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Plant-based pesticide using citronella (*Cymbopogon nardus* L.) extract to control insect pests on rice plants

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Abstract. The main enemy in rice production is the attack of stinky bugs, brown planthoppers, grasshoppers, ladybugs, aphids, and others. This attack inhibits the growth of rice plants, thereby reducing production or even thwarting the harvest. Chemical pesticide application can reduce pests and diseases. However, the long-term use of chemical pesticides can disrupt the ecosystem. This study aims to study the application of plant-based pesticides to the presence of pests and predatory insects for rice plants. The research was begun with the preparation of citronella-based pesticide from citronella extract obtained by mixing citronella with water at a weight ratio of 2:1. The extract was mixed with water at a ratio of 1 liter for 50 ml of citronella extract. The application of the prepared pesticide was carried out by spraying 21-DAP (day after planting) rice plants at two plots sizing 400 m² each. The types and numbers of pests and predatory insects were observed before every pesticide application. Spraying was repeated weekly for the following 4 weeks. Results showed a decrease of insects in experimental plots A and B after the application of pesticides. After the fourth application, only one type of insect (green grasshopper) was found in plot A, and no insect was found in plot B. However, four types of insects were found in the control plot. The application of citronella-based pesticides is also related to the decrease of predatory insects' population.

1. Introduction

Rice is the main food crop to produce white rice, which is the Indonesian people's staple food. However, Indonesia still routinely imports rice from Thailand, Vietnam, and the Philippines to meet national rice needs. This is due to the low productivity of Indonesia's rice plants. One of the threats that threaten rice farmers is the pests' attack, especially insects or plant diseases. Pest/disease attacks are a common condition in rice cultivation. Pests and diseases can cause total harvesting failure. Insect pests use rice plants as a place to breed or a source of food by sucking nutrients from plant tissues, making holes in plants, damaging leaves, and so on. Some insect pests that stick to plants also carry diseases, so that the plants grow unoptimally [1-5].

In general, plant pest control is carried out by using chemical pesticides. However, the application of chemical pesticides in crop cultivation has an adverse impact on the surrounding environment. The prolonged and excessive use of chemicals increases resistance of insect pests such that chemical pesticides have little effect on pest control. In addition, application of chemical pesticides also disrupts the surrounding ecosystem [1, 6]. For example, chemical pesticides kill not only insect pests, but also predatory insects which are useful in insect pest control. Chemical pesticides also contaminate the soil, affecting their texture and ability to hold water, and inhibit the development of decomposer



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microorganisms [6-9]. This certainly affects the availability of nitrogen and other nutrients in the soil. For that reason, a solution is needed to overcome the problem of insect pests in rice plants which is able to sustainably prevent environmental damage. The use of plant-based pesticides is one of the solutions in controlling plant pests. The content of plant-based pesticides is not desired by insect pests. The results of research in 2008 demonstrated that plant-based pesticides inhibited the growth of insect pests and pathogens [10].

One of the popular plants that is easy to cultivate and can be used as a pesticide is citronella (*Cymbopogon nardus* L.). This plant contains citronellol which causes a distinctive odor and is disliked by insect pests. This odor can irritate and reduce the destructive power of insect pests to plant tissue. The research state that extract of citronella leaves at a concentration of 8.5% can cause a mortality of 66.67% and inhibits the eating activity of larvae by 82.66% [11]. Other study stated that the use of citronella and cloves extracts cause pest mortality more than 50% with average efficacy of 89.29% and the loss of pepper fruit yield decreased to 4.1% [12]. The other study found that citronella extract at a concentration of 0.2% caused 91.62% mortality of *Helopeltis antonii* by six hours after application [13]. A study found that citronella leaf extract can suppress larvae appetite, inhibit pupa and imago development, and interfere the imago's reproductive system in cabbage cultivation [14]. The citronella contains monoterpenes (citronellal, limonene and geraniol) which provide plant defense from pests [15]. Field experiment showed that treatment of citronella oil at 2.0 mL/L significantly reduced fruit damage by *T. armigera* similar to the plots treated with spinosad at 0.06 kg ai/ha. Another study found that citronella oil application on chili pepper significantly decreased fruit damage by 72% [16].

