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COMPARATIVE EFFICACY OF FOUR INSECTICIDES TO CONTROL BRINJAL (*SOLANUM MELONGENA* L.) SHOOT AND FRUIT BORER

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ABSTRACT

Brinjal (*Solanum melongena* L.) is a crucial vegetable in the agricultural landscapes of South and South-East Asia, experiencing widespread cultivation globally. However, the prevalence of pests, including the brinjal shoot and fruit borer identified as *Leucinodes orbonalis*, poses a significant threat to crop yield. In the present study, four insecticides namely Ampligo, Emamectin, Volium Flex, and Proclaim having concentration of 0, 5, 10, 20 and 30% were used against 3rd and 5th instar. Among these, Ampligo exhibited noteworthy efficacy as evidenced by the lowest LC_{50} value. Moreover, increasing concentrations of fungicides were correlated with higher mortality percentage in both 3rd and 5th instars of the borer. These results emphasize the promising potential of Ampligo as a key player in controlling the infestation of the brinjal shoot and fruit borer, offering a robust and effective solution to mitigate the economic impact of this persistent pest on brinjal crop.

Key-words: Ampligo, Eggplant, Insecticides, *Leucinodes orbonalis*, Shoot and fruit borer.

INTRODUCTION

Brinjal also known as eggplant stands as an important vegetable in the agricultural landscapes of South and South-East Asia, particularly in regions characterized with hot and humid climates such as Nepal and Mainali (Neupane *et al*., 2020). Belonging to the Solanacae family, it ranks among the most commonly cultivated vegetables within this botanical group (Motti, 2021). Originating from the Indo-Pak Subcontinent, brinjal holds global significance, with cultivation extending over 2,766,181 hectares and a production volume of 96,105,332 tons (Butt *et al*., 2018). In Pakistan, it occupies 7,194 hectares, contributing to an annual production of 106,177 tons (Khokhar, 2014). Brinjal cultivation faces challenges from a range of pests, both insect and non-insect, in total more than 36 identified attackers (Omprakash *et al*., 2014). Notable among these are the brinjal shoot and fruit borer represented by *Leucinodes orbonalis* (Hamza *et al*., 2023), the coccinellid beetle (*Epilachna vigintioctopunctata*) (Ullah *et al*., 2022), whitefly (*Bemisia tabaci*), aphid (*Aphis gossypii*), Jassid (*Amrasca bigutulla bigutulla*), hairy caterpillar (*Amsacta albistriga*), spider mites (*Tetranychus urticae*), and brinjal mealy bug (*Coccidohystrix insolita*) (Shivalingaswamy *et al*., 2022; Maqsood *et al.*, 2023). The shoot and fruit borer, acknowledged as the primary pest of brinjal, poses a significant threat in brinjal-producing nations worldwide (Rahaman, 2017). The potential damage inflicted by a single larva is considerable, capable of affecting 4-6 healthy fruits. In cases of severe infestation, the damage can escalate up to 90%, significantly diminishing the economic value of the brinjal crop (Nath, 2007). The larvae of the brinjal shoot and fruit borer exhibit a destructive behavior by burrowing into the fruit or shoots, leading to the withering of the affected plant. The adult female moths deposit their eggs on the undersides of flower buds, leaves, or the base of developing fruits. The larvae undergo five to six instars and subsequently pupate on plant fragments or waste found on the soil surface (Mainali *et al*., 2013). The impact of *L. orbonalis* larvae extends to a reduction in plant growth and a decrease in the size of the affected fruits. The overall consequences of this infestation contribute to significant agricultural challenges, compromising the health and productivity of brinjal crops (Shaukat *et al*., 2018). Despite the adverse effects of pesticide residues on human health and the environment, it is essential to recognize the significant benefits that pesticides bring to agriculture. Pesticides are instrumental in safeguarding crops from pests, diseases, and weeds, thereby ensuring increased agricultural productivity and a stable food supply (Ali *et al.*, 2023). Moreover, they offer a cost-effective means of pest control compared to alternative methods, contributing to the efficiency of farming practices. The use of pesticides helps in maintaining crop quality and aesthetics by preventing damage and ensuring that fruits and vegetables meet market standards (Nicolopoulou-Stamati *et al.*, 2016). Additionally, pesticides play a crucial role in stabilizing food prices and promoting global food security by preventing crop failures due to pest infestations. Ongoing research and development in pest control contribute to the creation of more targeted and environment friendly products, such as integrated pest management approaches. Responsible pesticide use, incorporating sustainable practices, is key to mitigating negative impacts on non-target organisms and the environment while maximizing the benefits of these essential agricultural tools (Dara, 2019). The objective of the present study was to utilize four distinct insecticides namely Ampligo, Emamectin, Volium Flex, and Proclaim to assess their effectiveness in controlling brinjal shoot and fruit borer. Each of these insecticides likely comes with unique properties and mode of action, contributing to a comprehensive approach in managing the pest infestation (Mostoviak *et al*., 2022). The choice of multiple insecticides may enhance the efficacy of control by targeting the brinjal stem and fruit borer at different stages of its life cycle or through varied mechanisms.

