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Bio-efficacy of entomopathogenic fungi and bacteria against invasive pest *Spodoptera frugiperda* (J.E. Smith) under laboratory condition

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Abstract
Laboratory experiment was conducted to determine the bio-efficacy of different strains of entomopathogenic fungi *viz*., *Beauveria bassiana*, *Metarhizium anisopliae* and *Nomuraea rileyi* and entomopathogenic bacteria *viz*., *Bacillus thuringiensis* against fall armyworm (FAW) *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) under laboratory condition. Among different entomopathogenic fungi evaluated, AAU strain of *M. anisopliae* @ $2x10^9$ conidia/ml showed the highest larval mortality i.e., 57.56% and 50.63% against 2nd and 3rd instar larvae respectively. The same strain registered the larval mortality of 55.50% and 48.45% against 2nd and 3rd instar larvae respectively @ 2 x 10^8 conidia/ml. In case of entomopathogenic bacteria, AAU strain of *Bacillus thuringiensis* showed 64.65% and 59.01% larval mortality against 2nd and 3rd instar larvae respectively when spore-crystal mixture was tested @ 3 ml. The present study emphasizes the significant efficacy of native strains of entomopathogenic fungi and bacteria as compared to non-native strains against invasive pest *S. frugiperda*.

Keywords: Entomopathogenic fungi, entomopathogenic bacteria, bio-efficacy, fall armyworm, *Spodoptera frugiperda*

Introduction
The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) is a new invasive pest of maize. In early 2016, it was reported in West and Central Africa for the first time [1]. In July 2018, it was first observed in Asia. The first report of occurrence of fall armyworm, an invasive pest on maize in Karnataka during June 2018 [2]. Afterwards, this pest has been reported on maize from different parts of the country. In Gujarat, first time report of the occurrence of fall armyworm on sweet corn at Anklav taluka of Anand district [3]. It has become invasive and threatened the food security in different countries whose staple crop is maize. In the absence of proper control methods, *S. frugiperda* can cause yield losses of maize to the tonnes of 8.3 to 20.6 million per annum in Africa. The value of crop losses is estimated between US$ 2.5 and 6.2 billion [4]. The chemical control is generally practiced by farmers for higher gains, but its injudicious application has created many problems. Sole reliance on chemical control leads to the problem of pest resistance, resurgence and environmental pollution.

The biological plant protection with entomopathogens has a key role in sustainable pest management. Entomopathogens as biocontrol agents have some advantages when compared with chemical insecticides. These include low cost, high efficiency, safety for beneficial organisms and reduction of residues in environment [5]. Fungal biocontrol agents have unique mode of infection, unlike bacteria and viruses, they do not need to be ingested and can invade their host directly through the cuticle. That is why entomopathogenic fungi are capable of infecting non feeding stage like eggs [6] and pupae of insects [7].

The objective of present study was to evaluate the potential of different strains of entomopathogenic fungi *viz*., *Beauveria bassiana*, *Metarhizium anisopliae* and *Nomuraea rileyi* and different strains of entomopathogenic bacteria (*Bacillus thuringiensis*) against fall armyworm, *Spodoptera frugiperda* infesting maize under laboratory condition.

Material and Methods

The laboratory experiment was conducted to determine the bio-efficacy of different strains of entomopathogenic fungi (*B. bassiana*, *M. anisopliae*, *N. rileyi*) and entomopathogenic bacteria (*B. thuringiensis*) at different concentration against larvae of *S. frugiperda* at AICRP on biological control of crop pests, Anand Agricultural University, Anand during September to November, 2019.

Bio-efficacy of entomopathogenic fungi

The bio-efficacy of different strains of entomopathogenic fungi was evaluated under laboratory condition against laboratory reared 2nd (3-5 days old) and 3rd (6-7 days old) instar larvae of *S. frugiperda*. The fungal isolates were tested at three different concentrations ($2x10^7$, $2x10^8$ and $2x10^9$ cfu/ml). The conidia of the fungal isolates were harvested from 10 days old cultures and it was washed with 100 ml of distilled water having 0.02% Tween 80. Conidial suspension from 10^7, 10^8 and 10^9 conidia or spore/ml was standardized by assessing the number of conidia in the suspension using Neubauer Haemocytometer.

Two ml of conidial suspension was sprayed on larvae of 2nd and 3rd instars by using Potter's tower. Ten larvae were taken in each treatment which were repeated thrice. A control treatment only with distilled water was also incorporated for comparison.

Bio-efficacy of entomopathogenic bacteria

Pure cultures of *B. thuringiensis* strains were maintained on T3 culture medium plates and they were used by inoculating a loopful culture in 250 ml sterile T3 medium broth. The flasks were incubated in an incubator shaker at 150 rpm for 3 days at 30 ^{0}C. After that the broth was centrifuged at 6000 rpm for 10 min.

