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BIO-EFFICACY OF *Beauveria bassiana* (Balsamo) VUILLEMIN WITH INSECTICIDES AGAINST FALL ARMYWORM, *Spodoptera frugiperda* (J.E. Smith) UNDER LABORATORY CONDITIONS

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ABSTRACT

A laboratory experiment was conducted during the period from September to November 2025 to evaluate the bio-efficacy of *Beauveria bassiana* in combination with selected insecticides against the third instar larvae of fall armyworm at the Biological Control Research Laboratory, ICAR Unit-9, Anand Agricultural University, Anand, Gujarat, India. Insecticides were evaluated alone at the recommended concentration and at half of the recommended concentration in combination with *B. bassiana*. Isocycloseram 18.1 SC, broflanilide 20 SC, chlorantraniliprole 18.5 SC, emamectin benzoate 1.9 EC and *B. bassiana* 1% WP + isocycloseram 18.1 SC recorded complete mortality after 96 hours. The larval mortality in *B. bassiana* 1% WP was 66.67 per cent.
Keywords **:** Bio-efficacy, *Beauveria bassiana*, Insecticide, Fall armyworm, Mortality

Introduction

Maize (*Zea mays* Linnaeus) has been one of the most significant and widely grown cereal crops, valued not only as a staple food but also for its straw, which is used for animal feed, fuel and construction (Abebe & Feyisa, 2017). Globally, in 2024, it was grown on approximately 204.23 million ha area with a total production of 1,241.56 million tonnes and productivity of 5962 kg/ha (Anonymous, 2024). In India, during 2023-24, maize was cultivated on 10.74 million ha, with 8.66 million ha in the *kharif* season and 2.08 million ha in the *rabi* season. The total annual maize production was 38.08 million tonnes, comprising 25.75 million tonnes from *kharif* and 12.33 million tonnes from *rabi*. The average productivity was recorded at 3545 kg/ha, with the productivity of 2706 kg/ha in *kharif* and 4436 kg/ha in *rabi* (Anonymous, 2024). The leading maize-producing states in India are Madhya Pradesh, Karnataka, Maharashtra, Rajasthan, Tamil Nadu, Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Himachal Pradesh and Uttar Pradesh (Kumar *et al*., 2014). In India, maize is susceptible to infestations by approximately 130 species of insect pests (Atwal & Dhaliwal, 2002).

Fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) is a highly migratory, nocturnal pest with a strong reproductive capacity and intense feeding activity. It is originally native to the tropical and subtropical regions of the Americas (Sah *et al*., 2019). In West and Central Africa, it was first reported in early 2016 (Goergen *et al*., 2016). Since then, it has expanded its presence to numerous countries across the globe. In India, it was first time reported from Karnataka on maize by Sharanabasappa *et al*. (2018).

Fall armyworm is highly polyphagous pest with an immense appetite for maize and the ability to survive on more than 76 plant families and 353 crop species (Montezano *et al*., 2018). In addition to cereals such as maize, wheat, sorghum, millet and rice, it also infests pasture grasses, sugarcane, cotton, potato, sweet potato, ginger, chrysanthemum, tomato, tobacco, spinach, crucifers, cucurbits, cucumber, cowpea, common bean, soybean, groundnut and banana

(Anonymous, 2018). The fall armyworm has two distinct strains: the 'rice strain' and the 'maize strain' (Adamczyk *et al*., 1997). Among these, the maize strain is more dominant and it primarily feeds on maize leaves and stems. The damage caused by fall armyworm infestations can lead to significant yield losses, reducing maize yield by up to 34 per cent in Brazil (Lima *et al*., 2010), between 20 to 50 per cent in Africa (Early *et al*., 2018).

This pest causes severe damage to maize crops, often leading to the use of chemical insecticides. To reduce insecticide usage and promote environmental safety, combining entomopathogenic fungi with insecticides is a sustainable solution. Entomopathogenic fungi, *viz*., *Beauveria bassiana*, *Metarhizium anisopliae* and *Lecanicillium lecanii* have significant potential to effectively control various arthropod pests (Ferron, 1978). Variations in toxicity response of entomopathogenic fungi from synergistic, antagonistic or neutral to insecticides have been observed (Mietkiewski & Gorski, 1995; Gupta *et al*., 1999). Fungal biological control agents and selective insecticides may act synergistically, increasing the efficiency of the control, allowing the lower doses of insecticides, preservation of natural enemies, minimizing environmental pollution and decreasing the likelihood of development of resistance to either agent (Ambethgar, 2009). Considering the significance of the pest and the facts discussed above, the present study was conducted to evaluate the bio-efficacy of *B. bassiana* with insecticides against fall armyworm, *S. frugiperda*, under laboratory conditions.

