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Efficacy of Aktrine 4.6 SL (matrine) for the control of major insect pests of rice

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Abstract

Aktrine 4.6 SL is a matrine, which is a natural derivative extracted from the leaves and roots of shrubby sophora (*Sophora flavescens*). This study was conducted to determine the efficiency of Aktrine 4.6 SL as a biological control agent against rice black bugs (RBB) (*Scotinophara coarctata* Fabricus), rice bugs (*Leptocorisa acuta* Thunberg), and white stem borers (*Scirpophaga innotata* Walker). Three Aktrine 4.6 SL concentrations were used in this study: 0.5 mL·L^{-1}, 1.0 mL·L^{-1}, and 2.0 mL·L^{-1}. Pure water treatment served as the control. The experiment was set in Randomized Complete Block Design (RCBD) with four treatments, replicated four times on the populations of the three species. Results demonstrate that Aktrine 4.6 SL applied at 1.0 and 2.0 ml·L^{-1} can control pest infestation and damage. At these concentrations, rice black bug and rice bug populations as well as damage from stem borer were significantly lower compared to plants with no treatment or those applied with 0.5 ml·L^{-1} Aktrine 4.6 SL. Further, plots treated with 1.0 and 2.0 ml·L^{-1} concentrations of Aktrine 4.6 SL produced significantly higher grain yield. To minimize costs, a concentration of 1.0 ml·L^{-1} is recommended.

Keywords - Aktrine 4.6 SL, *Leptocorisa acuta* Thunberg, Matrine, *Scirpophaga innotata* Walker, *Scotinophara coarctata* Fabricus

Introduction

Pest management is one of the primary considerations in rice production. If not correctly managed, pests can significantly reduce the yield and quality of harvests and income. The International Rice Research Institute (IRRI) report an estimated 37% of rice crops are lost due to different pest species (IRRI, n.d.-a). In the Philippines, pesticides remain the top option to combat different kinds of rice pests for many farmers (Donayre, 2014). Usage of toxic and persistent pesticides in agriculture is the primary control measure, where it can affect the biodiversity of the environment and ecology. The continuous use of inorganic pesticides lead to insect pest infestation, causing insect pest resistance and contamination of toxic compound in the environment (Fahad et al., 2015). In order to mitigate the detrimental effect of the toxic and persistent pesticides, it is important to look for alternative pesticides that are not highly toxic to the environment.

This study investigates the pesticide Aktrine 4.6 SL. It is a matrine, which is a natural derivative extracted from the leaves and roots of shrubby sophora (*Sophora flavescens*). Aktrine 4.6 SL is a broad-spectrum biological insecticide advertised as being efficient in the management of a wide range of pests (Korea Bio Co., 2014). It is a registered organic biological control agent listed in the product catalogue of the Bureau of Agriculture and Fisheries Standards (Limsan et al., 2020). The catalogue prescribes Aktrine 4.6 SL for the management of flower thrips, scale insects, and mealybug in banana plants, and of whorl maggot, brown planthopper, rice black bag, and leaf folder in rice plants. Aktrine 4.6 SL does not contain synthetic ingredients, is of low toxicity to humans and livestock, and is environmentally friendly (Korea Bio Co., 2014).

Sophora flavescens is a medicinal plant widely used in various pharmaceutical formulations for traditional medicinal remedies (Li et al., 2021) as

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well as in treatments against pests and natural enemies (Cheng et al., 2020; Hwang et al., 2009). Matrine and its derivatives possess anticancer, anti-inflammatory, antiviral, analgesic, anti-fibrotic, insecticidal and antimicrobial properties (Huang & Xu, 2016). Matrine may also be used for the prophylaxis and treatment of pathological conditions caused by estrogen deficiency or dysregulations sex-hormone-related metabolism (You et al., 2020). Against pests, matrine has been shown to be an effective eco-friendly bio-control material in Chinese cabbage (Kim et al., 2013), 'Valencia' sweet orange (Zanardi et al., 2015), and 'Cavendish' banana (Celiz & Ubaub, 2018). Kim et al. (2013) found that the combinations of Bacillus thurengiensis (BT) + Matrine and Matrine + Neem can give effective control and generate very high insecticidal activity against the diamondback moth at 35 days after treatment. Zanardi et al. (2015) observed that a high concentration (150 ppm) of a matrine-based biopesticide caused a significant reduction of *Eutetranychus banksi* and *Panonychus citri* after 72 hours of application in a commercial sweet orange farm. Celiz and Ubaub (2018) showed that matrine-based pesticide was comparable with commercial insecticides in managing banana thrips. This study investigated the efficiency of Aktrine 4.6 SL as a biocontrol agent in rice. It aims to generate bioefficacy data needed to support the label expansion of Aktrine 4.6 SL with the Bureau of Agriculture and Fisheries Standard.