The resulted pellet containing spore and parasporal protein crystals was washed with sterile distilled water and centrifuged at 6000 rpm for 5 minutes. The pellets were resuspended in 10 ml of sterile distilled water and kept at 4 ^{0}C for bio-efficacy studies. The bio-efficacy of *B. thuringiensis* strains were studied under laboratory conditions against laboratory reared 2nd and 3rd instars larvae of fall armyworm. Different concentrations of spore crystal mixture *viz.*, 1.0, 2.0 and 3.0 ml were prepared for each *Bt* strain. *Bt* strains suspension was treated to 5 g fresh maize leaf bits. Ten larvae were tested per treatment with three repetitions. A control treatment only with distilled water was also maintained.

The observations on larval mortality were recorded at 48, 72, 96 and 120 hrs after imposition of treatments.

The percent larval mortality was calculated by using formula given by Abbott [8].

$$P = \frac{P1 - C}{100 - C} \times 100$$

Where,

P = Corrected mortality (%)

P_1= Observed mortality (%) of the test insect in treatments

C = Observed mortality (%) of the test insect in control

The data on percent mortality was subjected to ANOVA after adopting arc sine transformation.

Results and Discussion

Entomopathogenic fungi

All the evaluated entomopathogenic fungi were found significantly superior by causing higher mortality of *S. frugiperda* larvae to the control in both the instars (Table 1). The mortality data of 2nd and 3rd instar larvae at 48 hrs after imposition of the treatment indicated that the highest larval mortality was observed in the treatment of *M. anisopliae* (AAU Strain - 2×10^9) (33.31% and 32.18%), which was remained at par with *M. anisopliae* (AAU Strain - 2×10^8) (32.18% and 31.08%), *M. anisopliae* (NBAIR Strain - 2×10^9) (31.08% and 29.98%) and *M. anisopliae* (NBAIR Strain - 2×10^8) (29.98% and 29.98%). Whereas, the treatment of *N. rileyi* (AAU Strain - 2×10^9) (22.20% and 21.45%) was found second best treatment in their efficacy, followed by *N. rileyi* (AAU Strain - 2×10^8) (20.71% and 20.71%), which was at par with treatment of *M. anisopliae* (AAU Strain -2×10^7) (19.98% and 19.98%) and *M. anisopliae* (NBAIR Strain - 2×10^7) (19.48% and 20.54%). While, the treatment of *B. bassiana* (AAU Strain – 2×10^9) (11.10% and 10.73%) was found next best treatment in their efficacy, which was at par with the *B. bassiana* (AAU Strain-2×10^8) (10.35% and 4.90%) and *Nomuraea rileyi* (AAU Strain - 2×10^7) (9.99% and 9.99%). *B. bassiana* (AAU Strain – 2×10^7) was found least effective by causing 4.90% mortality of 2nd and 3rd instar larvae of *S. frugiperda*.

At 72 hrs after imposition of treatments, the highest mortality of 2nd and 3rd instar larvae were found in the treatment of *M. anisopliae* (AAU Strain - 2×10^9) (36.07% and 39.13%), which was found at par with treatment of *M. anisopliae* (AAU Strain - 2×10^8) (34.68% and 37.48%), *M. anisopliae* (NBAIR Strain - 2×10^9) (34.37% and 36.07%) and *M. anisopliae* (NBAIR Strain - 2×10^8) (33.23% and 35.28%), followed by treatment of *N. rileyi* (AAU Strain - 2×10^9) (24.86% and 26.50%), *N. rileyi* (AAU Strain - 2×10^8) (24.71% and 25.68%), *M. anisopliae* (AAU Strain - 2×10^7) (23.89% and 24.89%), *M. anisopliae* (NBAIR Strain - 2×10^7) (23.27% and 23.93%). The lowest larval mortality was observed in treatment of *B. bassiana* (AAU Strain - 2×10^7) (12.39% and 11.10%) and remained at par with *N. rileyi* (AAU Strain - 2×10^7) (13.83% and 13.01%), *B. bassiana* (AAU Strain - 2×10^8) (14.83% and 13.83%) and *B. bassiana* (AAU Strain - 2×10^9) (16.79% and 16.34%).