Materials and Methods

The study on the bio-efficacy of *B. bassiana* in combination with insecticides against fall armyworm was conducted at the Biological Control Research Laboratory, ICAR Unit-9, Anand Agricultural University, Anand, Gujarat, India in the year 2025. The experiment was conducted using a Completely Randomized Design (CRD) comprising ten treatments, including one untreated control. Three repetitions were maintained for each set. Detailed information regarding the treatments is given below.

Table 1: Details of treatments

Tr. No.	Treatments	Quantity of formulations required (ml or g/L of water)
T_1	*B. bassiana* 1% WP + isocycloseram 18.1 SC	2.00 + 0.30
T_2	*B. bassiana* 1% WP + chlorantraniliprole 18.5 SC	2.00 + 0.15
T_3	*B. bassiana* 1% WP + emamectin benzoate 1.9 EC	2.00 + 0.525
T_4	*B. bassiana* 1% WP + broflanilide 20 SC	2.00 + 0.125
T_5	Isocycloseram 18.1 SC	0.60
T_6	Chlorantraniliprole 18.5 SC	0.30
T_7	Emamectin benzoate 1.9 EC	1.05
T_8	Broflanilide 20 SC	0.25
T_9	*B. bassiana* 1% WP	4.00
T_{10}	Control	-

Mass rearing of fall armyworm

The culture of fall armyworm, *S. frugiperda*, was initiated by collecting larvae from the field and bringing them to the Biological Control Research Laboratory, ICAR Unit-9, Anand Agricultural University, Anand. Each larva was transferred into separate plastic vial (Diameter: 50 mm, height: 40 mm) having pin-sized holes on the cap. Pieces of fresh maize leaves were provided daily as food to the larvae and frass was discarded regularly. After pupation, the pupae were collected and placed in Petri plate (Diameter: 90 mm). Before adult emergence, the pupae were transferred into oviposition cage (length: 30 cm, breadth: 30 cm and height: 30 cm) made from glass. Aproximately 30 day old maize plants with stem were placed in conical flasks (Capacity: 250 ml) containing 150 ml of water. The mouth of the conical flask was sealed with a cotton plug. Cotton swabs dipped in a 5 per cent honey solution were placed in the cage as food for the adults. Maize plants were replaced after every two days and egg masses were carefully collected. The collected eggs were transferred into plastic containers (Diameter: 20 cm, height: 7 cm) covered at the top with black muslin cloth to prevent escape of larvae and to maintain favourable conditions for nocturnal larvae. After every 24 hours fresh food was provided and frass as well as uneaten food was removed. After reaching the third instar, the larvae were individually transferred into plastic vials (Diameter: 50 mm, height: 40 mm) to prevent cannibalism and subsequently used for mass culturing and bio-efficacy trial.

Bio-efficacy of *B. bassiana* in combination with insecticides

Ten third-instar larvae of *S. frugiperda* were obtained from mass culture and released into plastic vials (Diameter: 50 mm, height: 40 mm). To avoid cannibalism, only one larva was released into one plastic vial. Larvae were starved for 6 hours, thereafter treatment wise treated food was provided. Fresh leaves of maize were cut into small pieces and were sprayed with respective spray solution. The spray solution was prepared as per the treatment details given earlier. Sprayed leaves were allowed to dry under the fan. After drying, pieces of leaves were placed into plastic vials (Diameter: 50 mm, height: 40 mm) as food to the larvae. After 24 hours, untreated fresh food was provided to the larvae. Larval mortality was recorded at 24, 48, 72 and 96 hours after exposure of larvae to the treated food.

The per cent of larval mortality was calculated using the following formula.

$$\text{Mortality (\%)} = \frac{\text{No. of dead larvae}}{\text{Total no. of larvae}} \times 100$$

Statistical Analysis

The data on per cent larval mortality were subjected to analysis of variance (ANOVA). Before analysis the data on per cent larval mortality were transformed using arcsine transformation. The treatment means were compared using Duncan's New Multiple Range Test at 5% level of significance (Steel & Torrie, 1980).

Results and Discussion

The data on larval mortality of *S. frugiperda* recorded after 24,48,72 and 96 hours are presented in Table 2.