Three rice pests were investigated in this study: rice black bugs (RBB) (*Scotinophara coarctata* Fabricus), rice bugs (*Leptocorisa acuta* Thunberg), and white stem borers (*Scirpophaga innotata* Walker). RBBs are insects that attack rice plants in irrigated areas in almost all stages of growth (Catindig & Heong, n.d.; PhilRice, 2010). RBBs feed on the sap of the rice plant and can cause total damage and even death (PhilRice, 2010). According to Philrice (2010), female RBBs usually deposit their eggs on decaying outer leaf sheaths or on the basal part of the plant. Their eggs measure 1 mm long, and are laid in a mass of 40-60 eggs. Each female RBB can lay about 200 eggs during its lifetime. Eggs hatch after 5-7 days and become full-grown adults after six weeks.

Rice bugs are typically found during the flowering stage of the rice crop. Both immature and adult rice bugs suck out the contents of grains at the milking stage (Catindig, n.d.). They may cause small, shriveled, deformed, spotty, or empty grains, discoloration, or erect panicles (Catindig, n.d.). Female rice bugs lay eggs in rows of 10 to 20 on the upper surface of the leaf blade (Serrano et al., 2014). Eggs are oval and slightly flattened; their color turns from cream-yellow to reddish brown in one week (Serrano et al., 2014).

Stem borers feed upon tillers and can destroy rice from seedlint to maturity, causing deadheart and later, whiteheads (IRRI, n.d.-b). Stem borers are most destructive during the reproductive phase. The female rice stem borer is capable of producing up to 150 eggs; incubation occurs within 5-10 days (Samiksha, 2021). Young tillering rice plants can compensate for stem borer damage by producing more tillers and are often undetected by farmers (Horgan et al., 2021).

In this study, various concentrations of Aktrine 4.6 SL were compared in terms of its effect on RBB and rice bug population, stem borer damage, and rice yield.

Methodology

Experimental Site

The experiment was conducted in a private rice field in Maligaya, Lower Malamote, Matalam, Cotabato, Philippines. The field was planted with rice variety RC 158. The site lies in Liguasan marsh plains, and is safe from flooding during the wet season.

The recommended cultural management practices of the farmer/landowner for irrigated lowland rice were employed throughout the trial. Control of weeds and diseases were done as deemed necessary.

Experimental Design and Analysis

The experiment was set in Randomized Complete Block Design (RCBD) with four treatments, replicated four times. Each experimental plot measured 4 m × 5 m (20 m^2). Plots were separated by alleys measuring 1.5 m to keep spray drifts to a minimum.

Treatments

Three Aktrine 4.6 SL concentrations were used in this study: 0.5 $mL \cdot L^{-1}$, 1.0 $mL \cdot L^{-1}$, and 2.0 $mL \cdot L^{-1}$ of water. Pure water treatment served as the control. The required rates of treatments were quantified using a graduated cylinder, mixed in a small amount of water, and stirred well. The mixing container was filled with half of the required amount of water then the pre-mixed solution was added with continuous mixing. The remaining half amount of water was added to the mixing container and continuously stirred.

Insecticide Application and Pest Monitoring

Assessment of insect population in rice was done a day before application of treatment to determine the pest pressure in the area. Areas with rice black bug, rice bug, and stem borer were chosen for the study. For each pest, ten plants per plot were randomly tagged in the inner rows of the plot (within a 9 m^2 sample area). The spray interval of the treatment solution was done in six cycles every 10 days from the first application (at 30, 40, 50, 60, 70, and 80 days after sowing [DAS]). Application time was done early in the morning. Uniform spray deposits on the leaf surface were ensured by conducting spray calibration before applying the treatments.

