

Preliminary Investigation On The Toxicity Of Liquid Potassium Silicate From Rice Husk Ash Against Second Instar Larvae Of *Spodoptera Frugiperda*

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ABSTRACT

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Spodoptera frugiperda (FAW) has become a major pest of many agricultural commodities. This pest has the potential to cause damage of up to 100%. One approach that can be used to control FAW in an environmentally friendly way is to utilize biosilica extracted from rice husk ash (RHA). The biosilica was extracted from RHA using potassium hydroxide solution to produce the liquid potassium silicate (Liq-K-sil). The biosilica content from RHA makes plant parts stiffer which impacts the biology and feeding activity of FAW. This study aimed to investigate the toxicity of two Liq-K-sil formulas against second-instar FAW. Testing was conducted in the laboratory using the feed residue method. The results showed that Liq-K-sil was toxic because it caused the death of second-instar FAW larvae by up to 77.20-88.00% compared to the control, with an LC₅₀ of 3.22-5.48%. Initial information on the toxicity of Liq-K-sil can be used as a reference for further formulation changes to improve its activity and performance in controlling FAW.

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1. Introduction

Fall armyworm (FAW) (*Spodoptera frugiperda* J.E. Smith) (Lepidoptera: Noctuidae) is an invasive pest that currently poses one of the most serious threats to global corn production. This species has a high dispersal capacity, broad adaptability, and a diverse host range, enabling it to quickly adapt to new agroecosystems. In Indonesia, FAW was first reported attacking corn crops in 2019 and has since spread widely to various national corn production centers, causing increasing attack intensity year after year [1], [2], [3], [4].

FAW attacks can occur at all growth stages, from the early vegetative to the generative phase. However, the vegetative phase is reported to be the most vulnerable stage, as larvae feed on young leaf tissue and growing points, resulting in reduced effective leaf area and impaired plant growth [1], [5], [6]. At high infestations and without effective control, corn yield losses due to FAW

infestation can reach significant levels, potentially even causing crop failure under certain conditions [7].

The economic impact of FAW infestations has been widely reported in various regions of the world. In Africa country, FAW causes significant annual corn production losses, with serious implications for food security and smallholder farmers' incomes [8]. In Asia, including Southeast Asia, FAW has also been reported to cause significant yield reductions and increase production costs due to the need for intensive control [9]. This situation underscores the urgency of developing effective, sustainable, and environmentally friendly FAW control strategies.

To date, FAW control at the field level is still dominated by the use of synthetic insecticides. Although synthetic insecticides can rapidly suppress pest populations, repeated and poorly managed use has triggered various serious problems, such as the development of pest resistance, the death of non-target organisms, ecosystem disruption, and the accumulation of chemical residues that pose risks to human health and the environment [9], [10], [11]. FAW resistance to various insecticide groups, including diamides, organophosphates, spinosyns, pyrethroids, and benzoylureas, has been reported in several countries [12], [13], [14], [15].

With increasing awareness of the negative impacts of synthetic insecticides, more sustainable pest control approaches have become a focus of recent research. One potential alternative is the use of agricultural waste in the form of rice husk ash (RHA). RHA contains abrasive silicon that can damage the insect's cuticle, causing fluid loss and ultimately death. On the one hand, silica plays a role in strengthening plant cell walls, increasing the mechanical resistance of tissues, and inducing plant defense responses against herbivore attacks [16], [17].

Several studies have shown that the use of RHA-based formulas can reduce the level of plant damage caused by pests, including FAW, while increasing corn growth and yield [18], [19]. In addition to functioning as a pest control agent, biosilica-based formulas have the additional advantage of being sourced from natural ingredients, readily biodegradable, and leaving no harmful residues. The use of biosilica aligns with the concept of sustainable agriculture and circular economy-based agricultural waste management. Therefore, biosilica has the potential to be an important component in an Integrated Pest Management (IPM) system that aims to reduce dependence on synthetic insecticides without sacrificing pest control effectiveness [20], [21]. Based on this background, this study aims to investigate the toxicity of liquid biosilica extracted from RHA using potassium hydroxide solution to second-instar FAW larvae, as an effort to develop effective, environmentally friendly, and sustainable control technologies.