MATERIALS AND METHODS

Collection and sampling

Sampling was done during a field visit to a vegetable area situated along Multan Road in Lahore on June 15, 2022. Approximately 40 kilograms of infested brinjals were collected and transported to the Insecticides and Weedicides Resistance Laboratory within the Faculty of Agricultural Sciences (FAS) at the University of the Punjab, Lahore, Pakistan. Subsequently, a second survey was conducted at a farm covering an expansive 70-acre area near Jatti Umra, Raiwind Road, Lahore. During this survey, about 30 kg of infested brinjals were gathered and transported back to the laboratory. Upon securing the infested brinjal fruits, a precise dissection was carried out using a knife to collect various instars of brinjal fruit borers. These distinct larvae were then carefully segregated into different Petri dishes, employing a sterilized camel hairbrush, within a designated plastic container. To sustain the larvae during the research, all specimens were provided with nourishment in the form of small brinjal pieces, as illustrated in Fig. 1.

Mass rearing of borer using artificial diets

The adult population obtained from Lahore underwent a controlled rearing process within dedicated rearing cages at the Insecticides and Weedicides Resistance Laboratory. This population served as the stock for the reference population of the brinjal shoot and fruit borer. To establish the reference population, fifty pupae were selected and placed in Petri dishes, each located inside individual rearing boxes. Maintaining a gender ratio of 3:1 (female to male), the adults were carefully placed in a glass jar measuring 10 cm in height and 7 cm in diameter to facilitate successful mating. The open end of the jar was securely covered with a piece of white cloth, tightly sealed using a rubber band. To sustain the adults, a small cotton ball soaked in a 10% sugar solution was positioned inside the jar. Following successful mating, females deposited eggs, both in clusters and individually, on the inner surface of the white cloth. For further observations, 10 to 15 newly hatched larvae were delicately extracted from the jar and placed on slices of an artificial diet. This diet was then housed in containers with hygienic tissue paper. A consistent supply of fresh diet pieces occurred at intervals of 3 to 4 days, ensuring the sustenance of the larvae. Only 2nd instar larvae were transferred to a new piece of the diet during this process. The collection of pupae marked the conclusion of each cycle, and this comprehensive procedure was repeated continuously throughout the study duration.