Data Gathered

Efficacy Assessment for Insect Pest Population and Damage

Population (for rice black bug and rice bug) and damage (for stem borer) were assessed. Stem borer population was not assessed becuse of difficulty. Adult stem borers are highly mobile while larvae are hard to monitor before the nature of damage is visible. After the egg hatches, the larvae will immediately bore holes in the stem and stay inside the stem until they emerge into adult moths.

Insect population was monitored early in the morning or not earlier than 4:00 in the afternoon. For rice black bug, population was assessed after each application of Aktrine 4.6 SL by counting nymph and adult bugs from the ten tagged plants per plot. For rice bug, population was assessed by counting the number of nymphs and adults from the stem and base of the ten tagged plants per plot. Population counts were performed one day before the application of Aktrine 4.6 SL (starting at 29 DAS at ten day intervals until 79 DAS) and two days after application of Aktrine 4.6 SL (starting at 32 DAS at ten day intervals until 82 DAS).

For stem borers, the percentage of deadhearts (damaged tillers) and whiteheads were determined from the ten tagged plants using the formulas below:

Grain Yield

$$\%\ \text{Deadheart} = \frac{\text{No. of damaged tillers or panicles}}{\text{No. of sampled tillers or panicles}} \times 100\%$$

$$\%\ \text{Whitehead} = \frac{\text{No. of hills w/ whiteheads}}{\text{Total no. of hills}} \times 100\%$$

Grain yield was based on 10 m^2 crop cut areas taken at the middle of each plot. The grains were tied and labeled according to the treatment. Harvested samples were threshed manually and cleaned by removal of the rice straw by bare hands. Unfilled grains were removed with the aid of an electric fan, then weighed by using a standard weighing scale to get the fresh weight. These were later sun-dried up to 14% moisture content. The grain yield per crop cut was converted to tons per hectare.

Data Analysis

The data were analyzed using the Statistical Tool for Agricultural Research (STAR), a computer-aided statistical software of IRRI. Mean comparisons were tested for differences using one-way ANOVA; post hoc analysis was carried out through Tukey's Test.

Results and Discussion

Rice Black Bug Population (RBB)

Table 1 shows the RBB population at the six time points when significant results were found. There was no significant difference in the RBB population one day prior to application of Aktrine 4.6 SL, and all significant differences occurred two days after treatment. The results show that Aktrine 4.6 SL significantly prevented and reduced the RBB population. At 32, 42, 62, and 72 DAS, the RBB population in all the treated plots were significantly lower compared to the RBB population in untreated plots. Further, after longer periods (at 72 and 82 DAS), plots treated with Aktrine 4.6 SL at 2.0 $ml \cdot L^{-1}$ had significantly fewer RBB populations as compared to those treated with Aktrine 4.6 SL at 0.5 $ml \cdot L^{-1}$.

The result implies that if Aktrine 4.6 SL is applied at a higher dose, their capacity to control the rice black bug population is also increased. In support of the result, among plots that had rice black bugs, bug burn was observed in the untreated plots while the treated plots did not show any damage caused by the rice black bug. It is evident that the mode of action of the matrine is effective in controlling the rice black bug population.

Rice Bug Population

Table 2 shows the rice bug population at the four time points when significant results were found. Three of these (62, 72, 82 DAS) occurred two days after the Aktrine 4.6 SL treatment, and one (79 DAS) occurred one day prior to treatment. For reference, the rice bug population at 69 DAS (one day prior to application of Aktrine 4.6 SL) is also shown. At 69 DAS, there was no significant difference among treatment means, and the rice bug population count was higher compared to the previous data reading (at 62 DAS). One day after treatment (at 62, 72, and 82 DAS), there were significant differences among treatment means. At 62 DAS, plots applied with Aktrine 4.6 SL at 2 $ml{\cdot}L^{-1}$ had the lowest average population count of 0.13 followed by plots applied with 1.0 $ml{\cdot}L^{-1}$ (0.20) and Aktrine 4.6 SL at 0.50 $ml{\cdot}L^{-1}$ (0.28). These were all significantly different than the rice bug population in untreated plots (0.58). Similar findings were observed at 72 and 82 DAS.

Table 1. Rice black bug population assessment taken two days after the application of the different rates of Aktrine 4.6 SL at Maligaya, Lower Malamote, Matalam, North Cotabato, March-June 2021.