Larval mortality after 24 hours

At 24 hours after treatment, differences in larval mortality of fall armyworm were significant (Table 1). Isocycloseram 18.1 SC recorded the highest larval mortality of 43.33 per cent and was significantly superior to the rest of the treatments, except broflanilide 20 SC (40.00%). The treatment of broflanilide 20 SC was also at par with chlorantraniliprole 18.5 SC (36.67%). Emamectin benzoate 1.9 EC, *B. bassiana* 1% WP + isocycloseram 18.1 SC and *B. bassiana* 1% WP + broflanilide 20 SC recorded similar larval mortality of 30.00 per cent. They were followed by *B. bassiana* 1% WP + chlorantraniliprole 18.5 SC (23.33%) and *B. bassiana* 1% WP + emamectin benzoate 1.9 EC (20.00%) and they were also at par with each other. The larval mortality in *B. bassiana* 1% WP and control was 10.00 and 0.00 per cent respectively. Both treatments differed significantly from each other.

Table 2: Effect of *B. bassiana* in combination with insecticides on mortality of fall armyworm, *S. frugiperda*

Tr. No.	Treatments	Quantity of formulations required (ml or g/L of water)	Larval mortality (%) at indicated hours			
			24	48	72	96
T_1	*B. bassiana* 1% WP + isocycloseram 18.1 SC	2.00 + 0.30	33.21^{c} (30.00)	44.99^{cd} (50.00)	56.79^{cd} (70.00)	88.97^{a} (100.00)
T_2	*B. bassiana* 1% WP + chlorantraniliprole 18.5 SC	2.00 + 0.15	28.78^{d} (23.33)	39.23^{ef} (40.00)	50.77^{ef} (60.00)	66.14^{c} (83.33)
T_3	*B. bassiana* 1% WP + emamectin benzoate 1.9 EC	2.00 + 0.525	26.56^{d} (20.00)	37.22^{fg} (36.67)	48.85^{fg} (56.67)	63.43^{c} (80.00)
T_4	*B. bassiana* 1% WP + broflanilide 20 SC	2.00 + 0.125	33.21^{c} (30.00)	43.08^{de} (46.67)	54.76^{de} (66.67)	77.71^{b} (93.33)
T_5	Isocycloseram 18.1 SC	0.60	41.15^{a} (43.33)	54.78^{a} (66.67)	68.86^{a} (86.67)	88.97^{a} (100.00)
T_6	Chlorantraniliprole 18.5 SC	0.30	37.22^{b} (36.67)	50.77^{ab} (60.00)	63.43^{ab} (80.00)	88.97^{a} (100.00)
T_7	Emamectin benzoate 1.9 EC	1.05	33.21^{c} (30.00)	48.85^{bc} (56.67)	61.22^{bc} (76.67)	88.97^{a} (100.00)
T_8	Broflanilide 20 SC	0.25	39.23^{ab} (40.00)	52.78^{ab} (63.33)	83.33^{ab} (83.33)	88.97^{a} (100.00)
T_9	*B. bassiana* 1% WP	4.00	18.43^{e} (10.00)	33.21^{g} (30.00)	45.00^{g} (50.00)	55.05^{d} (66.67)
T_{10}	Control	-	0.91^{f} (0.00)	0.91^{h} (0.00)	0.91^{h} (0.00)	0.91^{e} (0.00)
S.Em. ±			1.12	1.40	1.65	2.72
CD at 5%			3.31	4.11	4.87	8.03
C.V. (%)			6.67	5.96	5.54	6.66

Notes: (1) Figures outside the parentheses are arcsine transformed values and those inside the parentheses are original values

(2) Treatment means followed by the same letter within a column are not significantly different by Duncan's New Multiple Range Test at 5% level of significance

Larval mortality after 48 hours

Larval mortality of fall armyworm at 48 hours after exposure differed significantly among the treatments. The highest larval mortality was observed in isocycloseram 18.1 SC (66.67%), which was at par with broflanilide 20 SC (63.33%) and chlorantraniliprole 18.5 SC (60.00%). The treatment of broflanilide 20 SC and chlorantraniliprole 18.5 SC were also at par with emamectin benzoate 1.9 EC, which recorded 56.67 per cent larval mortality and was statistically not different from *B. bassiana* 1% WP + isocycloseram 18.1 SC (50.00%). The treatment of *B. bassiana* 1% WP + broflanilide 20 SC (46.67%) was statistically at par with *B. bassiana* 1% WP + chlorantraniliprole 18.5 SC, which recorded 40.00 per cent larval mortality. The treatment of *B. bassiana* 1% WP + chlorantraniliprole 18.5 SC was also at par with *B. bassiana* 1% WP + emamectin benzoate 1.9 EC (36.67%). The treatment of *B. bassiana* 1% WP (30.00%) exhibited lowest larval mortality among all the treatments except control, indicating lower effectiveness as compared to chemical insecticides and their combined application with *B. bassiana*. The larval mortality in the control was nil.