2. Method

2.1. Preparation of Liquid Potassium Silicate from RHA

Biosilica was extracted from RHA using the sol-gel technique. This technique relies on the solubility of amorphous silica in alkaline solutions, followed by precipitation of the dissolved silica using an acidic solution [22], [23]. A total of 300 g of RHA was reacted with 1,800 mL of 10% (w/v) potassium hydroxide solution. The extraction was carried out at $\pm 100^{\circ}\text{C}$ with stirring at 525 rpm for 90 minutes. At the end of the extraction time, the temperature was allowed to cool to room temperature. The extracted solution was then filtered through a filter cloth to separate the filtrate, which was a potassium silicate solution (silica sol). Silica sol is a dispersion of SiO_2 (nano-sized) in water. This solution was further concentrated using a rotary evaporator at a temperature of 75°C , a rotating speed 50 rpm, and a pressure of 125 mbar. The evaporation was stop when the total soluble solid content reached 50°brix, which checked using a hand refractometer. This solution, hereinafter referred to as liquid potassium silicate from RHA (Liq-K-sil A) was then stored in a glass bottle for use in testing the efficacy against the second instar larvae of FAW. The dilute version of the extract was also prepared with the same method without evaporation (Liq-K-sil B).

2.2. Mass Rearing of FAW

FAW was obtained from corn fields in the Babakan area, Dramaga, Bogor, West Java ($6^{\circ}3'04.1''\text{S}$ $106^{\circ}44'05.6''\text{E}$) method. Insects collected from the field were in the form of final instar larvae (prepupae). After being collected from the field, the insects were placed in a plastic jar containing food in the form of young corn and leaves. After that, the jar was covered with a cloth to prevent the insects from escaping. After turning into pupae, the insects were separated in another

jar lined with paper until they became imago. After becoming imago, the insects were paired in a plastic container and fed 10% honey, until they produced eggs. The hatched eggs were transferred to another jar container until they became larvae. The larval stage used in this test was the second instar.

2.3. Toxicity Testing

Testing used 2 formulas, namely (1) Liq-K-sil UnC (unconcentrated Liq-K-sil) and (2) Liq-K-sil C using concentrations of 2.5; 5.0; 10.0; 20.0; and 40.0% with water as a control. Toxicity testing was carried out using second instar of FAW larvae with five replications. Each replication used 10 larvae, separately for each individual. The method used in this efficacy test was feed residue, which was carried out by soaking baby corn in the test solution for 5 minutes then drying it for five minutes then putting it into a petri dish with a diameter of 8 cm. Next, the second instar test insects were put into the round thin wall. The mortality of the test insects was observed up to seven days after treatment (DAT). The Polo Plus Ver. 1.0 program was applied to analyze the relationship between mortality and lethal concentration (LC) using a probit approach.

3. Results and Discussion

Both treatments showed an increasing response pattern with increasing concentration and time after application. In the control treatment, both the Liq-K-sil UnC and Liq-K-sil C groups showed relatively low response values and tended to be stable until the end of the observation, reflecting natural conditions without any active ingredient intervention. In contrast, all treatments of both formulas showed an increase in response values from 2 to 7 DAT, especially at medium to high concentrations (10–40%).

Tabel 1 Average mortality of second instar FAW larvae using Liq-K-sil treatments

Treatments	%	1 DAT	2 DAT	3 DAT	4 DAT	5 DAT	6 DAT	7 DAT
Control	0.0	0.00	0.00	0.00	0.00	0.00	0.14	0.14
Liq-K-sil UnC	2.5	0.00	0.57	2.29	2.43	3.71	4.00	4.43
Liq-K-sil UnC	5.0	0.00	1.29	2.71	3.57	4.29	4.71	5.29
Liq-K-sil UnC	10.0	0.00	1.71	2.57	4.57	4.71	5.86	6.43
Liq-K-sil UnC	20.0	0.29	2.14	3.86	4.86	5.57	6.71	7.29
Liq-K-sil UnC	40.0	1.00	2.71	4.57	5.29	6.00	7.57	7.86
Control	0.0	0.00	0.00	0.00	0.60	0.80	0.80	0.80
Liq-K-sil C	2.5	0.40	0.60	3.40	4.40	5.00	5.20	5.20
Liq-K-sil C	5.0	1.00	1.60	3.80	4.60	5.40	6.00	6.20
Liq-K-sil C	10.0	1.40	2.60	4.80	5.00	5.80	6.80	6.80
Liq-K-sil C	20.0	2.60	3.20	5.60	6.20	6.80	7.40	7.80
Liq-K-sil C	40.0	3.20	4.80	6.60	6.60	7.40	7.80	8.60

DAT = days after treatment.