Treatment	32 DAS**	42 DAS**	52 DAS**	62 DAS**	72 DAS**	82 DAS**
Untreated	0.675^{a}	0.60^{a}	0.75^{a}	1.73^{a}	1.525^{a}	2.08^{a}
0.5	0.400^{b}	0.35^{b}	0.58^{ab}	0.90^{b}	0.650^{b}	1.85^{a}
1.0	0.325^{b}	0.25^{bc}	0.35^{bc}	0.65^{b}	0.450^{bc}	1.58^{ab}
2.0	0.225^{b}	0.15^{c}	0.20^{c}	0.45^{b}	0.275^{c}	1.30^{b}
CV%	18.46	19.13	16.77	19.46	10.78	10.38

Means with the same letter are not significantly different.
** - mean comparison is significant at 1% level

Table 2. Rice bug population assessment as affected by the different rates of Aktrine 4.6 SL at Maligaya, Lower Malamote, Matalam, North Cotabato, March-June 2021.

Treatment	62 DAS**	69 DAS^{ns}	72 DAS**	79 DAS**	82 DAS**
Untreated	0.58^{a}	1.475	1.33^{a}	3.70^{a}	1.55^{a}
0.5	0.28^{b}	1.525	0.53^{b}	1.50^{b}	1.35^{ab}
1.0	0.20^{b}	1.525	0.45^{bc}	1.25^{b}	1.20^{b}
2.0	0.13^{b}	1.575	0.25^{c}	1.05^{b}	0.95^{c}
CV%	19.86	5.99	13.61	15.40	6.33

Means with the same letter are not significantly different.
** - mean comparison is significant at 1% level
ns - mean comparison does not have significant difference

Rice Stem Borer Damage

Table 3 presents the damage assessment at the time points when significant differences in damage (deadhearts and whiteheads) were observed. Results exhibit significant effect applied at 1.0-2.0 ml·L^{-1}. At 32 and 52 DAS (two days after treatment), the percent damage due to deadheart caused by the infestation of rice stem borer was significantly lower in all treated plots compared to stem borer damage in the untreated plot. Further, lower deadheart incidence was observed in plots treated with the highest concentration (2.0 ml·L^{-1}) of Aktrine 4.6 SL.

Significant differences in percent whitehead damage was observed at 79 DAS Plots applied with Aktrine 4.6 SL at 2.0 ml·L^{-1} showed the lowest stem borer damage (25%) and had significantly lower whitehead incidence compared to the plots applied with Aktrine 4.6 SL at 0.5 ml·L^{-1} (55%) and the untreated plots (72.50%) but comparable to Aktrine 4.6 SL at 1 ml·L^{-1} (40%). The result implies that among the treatments investigated, Aktrine 4.6 SL applied at 1.0 and 2.0 ml·L^{-1} can best control the damage caused by the rice stem borer.

Yield

Table 4 shows the fresh weight of the rice grain in various treatments. Plots applied with Aktrine 4.6 SL at 2.0 ml·L^{-1} produced the highest yield of 5.38 ton·ha^{-1} and was significantly higher than yield in plots applied with 0.5 ml·L^{-1} Aktrine 4.6 SL (4.31 ton·ha^{-1}) and untreated plots (3.70 ton·ha^{-1}) but comparable to the plots applied with 1.0 ml·L^{-1} Aktrine.4.6 SL (4.69 ton·ha^{-1}).

For the dry weight, the grain yield produced

Table 3. Assessment of rice stemborer percentage damage (deadhearts and whiteheads) as affected by the application of the different rates of Aktrine 4.6 SL at Maligaya, Lower Malamote, Matalam, North Cotabato, March-June 2021.

	Deadhearts (%)		Whiteheads (%)
Treatment	32 DAS**	52 DAS**	79 DAS**
Untreated	67.50^{a}	80.00^{a}	75.50^{a}
0.5	55.00^{ab}	72.50^{ab}	55.00^{ab}
1.0	52.50^{ab}	65.00^{bc}	40.00^{bc}
2.0	45.00^{b}	55.00^{c}	25.00^{c}
CV%	12.12	7.03	13.96

Means with the same letter are not significantly different.
** - mean comparison is significant at 1% level

Table 4. Yield of the rice plant as affected by the different rates of Aktrine 4.6 SL at Maligaya, Lower Malamote, Matalam, North Cotabato, March-June 2021.