Larval mortality after 72 hours

At 72 hours after treatment, larval mortality of fall armyworm showed significant differences among the treatments (Table 1). The highest mortality of 86.67 per cent was recorded in isocycloseram 18.1 SC, which was at par with broflanilide 20 SC (83.33%) and chlorantraniliprole 18.5 SC (80.00%). The treatment of broflanilide 20 SC and chlorantraniliprole 18.5 SC were statistically not different from emamectin benzoate 1.9 EC (76.67%). The next treatment in order to be effectiveness was *B. bassiana* 1% WP + isocycloseram 18.1 SC, which recorded 70.00 per cent larval mortality and was at par with *B. bassiana* 1% WP + broflanilide 20 SC (66.67%). The larval mortality in *B. bassiana* 1% WP + chlorantraniliprole 18.5 SC (60.00%) and *B. bassiana* 1% WP + emamectin benzoate 1.9 EC (56.67%) were also statistically similar. The treatment of *B. bassiana* 1% WP (50.00%) resulted in the lower larval mortality, making it the least effective treatment among the insecticidal and biopesticidal treatment or their combination. The larval mortality in the control was nil. Larval mortality after 96 hours

At 96 hours after exposure, the data on larval mortality revealed significantly diffrences among treatments (Table 1). Treatment of *B. bassiana* 1% WP + isocycloseram 18.1 SC, isocycloseram 18.1 SC, chlorantraniliprole 18.5 SC, emamectin benzoate 1.9 EC and broflanilide 20 SC recorded complete mortality (100%) of larvae of *S. frugiperda*. The next treatment in order of effectiveness was *B. bassiana* 1% WP + broflanilide 20 SC, which recorded 93.33 per cent larval mortality. The treatment of *B. bassiana* 1% WP + chlorantraniliprole 18.5 SC (83.33%) and *B. bassianna* 1% WP + emamectin benzoate 1.9 EC (80.00%) recorded lower larval mortality and both were statistically similar to each other. Treatment of *B. bassiana* 1% WP recorded the lower larval mortality of 66.67 per cent. Nil mortality was observed in the control.

The findings of the present study are in close agreement with Idrees *et al*. (2022), who reported that broflanilide 100 SC caused the highest larval mortality of *S. frugiperda* among the tested insecticides. Similarly, studies conducted by Adhikari *et al*. (2024) and Khanal *et al*. (2024) found that chlorantraniliprole recorded comparatively higher larval mortality of *S. frugiperda* than emamectin benzoate. Ismail *et al*. (2017) also reported that the combination of *B. bassiana* with chlorantraniliprole resulted in higher larval mortality of *S. frugiperda*. Ismail (2024), reported that *B. bassiana* applied alone resulted in lower larval mortality of *S. frugiperda* than the combination application with insecticides.

Conclusion

It can be deduced from the present investigation that the four insecticides (isocycloseram 18.1 SC, broflanilide 20 SC, chlorantraniliprole 18.5 SC, emamectin benzoate 1.9 EC), applied either at the recommended concentration or at half of the recommended concentration in combination with *B. bassiana*, exhibited varying levels of bio-efficacy against the third instar larvae of *S. frugiperda* under laboratory conditions. At 96 hours after exposure, isocycloseram 18.1 SC, broflanilide 20 SC, chlorantraniliprole 18.5 SC, emamectin benzoate 1.9 EC and *B. bassiana* 1% WP + isocycloseram 18.1 SC recorded the complete (100%) mortality. The larval mortality in the treatment of *B. bassiana* 1% WP was 66.67 per cent, which showed lower efficacy against the larvae compared to other treatments.

References

Abebe, Z., & Feyisa, H. (2017). Effects of nitrogen rates and time of application on yield of maize, rainfall variability influenced time of N application. *International Journal of Agronomy*, 2017 (1), 10.

Adamczyk, J. J., Holloway, J. W., Leonard, B. R., & Graves, J. B. (1997). Susceptibility of fall armyworm collected from different plant hosts to selected insecticides and transgenic *Bt* cotton. *Journal of Cotton Science*, **1** (1), 21-28.

Adhikari, C., Dhungana, S., Tiwari, S., Thapa, R. B., Neupane, S., & Sharma, S. D. (2024). Laboratory and field evaluation of insecticides against fall armyworm (*Spodoptera frugiperda* J. E. Smith) larvae on maize. *Journal of Plant Protection Society*, **9**(1), 66-78.

Ambethgar, V. (2009). Potential of entomopathogenic fungi in insecticide resistance management, a review. *Journal of Biopesticides*, **2** (2), 177-193.