The more rapid and consistent increase in response at higher concentrations indicates a dose–response relationship between application and biological effects on FAW larvae. At concentrations of 20 and 40%, effects were already apparent earlier (1–2 DAT) and continued to increase until the end of the observation period. This pattern is consistent with previous reports that biosilica, particularly in dissolved or nanoparticle form, can accelerate physiological disturbances in herbivorous insects through direct contact mechanisms or indirect effects through host plants [18], [19].

Mechanistically, silica is known to have abrasive properties that can damage the insect cuticle, increasing water loss and causing physiological stress, leading to decreased feeding activity, fecundity, and larval mortality. This effect is cumulative, resulting in a more pronounced increase in response in the final days of observation [24], [25], [26]. This explains why the difference between treatment and control was greater at 5–7 DAT than at the beginning of the observation.

The differences in response patterns between Liq-K-sil UnC and Liq-K-sil C also suggest that the biosilica formulation may influence its effectiveness. Liq-K-sil C treatment tended to show higher response values at the same concentration and time, particularly at concentrations of 20 and 40%. This suggests that the composition or availability of biosilica in the formulation may be more

effective in interacting with the larval body or plant surface, as reported in previous studies on variations in the efficacy of silicone formulations against insect pests.

In addition to its direct effect on larvae, silica also plays a role in strengthening plant tissues and increasing the mechanical resistance of leaves through silica deposition in cell walls. Plants with higher silica content are less attractive to herbivorous insects and more resistant to damage from larval feeding [24], [19]. Thus, the increased response to biosilica treatment is likely a result of a combination of the direct effect of silica in the formula on larvae and an indirect effect through increased host plant resistance. The results of this study align with the findings of [18], who reported that the application of biosilica to corn plants reduced damage caused by FAW attacks.

The LC_{50} value of Liq-K-sil C (3.224%) was lower than that of Liq-K-sil UnC (5.480%), which indicated that Liq-K-sil C had a higher level of toxicity towards the test insects (Table 2, Fig. 1). This difference indicated that at the same concentration, biosilica was able to produce a greater mortality effect than Liq-K-sil UnC. This difference in effectiveness could be attributed to the physical and chemical characteristics of the formulation, such as particle size, specific surface area, and adhesion ability to the insect integument [27], [20].

The LC values at low mortality levels (LC_5 – LC_{25}) were relatively small in both treatments, indicating that at low concentrations, these two bio-silicas had begun to have sublethal effects on the test insects. This sublethal effect is important because it can affect the physiology, feeding activity, and development of insects before causing death, thus contributing to a gradual population decline [28], [29].

Tabel 2 Toxicity of Liq-K-sil C and Liq-K-sil C against second instar larvae of FAW

Value	Liq-K-sil C	Liq-K-sil UnC
LC5	0.045 (0.000 - 0.267)	0.070 (0.002 - 0.307)
LC15	0.218 (0.006 - 0.787)	0.352 (0.033 - 0.981)
LC25	0.559 (0.036 - 1.510)	0.918 (0.163 - 1.977)
LC35	1.185 (0.153 - 2.570)	1.975 (0.579 - 3.517)
LC45	2.326 (0.546 - 4.230)	3.929 (1.746 - 6.101)
LC50	3.224 (0.993 - 5.468)	5.480 (2.897 - 8.187)
LC55	4.469 (1.772 - 7.213)	7.645 (4.635 - 11.393)
LC65	8.773 (5.081 - 14.730)	15.208 (10.249 - 26.942)
LC75	18.597 (11.538 - 46.451)	32.713 (20.023 - 87.024)
LC85	47.622 (24.473 - 257.345)	85.325 (41.806 - 418.159)
LC95	231.35 (75.202 - 5269.5)	427.53 (135.69 - 6214.2)
LC99	1358.9 (253.33 - 0.16187E+06)	2599.7 (495.72 - 0.13069E+06)
χ^2	3.583	4.620
heterogeneity	0.156	0.140
$a \pm SE$	4.549 ± 0.231	4.358 ± 0.196
$b \pm SE$	0.886 ± 0.220	0.869 ± 0.182

a = intercept of probit regression line; b = probit regression slope; SE = standard error; LC = lethal concentration; CI = confidence interval.