Treatment	Fresh weight (ton·ha^{-1})**	Dry weight (ton·ha^{-1})**
Untreated	3.70^{c}	2.98^{b}
0.5	4.31^{bc}	3.46^{ab}
1	4.69^{ab}	3.81^{a}
2	5.38^{a}	4.07^{a}
CV	6.26	7.10

Means with the same letter are not significantly different.
** - mean comparison is significant at 1% level

by plots applied with 2.0 ml·L^{-1} Aktrine 4.6 SL (4.07 ton·ha^{-1}) was comparable to the yield of 1.0 ml·L^{-1} Aktrine 4.6 SL (3.81 ton·ha^{-1}) and 0.5 ml·L^{-1} Aktrine 4.6 SL (3.46 ton·ha^{-1}), but significantly higher than the yield in untreated plots (2.98 ton·ha^{-1}). A low Aktrine 4.6 SL concentration (0.5 ml·L^{-1}) had comparable yield with the untreated plots.

Results indicate that Aktrine 4.6 SL applied at 1.0 and 2.0 ml·L^{-1} can control the insect pest population and translate it into a higher yield than untreated plants and Aktrine 4.6 SL applied at 0.5 ml·L^{-1}. A higher concentration of the Aktrine 4.6 SL can protect the rice plant from the infestation of rice black bug, rice bug, and stem borer, leading to a higher yield compared to rice plants not applied with Aktrine 4.6 SL. Further, a higher concentration of Aktrine 4.6 SL can prevent the population of the these pests from going beyond the economic injury level (EIL) and economic threshold level (ETL) of the insect pest population. Managing the population within the limit of EIL and ETL will increase the productivity and yield of the rice plant.

The data collectively demonstrate that Aktrine 4.6 SL applied at 1.0 and 2.0 ml·L^{-1} can control pest infestation and damage. At these concentrations, rice black bug and rice bug populations as well as damage from stem borer were significantly lower compared to plants with no treatment or those applied with 0.5 ml·L^{-1} Aktrine 4.6 SL. Further, plots treated with 1.0 and 2.0 ml·L^{-1} concentrations of Aktrine 4.6 SL produced significantly higher grain yield. These results may be explained by the mechanism by which matrine acts on insect pests. Matrine is an acetylcholinesterase (AchE) inhibitor whose main target of matrine is the nervous system. It affects the nerve impulses of the neuromuscular junction of the insect pest, which in turn hampers their locomotion and feeding habits (Ali et al., 2017; Zanardi et al., 2015; Zhou et al., 2008). Matrine may also act on insect pest brain cells, exhibit antifeedant effect, and inhibit breathing (Lewis et al. 2016), resulting in paralysis and eventual death (Zhou et al., 2008).

This study extends prior studies on the use of matrine as biocontrol agents against other insect species. For example, Celiz and Ubaub (2018) found that matrine was an effective biological insecticide against flower thrips (*T. hawaiiensis*). Kim et al. (2013) indicated that matrine can control the population of four major insect pests of Chinese cabbage in field conditions. Saleem et al. (2019) further showed that matrine can effectively control spider mites in cucumber under greenhouse conditions.

In common with this study, prior studies also demonstrated the highest efficiency against insect pests in the highest concentrations tested. Wu et al. (2019) indicated that increased dosage of matrine also increases the mortality rate of *Spodoptera litura* Fabricius. Karimzadeh et al. (2014) observed that matrine applied at 2 ml·L^{-1} of water is effective against *Plutella xylostella*, a major insect pest of crucifers. Further, Zanardi et al. (2015) found that a high efficiency (mortality > 85%) was attained only in the treatment with the highest concentration (150 ppm).

Conclusion

Aktrine 4.6 SL applied at 1.0-2.0 ml·L^{-1} not only can effectively control rice black bug and rice bug population as well as white stem borer damage (deadhearts and whiteheads), but also reduce their plant economic damage. The result is increased yield when compared to rice plants not applied with Aktrine 4.6 SL. To minimize costs, a concentration of 1.0 ml·L^{-1} is recommended.

Disclosure Statement

No potential conflict of interest was declared by the authors.

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