The use of pesticides made from lemongrass is also able to reduce the population of insects that interfere with humans such as flies, cockroaches, fleas, and others [17,18]. This impact will inhibit the development of insect pests. Another study on non-chemical pest control was conducted using automatic insect pest trap [19,20]. The use of citronella extract can be combined with this trap to support the development of automatic pest trapping system. In order for the spraying of organic pesticides to be more precise, the spraying system can use a microcontroller as an information processor [21-24]. Automatic pest control system using organic pesticides (citronella pesticides) is one step towards precision agriculture to increase organic agricultural production in Indonesia.

2 This current study aims to determine the effect of pesticide application based on citronella extract on the types and numbers of insect pests and predatory insects in the cultivation of rice (Ciherang varieties). Application of citronella pesticides to rice plants using manual spraying using a knapsack. Through this research, it is expected to know the effectiveness of pesticides from citronella extract in controlling pests of rice plants.

2. Material and Method.

2.1. Place and materials



Figure 1. Citronella harvesting (left) and lemongrass (right) space.

The materials used were citronella (Figure 1) and water without a mixture of other ingredients. Citronella is very close to its cousin lemongrass because they belong to the same genus, namely *Cymbopogon*. But, they both have different scents. Citronella is used to produce essential oils, while lemongrass is used for flavoring food. Visually, citronella has slightly red bark, while the bark of lemongrass is green like the leaves.

This research was conducted at the experimental field for Food and Horticulture Crops Protection of Agriculture Service, Pringsewu Regency, Indonesia (Figure 1). The equipments used in this study included a set of tools for extracting citronella plants such as knives, blender, filters, containers, and so on. A knapsack sprayer was used for application of citronella extract to rice plants. A logbook and laptop was used to document the observation data.

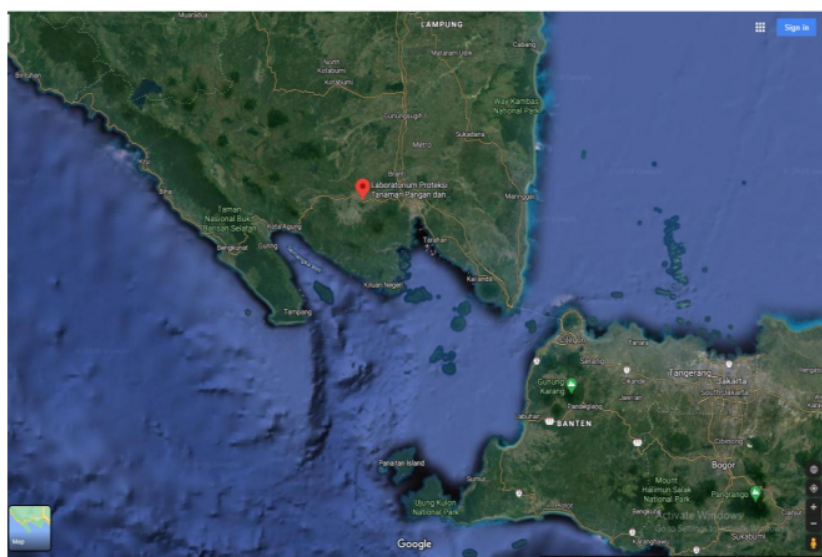


Figure 2. Location of field experiment (red baloon) on the Google map

2.2. Pesticide Preparation

The preparation of citronella-based pesticide was carried out at the Laboratory of Food and Horticulture Crops Protection. In this case, leaves and stems of citronella were used. These materials were wilted first by windrowed outside, and then cut into pieces about 2 cm in length. These chips were then crushed using a kitchen blender with the addition of tap water at a ratio of 1 : 2 (citronella : water). This maceration aims to expand the mass transfer surface of the solvent with raw materials (solids). The milled material is left for 2 hours so that the compounds in the citronella can adhere to the solvent. The next step is extraction to separate the solution from the solid using a filter. The separated solution is then stored in a tightly closed jerry can and then stored in a refrigerator until application time.

2.3. Pesticide Application

Pesticide application was carried out on rice plants that were 21 days old. The research field consisted of three plots, namely experimental plot A, experimental plot B and control plot. The area of each plot is 400 m² and each plot is separated by a bund. Citronella extract was diluted using water at a ratio of 50 ml of extract in one liter of water. Pesticide spraying was carried out using a knapsack sprayer on the rice plants. Spraying was carried out on experimental plots A and B at the same rate (10 liters per plot). Spraying was not carried out for control plot. Pesticide application was repeated on experimental fields A and B every week for the next 4 weeks.