Anonymous (2018). Fall armyworm. Retrieved from, https,// www.armyworm.org/ species/fall-farmyworm

Anonymous (2024). Area, production and yield of field crops. Food and Agriculture Organization of the United Nations. Retrived from, https,//www.fao.org /faostat/en/#data/QCL

Atwal, A. S., & Dhaliwal, G. S. (2002). *Agricultural pests of South Asia and their management*. New Delhi, India, Kalyani Publishers.

Early, R., Gonzales-moreno, P., Murphy, S. T., & Day, R. (2018). Forecasting the global of invasion of the cereal pest fall armyworm, *Spodoptera frugiperda*. *Neobiota*, **40**(3), 25-50.

Ferron, P. (1978). Biological control of insect pests by entomopathogenic fungi. *Annual Review of Entomology*, **23**(3), 409-423.

Goergen, G., Kumar, P. L., Sankung, S. B., Togola, A., & Tamò, M. (2016). First report of outbreaks of the fall armyworm, *Spodoptera frugiperda* (J. E. Smith) a new alien invasive pest in West and Central Africa. *PLOS ONE*, **11** (10), 1-9.

Gupta, P., Paul, M. S., & Sharma, S. N. (1999). Studies on compatibility of white muscardine fungus *Beauveria bassiana* with neem products. *Indian Phytopathology*, **52** (3), 278-280.

Idrees, A., Qadir, Z. A., Afzal, A., Ranran, Q., & Li, J. (2022). Laboratory efficacy of selected synthetic insecticides against second instar invasive fall armyworm, *Spodoptera frugiperda* (Lepidoptera, Noctuidae) larvae. *PLOS ONE*, **17** (5), e0265265.

Ismail, M., Wakil, W., Bashir, N. H., Hassan, W., & Muhammad, U. W. (2017). Entomocidal effect of entomopathogenic fungus *Beauveria bassiana* and new chemistry insecticides against *Spodoptera litura* (Fabricius) (Noctuidae, Lepidoptera) under controlled conditions. *International Journal of Agriculture Innovations and Research*, **5** (6), 1473-2319.

Ismail, S. M. (2024). Synergistic effects of *Beauveria bassiana*, diatomaceous earth and insecticides on mortality and enzyme activities of *Spodoptera frugiperda* (J. E. Smith). *International Journal of Advanced Biological and Biomedical Research*, **12** (3), 273-283.

Khanal, D., Subedi, D., Banjade, G., Lamichhane, M., Shrestha, S., & Chaudhary, P. (2024). Efficacy of different pesticides against fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera, Noctuidae) under laboratory conditions in Rupandehi, Nepal. *International Journal of Agronomy*, **20** (2), 71-88.

Kumar, N. V., Yasodha, P., & Justin, C. G. L. (2014). Seasonal incidence of maize fall armyworm *Spodoptera frugiperda* (J. E. Smith) in Perambalur district of Tamil Nadu, India. *Journal of Entomology and Zoology Studies*, **8** (3), 1-4.

Lima, M. S., Silva, P. S., Oliveira, O. F., Silva K. M., & Freitas, F. C. (2010). Corn yield response to weed and fall armyworm control. *Planta Daninha*, **28** (1), 103-111.

Meitkiewski, R., & Gorski, R. (1995). Growth of selected entomopathogenic fungi species and isolates on media containing insecticides. *Acta Mycologica*, **30** (1), 27-33.

Montezano, D. G., Specht, A., Gomez, D. R., Specht, V. F., Silva, J. C., Moraes, S. V., Peterson, J. A., & Hunt, T. E., (2018). Host plants of *Spodoptera frugiperda* (Lepidoptera, Noctuidae) in the Americas. *African Entomology*, **26** (2), 286-300.

Sah, L. P., Lamichhaney, D., Colavito, L., Norton, G., & Muniappan, R. (2019). *The fall armyworm, Spodoptera frugiperda (J. E. Smith), Status and management options in Nepal*. In Oral presentation in 19th International Plant Protection Congress, Hyderabad, India.

Sharanabasappa, D., Kalleshwaraswamy, C. M., Asokan, R., Swamy, H. M., Maruthi, M. S., Pavithra, H. B., Hegbe, K., & Goergen, G. E. (2018). First report of the fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera, Noctuidae) an alien invasive pest on maize in India. *Pest Management in Horticulture Ecosystem*, **24** (1), 23-29.

Steel, R. G. D., & Torrie, J. H. (1980). *Principles and procedures of statistics, a biometrical approach*. New York, USA, McGraw-Hill.