Composition and preparation of the artificial diet

Rearing was conducted within a controlled environmental room with a light-to-dark cycle of 12:12 hours, relative humidity was maintained at 60±5%, and a temperature was set at 25±10°C. To enhance the diet's viscosity, 150 mL of double-distilled water was introduced during the dispensing of the final diet. The base ingredients consisted of a blend of 30 g of brinjal powder and 60 g of coarsely ground Bengal gram. Approximately 200 g of this diet mixture was dispensed into diet plates and allowed to solidify. An adjustment to the agar powder quantity was made by incorporating an additional 5 g of agar powder. The dried granules of yeast were substituted with a purified yeast extract. Diet plates measuring 12 × 75 mm were removed approximately 24 hours before use and acclimatized to room temperature. To maintain optimal moisture levels, lids were partially opened, allowing excess moisture to escape. The diet, cut into 2.5 g pieces, was then transferred to plastic containers. Utilizing a camel hairbrush, five neonate larvae were introduced into each plastic container. The overall artificial diet was prepared following the procedures outlined by **(**Sethi *et al*., 2016**)**

Probit analysis

Probit analysis was performed in MS Excel to evaluate the insecticidal efficacy of Ampligo, Emamectin, Volium, and Proclaim. Test organisms were exposed to varying concentrations of each insecticide at intervals of 5, 10, 20, and 30 minutes. Mortality rates were recorded and used to calculate Probit values. Following procedure were used for probit analysis.

- **Data input:** Concentration and mortality data were entered into MS Excel.
- **Probit Calculation:** Probit values were derived using linear regression (y = mx + c).
- **LC50 Values:** Calculated to determine the concentration causing 50% mortality.

Statistical analysis

The survival data were transformed into percentage corrected mortality using Abbot's formula (Fleming and Retnakaran, 1985). Subsequently, the data from different treatments were subjected to analysis through ANOVA, and any observed means were further compared employing Tukey's HSD test. The statistical analysis of the data was performed using Statistix 8.1 software.

RESULTS

Efficacy of insecticides

The experiment conducted to evaluate the impact of various concentrations of four insecticides on larvae of brinjal stem and fruit borer at the 3rd and 5th instar stages employed a three-way analysis of variance (ANOVA). The effects of insecticides (I), instar stages (S) and the concentrations (C) were significant ($P \leq 0.001$) for mortality of brinjal shoot and fruit borer. Likewise, interactive effects of I × C and S × C were also significant ($P \leq 0.001$) for this studied parameter. By contrast, the effects of I × S and I × S × C were insignificant for the insect mortality (Table 1). The effect of insecticide (I) was pronounced, with a statistically significant F-value of 187. This suggests that the choice of insecticide had a substantial impact on the observed responses in the larvae. Similarly, the instar stage (S) was found to be a significant factor (F-value of 76), indicating that the developmental stage of the larvae played a crucial role in their responses to the insecticides. Concentration (C) was identified as a highly significant factor, with a substantial F-value of 2349. This underscores the importance of the concentration levels of the insecticides in influencing the responses of the larvae. Further analysis of interaction effects between factors revealed significant interactions between Insecticide and Concentration as well as between Instar Stage and Concentration, with F-values of 13.6 and 12.2, respectively. These interactions indicate that the combined effects of insecticide type and concentration, as well as instar stage and concentration, were crucial in determining the outcomes. Interestingly, no significant interactions were observed between Insecticide and instar stage, insecticide, instar stage, and concentration, suggesting that the combined effects of these factors did not significantly contribute to the observed variations.

The mortality was measured as percentages, and the results revealed a concentration-dependent effect for each insecticide. At 0% concentration (control), the mortality of 3^{rd} instar was relatively low, ranging from 1.33% to 4.33%. However, as the concentration increased, a significant rise in mortality was observed for all insecticides. At the highest concentration (30%), the mortality reached to 64.66% (Proclaim) to 90.33% (Ampligo) (Fig. 2A). In the investigation against 5^{th} instar larvae, effectiveness of the insecticides was similar as that against 3^{rd} instar larvae. In control treatment, the mortality ranged from 1.66% to 3.66%. As the concentration increased, a notable escalation in mortality was observed for all insecticides. At 5% concentration, the mortality was 24, 18, 114 and 13% due to application of Ampligo, Emamectin, Volium Flex, and Proclaim that was increased to 33, 36, 26 and 25% at 10% concentration, 72, 58, 55 and 44% at 20% concentration, and 82, 69, 64 and 56% at 30% concentration, respectively. These results indicate a concentration-dependent efficacy of the tested insecticides in controlling fifth instar brinjal stem and fruit borer, with higher concentrations demonstrating increased effectiveness. These results indicate that Ampligo demonstrated the highest effectiveness in controlling brinjal shoot and fruit borer (Fig. 2B).