Figure 3. Citronella harvesting (left) and lemongrass (right) space.

2.4. Observation and Data Analysis

The first stage in this research is to collect data on the types and populations of insect pests and predatory insects (natural enemies of pests) in the rice clumps in experimental plots A, B and control. Pests that may be present include brown planthoppers, green leafhoppers, white leafhoppers, green grasshoppers, stink bugs, green ladybugs, armyworms, and stem borer. Predatory insects include spiders, *Lycosa*, *Tetraganatha*, *Phederus*, *Micraspis*, *Ophionea*, parasitoids and dragonflies. The data is tabulated in graphical form to determine the pattern of decline each week. Observations were made every week before the spray application was carried out. Four students supervised by a field technician made this observation.

3. Result and Discussion

3.1. Insect Pests

Figure 4 shows the type and initial number of insect pests in each experimental plot before application of citronella-based pesticide. The types of insect pests in the three plots were the same and included brown planthoppers (BPH), green grasshoppers (GG), armyworms (AW), and stink bugs (SB). However, the number of each insect is different in each plot with plot B being the least. Overall, the control plot had the highest number of pests, namely 17 tails, followed by plot A 15 tails, and plot B 7 tails. According to its species, BPH was the most pest of 15 tails in total, followed by GG 12, SB 9, and AW 3 tails.

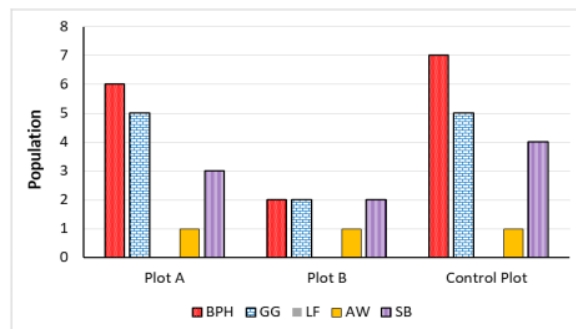


Figure 4. Type and number of insect pest before pesticide application (paddy 21 DAP)

Figure 5 shows the change in pest insect population after first application of citronella-based pesticide. Three types of insect pests still survive, namely the brown planthoppers, green grasshoppers, and stink bugs. Overall the number of insect pests is still 17 tails in the control plot, 13 in the A plot (2 less) and 11 in the B plot (4 more). Based on the type, BPH decreased by 4 (remained 11), GG was still 12 heads with a changed distribution, SB increased by 8 (become 17 heads), and AW disappeared from all experimental plots. However, a new insect pest was present in the control plot, namely leaf flies (LF). The results showed that the spraying of citronella-based pesticide in the first week had not had an effective impact on insect pest control, although the number of insect pests in control plots was still higher than in plots A and B.

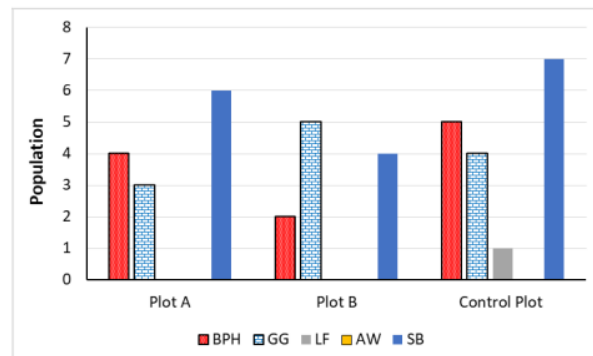


Figure 5. Type and number of insect pests after first application of pesticide (paddy 28 DAP)

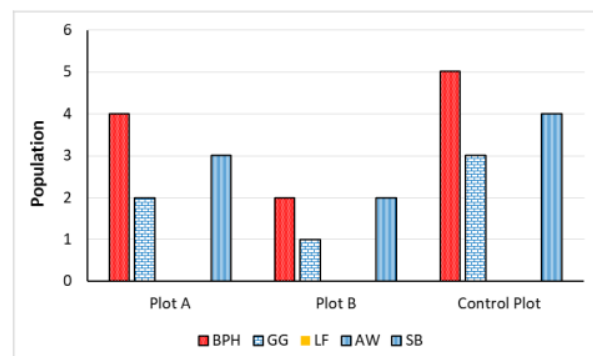


Figure 6. Type and number of insect pests after second application of pesticide (paddy 35 DAP)

In the second spraying when the rice plants were 35 DAP, the pesticide application began to show its effect. Figure 6 shows that there was a decrease in insect pests after the application of citronella-based pesticides. The results of the inspection showed that the types and number of insect pests began to decrease, especially on the application plots. Overall, there are only 3 types of pests left, namely BPH, GG, and SB. From the distribution, the control plot had the most insect pests, with a total of 12 animals, followed by the experimental plot A with 9 animals, and the plot B with only 5 animals. In terms of species, BPH was still the highest with a total of 11 tails, followed by SB 9 tails and GG 6 tails.

