Department of Agriculture and Food, Western Australia). The disease can affect all aboveground parts of a rice plant: leaf, collar node, neck, parts of panicle, and sometimes leaf sheath (IRRI).

Figure 8: Rice Blast Disease. Photo Credit: IRRI Knowledge Bank

A severe blast infection reduces leaf area for grain fill and typically reduces crops yield. While the plants in the control group were treated by the common method used by farmers - by using chemical fungicide, the plants in the treatment group were left untreated. This may be the reason why the yield in the treatment group was lower compared to the control group.

Cost Comparison of the Two Treatments

During the rice growing stage, the farmers in the control group reported that they use five different types of products including insecticides, fertilizers, rodenticide, fungicide and growth stimulant. The total expense for these products used during the experiment was IDR628,000 (US$44.63)[6], comprised of the following:

[6] Exchange rate US$1 = IDR14,072 on 15 November 2019

No	Product	Price (IDR)
1	Insecticide A	60,000
2	Insecticide B	45,000
3	Insecticide C	100,000
4	Fertilizer D	125,000
5	Fertilizer E	85,000
6	Rodenticide F	45,000
7	Fungicide G	90,000
8	Growth stimulant H	78,000
Total price (IDR)		**628,000**

Figure 8: Products used and their prices during the rice growing stage in the control group

In the treatment group, we calculated the cost of making the natural repellent and found that the cost of making the natural repellent was IDR196,900 or US$13.99 (Figure 9). This calculation does not take into account the farmers' time and energy to make the repellent. The laborious process of making the repellent could be a potential barrier for farmers in adopting this solution as an alternative to chemical treatments.

Compared to the cost of only the chemical rodenticide (IDR45,000 or US$3.20), the cost of natural repellent is 77 percent higher. However, when compared to the total expense of all chemical treatments (including those to fight other pests), the natural repellent is 69 percent cheaper.

Table 2: Ingredients used and the total expense in the treatment group

No	Ingredients*	Quantity	Price (IDR)	Remark
1	Ginger	200gr	4,800	Required
2	Garlic	200gr	6,000	Required
3	Chili	200gr	14,000	Required
4	Peppermint leaf	200gr	42,000	Optional
5	Papaya leaf	200gr	from wild plant	Required
6	Castor seed	200gr	from wild plant	Optional
7	Tulsi leaf	200gr	from wild plant	Optional
8	Marigold flower	200gr	3,600	Optional
9	Palm sugar	1,000gr	20,000	Required, can be replaced with any types of sugar/molasses available
10	EM4	1liter	30,000	Required, can be replaced with other natural microorganism available

11	Jerry can, hose, air valve	1 pieces	76,500	Air valve is to allow constant release of CO_2 produced during fermentation
Total Price			**IDR196,900**	

*Some of the ingredients can be replaced with other plants that are available in the area such as cloves, tobacco, neem, lemongrass. More information on certain plants as effective repellents can be found in Appendix 3.

CONCLUSION

This experiment showed that the natural rat repellent shows promise in reducing rat infestation in rice plantations as measured by a lower number of damaged stems in the treatment group compared to the control group that used chemical rodenticide. We found that the treatment group had 35 stems that were damaged, while the control group had 67 damaged stems.

The lower stem damage in the treatment group however did not result in a higher crop yield. In fact, the crop yield in the treatment group was 28 percent lower (175 kg) than the control group (244 kg). This difference was due to the presence of other pests which contributed to a reduction in yield, as well as the presence of the rice blast disease which occurred in both the treatment and control groups. While the farmers treated the control group with fungicide to treat the disease, the plants in the treatment group were untreated, contributing to the lower yield in this group.

Compared to the total expense of all chemical treatments (IDR628,000 US$44.63), the natural repellent is 69 percent cheaper. However, when compared to the cost of only chemical rodenticide (IDR45,000 or US$3.20), the cost of natural repellent (IDR196,900 or US$13.99) is 77 percent higher.

TESTIMONIAL

“I like the natural repellent solution as it comes from natural material and is cheaper than the conventional product we use. My candid observation shows that a lot of insects died directly after I sprayed the liquid on the plant. However, I sometimes felt that my hand was hot during the spraying application.” Pak Udin, Farmer

RECOMMENDATION

Based on the results of this experiment, Kopernik recommends to develop a more extensive natural treatment formula that repels not only rats but also other pests. If found to be effective, then we can explore a business model for people to make and sell this product to make it more widely available.

Appendix 1: Making the rat repellent

- **Ingredients and tools** per 20 L of water:
  - Airtight container with a one-way air valve to avoid gas buildup
  - 1 L of EM4
  - 1 kg of jaggery or palm sugar
  - Plants and fruits (250 g each):
    - Ginger
    - Garlic
    - Chili and/or pepper
    - Peppermint*
    - Papaya leaf
    - Maja (*Aegle marmelos*)*
    - Tulsi/holy basil*
    - Marigold flower*
    - Castor (*Ricinus communis)**

*optional, could be replaced by locally available materials

- **Steps:**
  1. Roughly chop plants and fruits
  2. Fill jerry can with water, jaggery/palm sugar and EM4, then shake
  3. Fill jerry can with plants and fruits that has been roughly chopped
  4. Ferment the natural repellent until the bubbling stops (15-30 days, depending upon temperature)
  5. Check the pH of the natural repellent. The product is stable and ready to use when its pH reaches 3.5
  6. Store the natural rodenticide in cool, dry place and avoid sunlight

- **Side note:** The product should be stable for up to 12 months when pH is at 3.5

Appendix 2: Application of the repellent

- Dilution rate: 100 ml of extract solution diluted in 10 liters of water.
- We aim to spray the rat repellent:
  - Onto the plant from above adequately so that the liquid will run down to the bottom part (spray to run off)
  - Onto the open soil between the rice plants. For a 250 m^2 rice plot, around 10 liters would be required (during the initial stage growth) to 20 litres (during the later stage growth) of rat repellent per application. To be consistent, we used 20 liters during the growth stage. Since the rat repellent is also a bio fertilizer, over-using it will not endanger the crop health.
- The rat repellent should be applied twice a week, for a period of 60 days. This will mean 18 applications of 20 milliliters extract solution per application.

18 x 200 ml = 3600 ml = 3.6 liter of extract solution

- The rice seeds sprayed by the natural repellent are safe for human consumption, even if the rice seed itself was sprayed directly. However, the rice husk comprises a double layer of silica and is waterproof, thus the liquid will not directly reach the seed.

Appendix 3: Ingredients of repellent and their toxicity

No	Plant	Plant Part	Toxicity/repellency
1	Garlic	Root/Bulb	Garlic has been long-recognized as a bactericide due to the effects of a variety of sulfur-containing compounds with strong biological activity (link). In a study by Bogor Agricultural Institute, garlic was found to have a 65% repellency level to rats (link).
2	Chili (small)	Fruit and Seeds	Capsaicinoids found in chili, including the chemical capsaicin, are the irritant ingredients responsible for the “hot” quality of peppers (link).
3	Castor (*Ricinus communis*)	Leaf and Beans	Castor beans contain a poisonous substance named Ricin. LD_{50} of ricin for mice were reported as 21.5 mg/kg and 30 mg/kg body weight through oral uptake (link)
4	Maja	Leaf	Toxic in high dosage, including for rats (link)
5	Castor (*Jatropha curcas*)	Seeds	Highly toxic for rats (link)