Probit analysis

In the presented Probit analysis, the relationship between concentration (x) and Probit values (y) can be interpreted akin to a linear equation, y = mx + c, where 'm' represents the slope and 'c' the intercept. In the conducted research, a comprehensive Probit analysis was employed to assess the insecticidal efficacy of four distinct compounds: Ampligo, Emamectin, Volium, and Proclaim. The investigation involved exposing a population of test organisms to varying concentrations of each insecticide at different time intervals (5, 10, 20, and 30). The concentration-response relationship was meticulously characterized through Probit values, representing the logarithmically transformed probability of observing a particular biological response, such as mortality, at each concentration. Notably, the LC_{50} values, denoting the concentration at which 50% mortality occurred, were identified as crucial indicators of insecticidal potency (Table 2).

The obtained LC_{50} values for each insecticide were as follows: 10.56 for Ampligo, 15.14 for Emamectin, 15.21 for Volium, and 16.83 for Proclaim. These values serve as pivotal benchmarks in assessing the relative toxicological impact of each compound on the target organisms. A lower LC_{50} value suggests a higher potency, signifying that a lower concentration of the insecticide is needed to achieve a significant mortality rate. Ampligo with the lowest LC_{50} value among the tested insecticides, found the most potent or effective insecticide in terms of mortality in the tested organisms at lower concentrations.

Table 1. Three-way ANOVA for the effect of different concentrations of four insecticides against larvae of brinjal stem and fruit borer at 3^{rd} and 5^{th} instar stages

Sources of variation	**Df**	**Sum of squares**	**Mean squares**	**F-values**
Insecticide (I)	3	4863	1621	187^{*}
Instar stage (S)	1	663	663	76^{*}
Concentration (C)	4	81419	20355	2349^{*}
I × S	3	12	3.9	0.44^{ns}
I × C	12	1414	118	13.6^{*}
S × C	4	423	106	12.2^{*}
I × S × C	12	37	3.1	0.36^{ns}
Error	80	693	8.7	
Total	119	89524		

*: Significant at $P \leq 0.001$; ns: Non-significant

Table 2. The Probit analysis of four insecticide.

Instar	**Conc.**	**Log(10)**	**Ampligo**	**Probit**	**Emamectin**	**Probit**	**Volium**	**Probit**	**Proclaim**	**Probit**
3rd Instar	5	0.698	26	4.36	20	4.16	16	4.01	13.66	3.92
	10	1.000	47.33	4.92	36.66	4.67	32	4.53	26	4.36
	20	1.301	81	5.88	69	5.5	64	5.36	53.33	5.08
	30	1.477	90.33	6.28	77.33	5.74	73	5.61	64.66	5.39
5th Instar	5	0.698	24	4.29	18	4.08	13.66	3.92	13.33	3.87
	10	1.000	33	4.56	35.66	4.64	26.33	4.36	24.66	4.33
	20	1.301	72.33	5.58	57.66	5.2	54.66	5.1	44.33	4.85
	30	1.477	82.33	5.92	69	5.5	63.66	5.33	56	5.15
			Lc50: 10.56		**Lc50: 15.14**		**Lc50: 15.21**		**Lc50: 16.83**	

Fig. 1. Collecting different instars of brinjal shoot and fruit borer from infested brinjal fruits.