Observations after the third application of citronella-based pesticide (paddy age 42 DAP) showed increasingly significant results. In both experimental plots A and B, only one BPH was found (Figure 7), and no insect pests that were found in the previous week, such as green grasshoppers and stink bugs. On the other hand, in the control plot, the three types of insect pests still survive. Although the

number was less than that of the previous week, there were still more BPH pests in the control plot as compared to those in the experimental plots.

The last application of pesticide was carried out when the rice plants were 49 DAP. Observations show the presence of green grasshoppers in experimental plot A, while in the experimental plot B there was no insect pest at all (Figure 8). In the BPH control plot, there were still 3 tails of BPH and one SB.

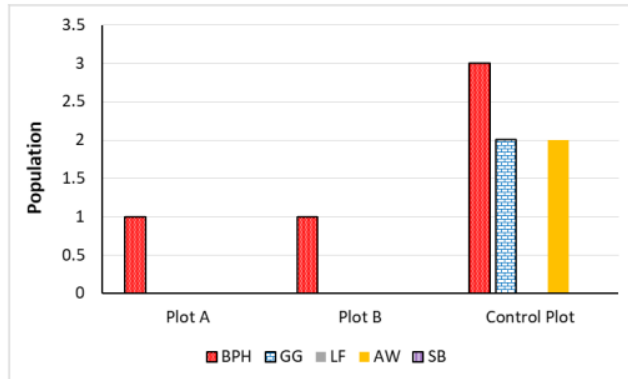


Figure 7. Type and number of insect pests after third application of pesticide (paddy 42 DAP)

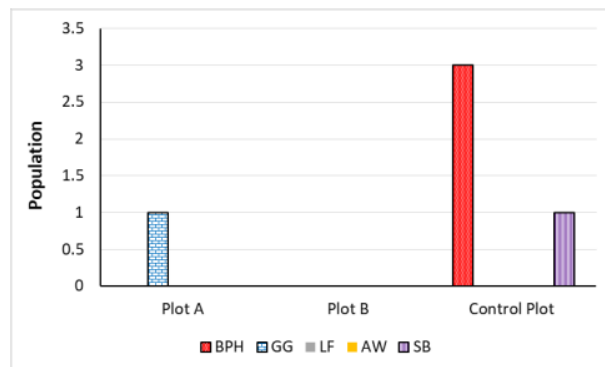


Figure 8. Type and number of insect pests after fourth application of pesticide (paddy 49 DAP)

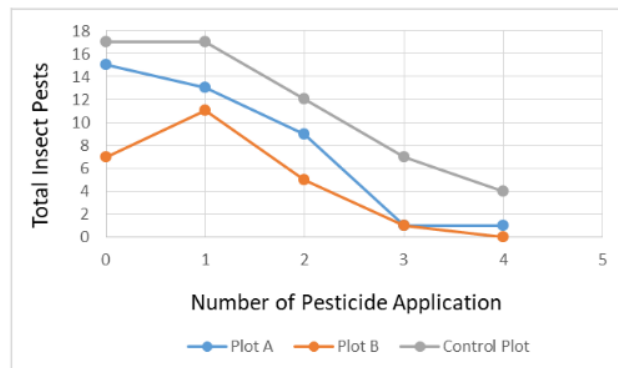


Figure 9. Progress of total number of insect pests during pesticide application

Figure 9 shows the progress of total insect pests population during five times application of citronella-based pesticide on the paddy field. These results concluded that the application of citronella-based pesticide can reduce the existence of insect pests in rice plants. The application of this pesticide can control even the very vicious pest like BPH. During the 4 application of citronella pesticide, the insect pest population decreased from 15 to 1 in plot A, down from 7 to 0 in Plot B. In the insect pest control plot it also decreased from 17 to 4. the impact of the experimental plot due to its adjacent location.