The widening of the confidence intervals at high LC (LC_{75} – LC_{99}) indicates increased variation in individual insect responses to high concentrations. This phenomenon is common in probit analyses and reflects heterogeneity in physiological tolerance within the test insect population. However, the relatively low chi-square (χ^2) values for both treatments (3.583 for Liq-K-sil C and 4.620 for Liq-K-sil UnC) indicate goodness-of-fit of the probit model and that the mortality data can be well explained by the probit regression model. The relatively shallow slope ($b \pm SE$) values for both formulations (0.886 ± 0.220 for Liq-K-sil C and 0.869 ± 0.182 for Liq-K-sil UnC) indicate that mortality increases gradually with increasing concentration. Low slope values generally reflect considerable individual response variation within insect populations, which is common in bioassays of mineral-based materials or agents with non-neurotoxic mechanisms of action. The relatively high intercept parameter ($a \pm SE$) indicates that the probability of a mortality response increases significantly after a certain concentration threshold is exceeded [30]. This is consistent with the physical mechanism of action of biosilica, which causes integument damage and body fluid loss, so

that toxic effects become more pronounced after particle accumulation reaches a critical level in the insect body [26], [19]. Thus, this probit analysis not only provides a quantitative overview of the relative toxicity of the two Liq-K-sils, but also provides a strong scientific basis for determining biologically and methodologically relevant further test concentrations.

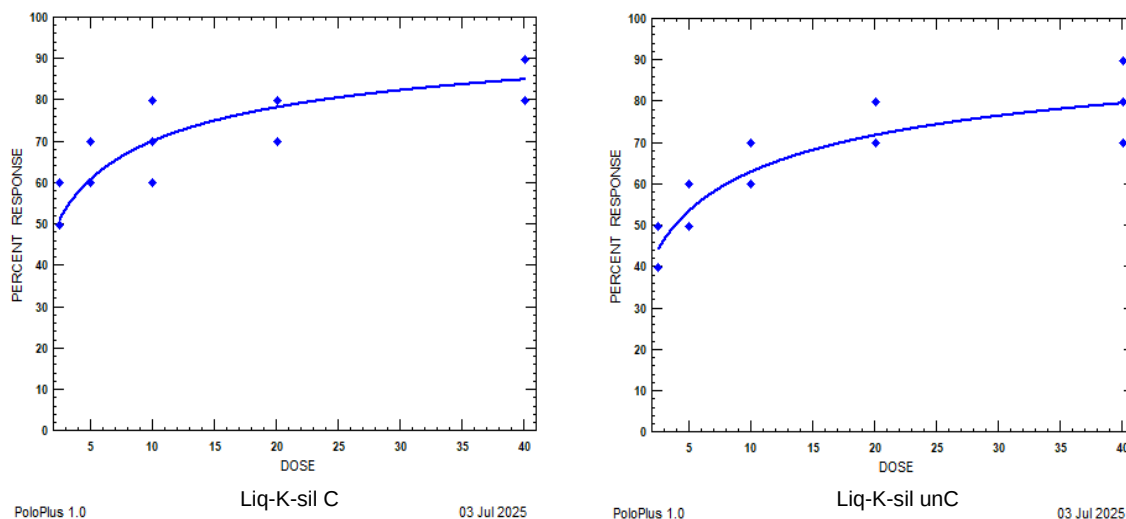


Fig. 1. The correlation between concentration and mortality of second instar larvae FAW threatened with Liq-K-sil C and Liq-K-sil unC

The use of biosilica supports a more sustainable pest control approach because it is derived from natural sources, readily biodegradable, and has the potential to reduce dependence on synthetic insecticides. Therefore, biosilica has strong prospects for development as a component of an Integrated Pest Management (IPM) system for FAW.

4. Conclusion

The results of this study indicate that Liq-K-sil has the potential to be developed as a biosilica-based pest control component within an IPM framework. However, further research is needed to provide more detailed formulation stability, field activity resistance, and toxicity mechanisms. Furthermore, evaluating the impact of Liq-K-sil on non-target organisms and its compatibility with biological control agents is crucial before field-scale application. This approach is expected to support the development of more effective, sustainable, and environmentally friendly FAW control strategies.

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