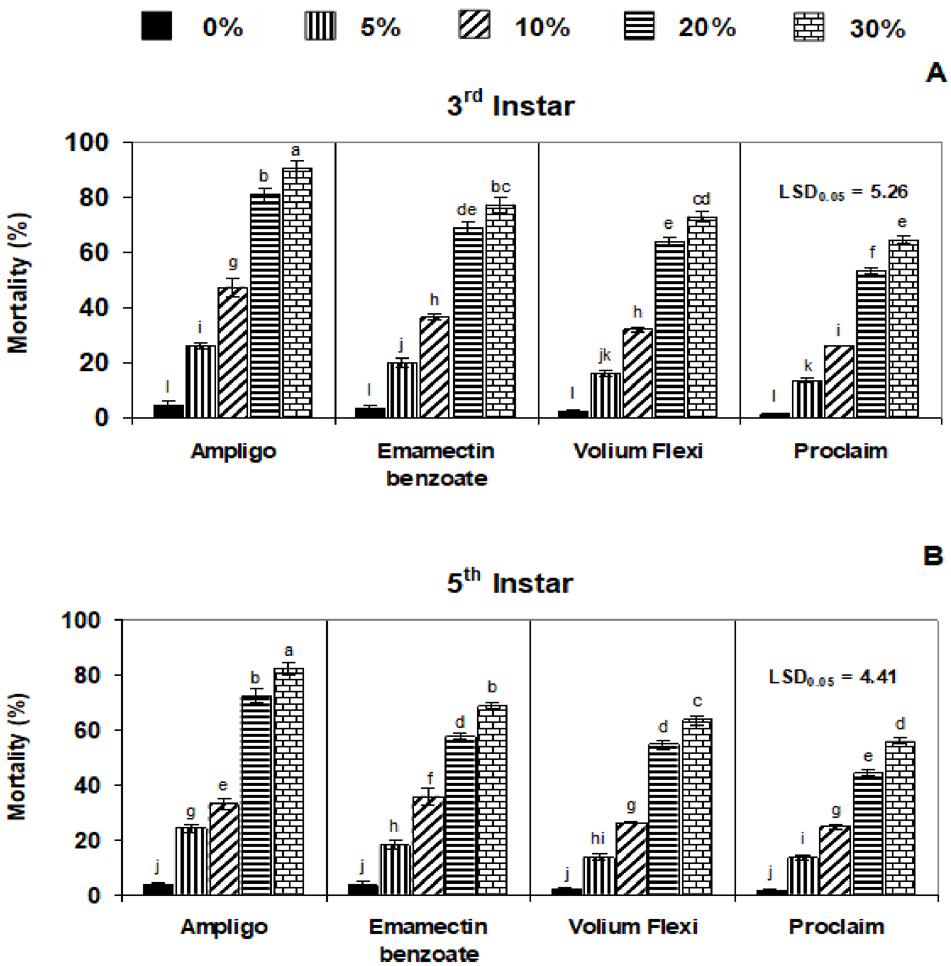

Fig. 2. Effect of different concentrations of four insecticides on mortality of brinjal stem and fruit borer at 3rd and 5th instar stages. Vertical bars show standard errors of means of three replicates. Values with different letters at their top show significant difference ($P \leq 0.05$) as determined by LSD Test.

DISCUSSION

The cultivation of brinjal faces a critical challenge in the form of the brinjal shoot and fruit borer that posing a threat to global crop yields (Dang *et al*., 2021). While acknowledging the well-documented adverse effects of pesticide residues on human health and the environment, it is imperative to underscore the indispensable role of pesticides in safeguarding brinjal crops. Pesticides play a pivotal role in ensuring increased agricultural productivity, maintaining a stable food supply, and offering a cost-effective means of pest control. Moreover, they contribute significantly to the efficiency of farming practices and the preservation of crop quality, aligning with market standards. The nuanced discussion surrounding pesticide use in brinjal cultivation calls for a balanced approach that considers both environmental concerns and the imperative of sustaining agricultural productivity through responsible and integrated pest management strategies (Verma *et al*., 2023).