3.2. Predatory Insects

Predatory insects are beneficial as they are natural enemies for the insect pests. They are important to help control insect pests. Figure 10 shows the types and initial numbers of predatory insects found in the three experimental plots. Predatory insects found included *Lycosa* sp. (LC), spiders (SP), *Paederus* sp. (PD), *Ophionea* sp. (OP), dragonflies (DF), and *Tettragnatha* sp. (TT). The distribution and numbers of predatory insects were uneven in the experimental plots. For example, in plots A and B there was *Lycosa* sp. which was not found in the control plot. On the other hand, dragonflies are found in plot A and control plot, but not in plot B. Only three types of predatory insects were found in all the three plots, namely spiders, *Paederus* sp., and *Ophionea* sp. Based on the type, *Paederus* sp. were the most common, namely 23, followed by *Lycosa* sp. 12, *Ophionea* sp. 10, spider 7, dragonflies 2, and *Tettragnatha* sp. 1.

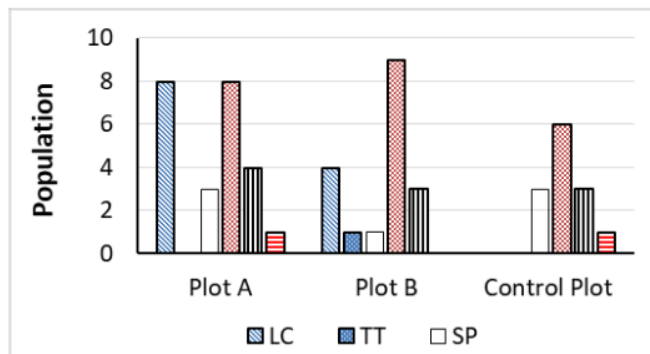


Figure 10. Type and number of predatory insects before pesticide application (paddy 21 DAP)

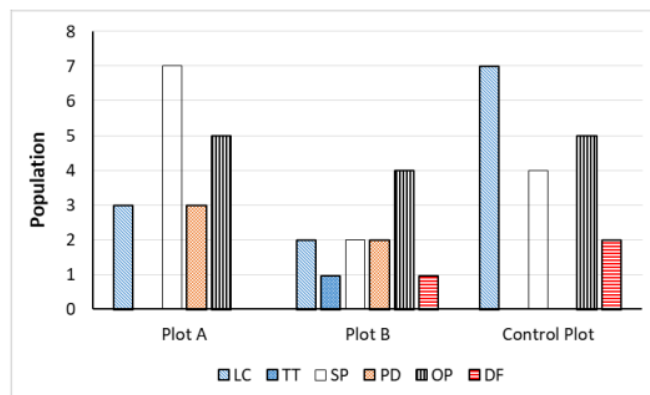


Figure 11. Type and number of predatory insects after first pesticide application (paddy 28 DAP)

Figure 11 shows the type and number of predatory insects after the first application of citronella-based pesticide. The types of predatory insects are still the same as those found before the application of pesticide, namely *Lycosa* sp., spiders, *Paederus* sp., *Ophionea* sp., *Tetragnatha* sp., and dragonflies. Based on the type, *Ophionea* sp. were the most common, namely 14, followed by spiders 13, *Lycosa* sp. 12, *Paederus* sp. 5, dragonflies 3, and *Tetragnatha* sp. 1.

Observations on 35 DAP (after the second spraying) showed that *Ophionea* sp. predatory insects predatory (Figure 12). Population of *Ophionea* sp. in fact, far exceeded the previous week's record (28 DAP). Other remaining predatory insects include spiders in all plots, *Tetragnatha* sp. only in the control plot, and *Paederus* sp. in plot B and control plot. Overall, the insect population in the control plot was higher than that in the experimental plot. This suggests that the application of citronella-based pesticide is also related to the decrease in the number and types of predatory insects in rice plants.

After the third pesticide application, only three types of predatory insects remained in the rice plots, namely spider, *Paederus* sp., and *Ophionea* sp. the population is not much different (Figure 13). These three types of insects also survived after the fourth pesticide application. However, this time the total population in the control plot is significantly more than the total population in experimental plot A or plot B. This supports the notion that the application of citronella-based pesticide is not only able to control insect pests but is also associated with a decrease in the number and types of predatory insects.

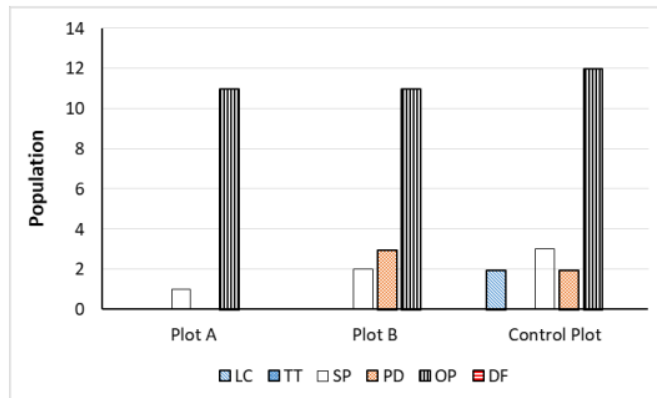


Figure 12. Type and number of predatory insects after second pesticide application (paddy 35 DAP)

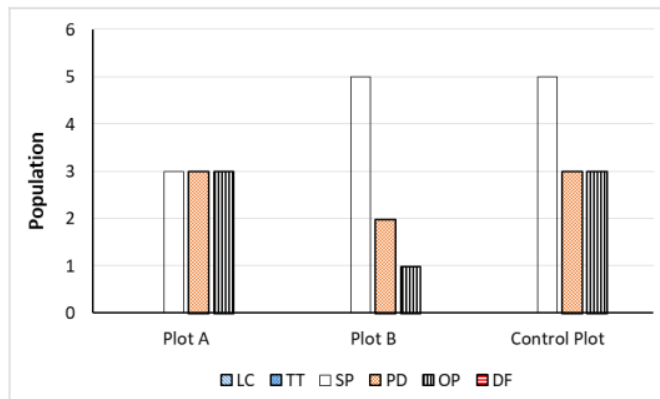


Figure 13. Type and number of predatory insects after third pesticide application (paddy 42 DAP)

Observations on 49 DAP have shown that there are still predatory insects in experimental plot A and experimental plot B. The number of predatory insects in plot A is 3 and plot B is 5. In the control plot, the number of predatory insects is 10 (Figure 14). The reduction in predatory insects in plot A and plot B is due to lack of food, namely insect pests, due to the influence of citronella pesticides.

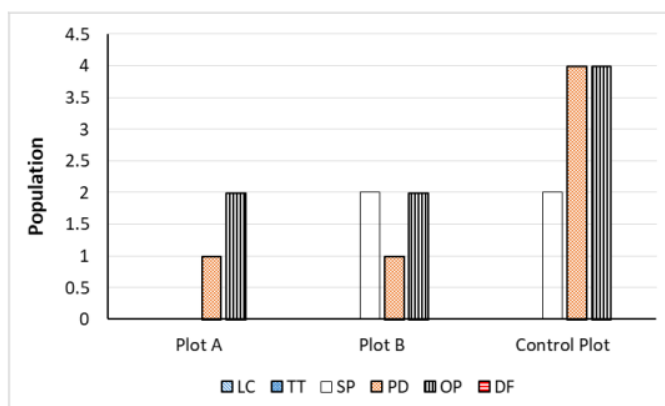


Figure 14. Type and number of predatory insects after third pesticide application (paddy 49 DAP)

From the results of observations during the spraying of citronella pesticide 4 times, it was found that there had been a decrease in the population of predatory insects in all observation plots. This population decline occurred gradually on land that had been exposed to pesticides (Figure 15). This proves that the application of citronella-based pesticide, also reduces the population of predatory insects in rice cultivation land. The nature of lemongrass containing secondary metabolics has been exposed to the tissues and environment of rice plants, thus disturbing insects. However, the citronella-based pesticide relationship may not be a direct one but a side effect of decreased insect pests. As the name suggests, predatory insects will hunt insect pests. If insect pests disappear from the rice plot, the predatory insects will also disappear.