The investigation into the efficacy of four distinct insecticides—Ampligo, Emamectin, Volium Flex, and Proclaim—reveals crucial insights into their effectiveness in controlling the mortality of third and fifth instar brinjal stem and fruit borer. The overarching theme of concentration-dependent efficacy emerged as a central aspect of the study's findings, underscoring the nuanced dynamics between insecticide concentrations and their impact on pest populations (Settar *et al*., 2023).

The pivotal observation in this study is the concentration-dependent effect exhibited by each of the tested insecticides. The clear correlation between increasing concentrations and elevated mortality rates signifies the relevance of dosage precision in formulating effective pest management strategies. As the concentration of insecticides rises, so does their efficacy, a fundamental principle that aligns with established practices in integrated pest management. This concentration-dependent trend aligns with existing literature on pesticide effectiveness. The dosage-response relationship is a well-documented phenomenon, emphasizing the need for meticulous calibration of insecticide concentrations to achieve optimal results. Farmers and practitioners can leverage this knowledge to tailor their insecticide application strategies, ensuring a judicious use of resources while maximizing pest control outcomes (Ebert *et al.,* 1999 Downer and Hall, 1999).

A noteworthy outcome of the study is the identification of differential efficacy among the tested insecticides. While all formulations demonstrated increased mortality rates with higher concentrations, Ampligo consistently outperformed its counterparts. This distinction is of practical significance, as it provides a basis for informed decision-making in selecting the most effective insecticide for brinjal stem and fruit borer control. Ampligo's superior performance suggests unique attributes or formulations that contribute to its heightened efficacy. Further exploration into the specific mechanisms underlying Ampligo's effectiveness could unveil valuable insights for refining insecticide formulations or developing targeted alternatives for enhanced pest management (Chinwada *et al.,* 2023).

The study's extension of its investigation to different instar stages contributes a nuanced understanding of insecticide efficacy. The comparable concentration-dependent patterns observed for both third and fifth instar larvae underscore the consistent mode of action exhibited by the tested insecticides across developmental stages. This finding simplifies decision-making for practitioners, indicating that the same concentration levels can be effective against larvae at different developmental phases. The consideration of instar stages is pivotal in developing comprehensive pest management strategies. The observed patterns suggest that the selected insecticides target vulnerabilities common to both instar stages, thereby providing a versatile approach to pest control in brinjal cultivation (Alam *et al.,* 2003).

Farmers can leverage this information to optimize their pest management approaches by adjusting insecticide concentrations based on the severity of infestations. Ampligo, with its consistently superior performance, emerges as a standout option for effective pest control, especially when higher concentrations are warranted. The practical implications extend beyond immediate pest control to considerations of sustainability and economic viability. Informed decision-making regarding insecticide selection and dosage not only enhances efficacy but also contributes to reduced environmental impact and minimized production costs (Shaikh *et al.,* 2022).

While the study sheds light on crucial aspects of insecticide efficacy, it is imperative to acknowledge its limitations. The focus on four specific insecticides may not capture the full spectrum of available formulations. Future research could broaden the scope to encompass a more extensive array of insecticides, providing a more comprehensive understanding of the comparative efficacy landscape. Moreover, the study's emphasis on mortality rates as the primary endpoint prompts consideration of additional factors. Future investigations could explore the broader ecological and agronomic impacts of the tested insecticides, including potential effects on non-target organisms, long-term effects on brinjal plant health, and the development of resistance in pest populations.

Conclusion

The findings of this study contribute valuable insights into the intricate dynamics of insecticide efficacy against brinjal shoot and fruit borer. Ampligo was found to be the most effective insecticide against this pest. However, the other three fungicides also showed considerable efficacy especially Emamectin against this pathogen.

Conflict of interest

The authors declare that they have no conflict of interest.

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