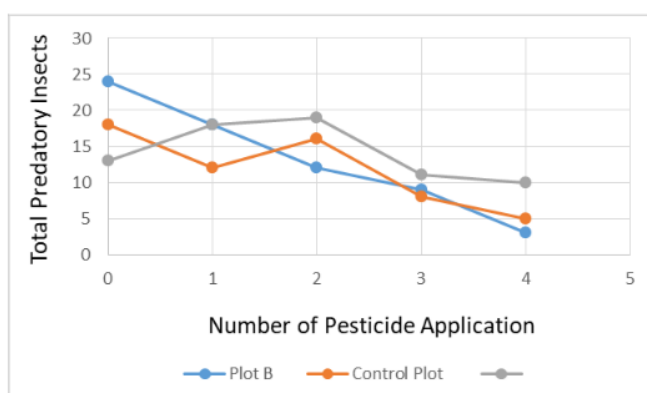


Figure 15. Progress of total number of predatory insect during pesticide application

Synthetic insecticides result in environmental pollution, pest resistance and residues problems; hence, focus is now given on plant based products for pest control. This study aims to assess the efficacy of two plant extracts, Citronella and Cinnamon against the two stored grain pests, *Tribolium castaneum*, *Sitophilus oryzae*, and the fruit fly *Drosophila melanogaster* under laboratory conditions. The extracts of two medicinal plants, Citronella and Cinnamon were applied separately at various

concentrations (1, 2 and 3 mL/petri dish) on filter papers in petri dish containing the test insects. Mortality was recorded after one, two and three hours exposure. The three hours exposure at 3mL/dish caused 90-99% mortality. Mortality was largely dependent on exposure time and concentrations of both the extracts. A decrease in concentration resulted in low fatality and vice versa. Mortality in control and solvent batches was less than 10% in all the experiments. Our results confirm that the extracts of Citronella and Cinnamon are highly effective against *Sitophilus oryzae*, *Tribolium castaneum* and *Drosophila melanogaster*. These findings further suggest the need for molecular studies of these medicinal plants.

The positive impact of the decline in the insect pest population is the reduction in rice plants' damage due to pest attacks. This also happened to predatory insects (natural enemies) in experimental fields A and B. The population of predatory insects in fields A and B has decreased compared to control fields. However, this population decline was not very significant compared to control areas (Figure 15). Perhaps this is due to the unavailability of natural food for predatory insects, namely insect pests. This may be the cause of predatory insects to move to another place.

Chemical pesticides can control (kill) insect pests quickly. It is different from organic pesticides, which are repellent (repellent for insects) due to their odor. Its anti-oxidant properties cause the insects to dislike the plants or cause the plant tissue to taste bitter, thereby reducing the interest of insect pests to eat them and lay their eggs. Citronella contains essential oils that are toxic to nerves, reduce reproductive capacity, disrupt the nervous system, and disrupt the hormonal system. Lemongrass (Citronella pesticides) contains saponins, flavonoids, polyphenols, alkaloids, and essential oils. The essential oil content of citronella is citral, citronellal, methylheptenone, dipentene, eugenol, metal ether, cadinene, geraniol, mirsenol, nerol, farsenol, cadinol and limonene [25]. Citronella is a contact poison. Citronella causes dehydration in insects, resulting in a continuous loss of fluids. This condition causes the death of insect pests [16]. Also, geraniol and citronellal compounds can be used as organic fungicides. Eugenol compounds in Citronella play a role in inhibiting the growth and development of pathogenic fungi. The citronella content can control (decrease) the population of *Tribolium sp*, *Sitophilus sp*, *Callosobruchus sp*, *Meloidogyne sp*, and *Pseudomonas sp*.

The advantages of using organic pesticides from lemongrass (Citronella) are organic materials, so they do not cause toxic effects. Predatory insects (natural enemies) do not die when exposed to organic pesticides so that pest control can sustainably take place. The costs required are more affordable and friendly (leaving no residue) to air, soil, water, and production plant tissue (consumption plants).

4. Conclusion

Pests in rice plants include brown planthoppers, green grasshoppers, stink bugs, leaf flies, and armyworms. While, the predatory insects found consisted of *Lycosa sp.* (LC), spiders (SP), *Paederus sp.* (PD), *Ophionea sp.* (OP), dragonflies (DF), and *Tetraganatha sp.* (TT). The application of citronella-based pesticides can significantly reduce the insect pest population. During the 4 application of citronella pesticides, the population of insect pests decreased from 15 to 1 in plot A, down from 7 to 0 in Plot B. In the insect pest control plot it also decreased from 17 to 4. In general, the application of citronella-based pesticides was also related to declining predatory insect populations. However, the citronella-based pesticide relationship may be due to the side effect of decreased insect pests.

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