Significantly the highest mortality of 2nd and 3rd instar larvae were observed in the treatments of *M. anisopliae* (AAU Strain - 2×10^9) (50.45% and 47.28%) at 96 hrs after imposition of treatments. However, it was at par with the treatment of *M. anisopliae* (AAU Strain - 2×10^8) (49.97% and 43.94%), *M. anisopliae* (NBAIR Strain - 2×10^9) (48.45% and 42.45%) and *M. anisopliae* (NBAIR Strain - 2×10^8) (48.12% and 41.63%). Treatment of *N. rileyi* (AAU Strain - 2×10^9), *N. rileyi* (AAU Strain - 2×10^8), *M. anisopliae* (AAU Strain - 2×10^7), *M. anisopliae* (NBAIR Strain - 2×10^7), *B. bassiana* (AAU Strain - 2×10^9), *B. bassiana* (AAU Strain - 2×10^8) and *N. rileyi* (AAU Strain - 2×10^7) recorded 37.48, 34.95, 32.42, 31.79, 24.86, 24.17 and 23.27% mortality of 2nd instar larvae, while 31.08, 30.22, 27.47, 27.30, 19.98, 16.79, 16.34% mortality of 3rd instar larvae, respectively. Lowest mortality of 2nd instar (21.61%) as well as 3rd instar (13.82%) larvae were observed in the treatment of *B. bassiana* (AAU Strain - 2×10^7).

Table 1: Bio-efficacy of different strains of entomopathogenic fungi against larvae of fall armyworm, *S. frugiperda* under laboratory condition

Tr. No.	Treatments	Concentration (conidia or spore/ml)	Corrected larval mortality (%) at indicated instars and hours							
			2nd instar				3rd instar			
			48	72	96	120	48	72	96	120
T_1	*Beauveria bassiana* (AAU Strain)	2 x 10^7	12.79e (4.90)	20.61e (12.39)	27.70e (21.61)	29.36e (24.04)	12.79d (4.90)	19.46f (11.10)	21.83c (13.82)	21.82e (13.82)
T_2	*Beauveria bassiana* (AAU Strain)	2 x 10^8	18.77d (10.35)	22.65e (14.83)	29.45de (24.17)	31.67e (27.57)	12.79d (4.90)	21.83f (13.83)	24.19c (16.79)	26.91de (20.48)
T_3	*Beauveria bassiana* (AAU Strain)	2 x 10^9	19.46d (11.10)	24.19de (16.79)	29.91cde (24.86)	32.78de (29.31)	19.12cd (10.73)	23.84ef (16.34)	26.55c (19.98)	27.57cd (21.42)
T_4	*Metarhizium anisopliae* (AAU Strain)	2 x 10^7	26.55c (19.98)	29.26cd (23.89)	34.70bc (32.42)	38.72cd (39.13)	26.55bc (19.98)	29.93d (24.89)	31.61b (27.47)	33.88b (31.08)
T_5	*Metarhizium anisopliae* (AAU Strain)	2 x 10^8	34.56a (32.18)	36.08a (34.68)	44.98a (49.97)	48.16a (55.50)	33.88ab (31.08)	37.75a (37.48)	41.52a (43.94)	44.11a (48.45)
T_6	*Metarhizium anisopliae* (AAU Strain)	2 x 10^9	35.25a (33.31)	36.91a (36.07)	45.26a (50.45)	49.35a (57.56)	34.56a (32.18)	38.72a (39.13)	43.44a (47.28)	45.36a (50.63)
T_7	*Metarhizium anisopliae* (NBAIR Strain)	2 x 10^7	26.19c (19.48)	28.84cd (23.27)	34.32bcd (31.79)	38.23cd (38.29)	26.95bc (20.54)	29.29de (23.93)	31.50b (27.30)	32.88bc (29.47)
T_8	*Metarhizium anisopliae* (NBAIR Strain)	2 x 10^8	33.20ab (29.98)	35.20ab (33.23)	43.92a (48.12)	46.42ab (52.48)	33.20ab (29.98)	36.44abc (35.28)	40.18a (41.63)	43.06a (46.62)
T_9	*Metarhizium anisopliae* (NBAIR Strain)	2 x 10^9	33.88a (31.08)	35.89a (34.37)	44.11a (48.45)	46.91ab (53.33)	33.20ab (29.98)	36.91ab (36.07)	40.66a (42.45)	43.92a (48.12)
T_{10}	*Nomuraea rileyi* (AAU Strain)	2 x 10^7	18.43d (9.99)	21.83e (13.83)	28.84e (23.27)	29.91e (24.86)	18.43d (9.99)	21.14f (13.01)	23.84c (16.34)	26.29de (19.62)
T_{11}	*Nomuraea rileyi* (AAU Strain)	2 x 10^8	27.07c (20.71)	29.81bc (24.71)	36.24b (34.95)	40.16c (41.59)	27.07ab (20.71)	30.45cd (25.68)	33.35b (30.22)	35.36b (33.49)
T_{12}	*Nomuraea rileyi* (AAU Strain)	2 x 10^9	28.11bc (22.20)	29.91bc (24.86)	37.75b (37.48)	40.93bc (42.92)	27.59ab (21.45)	30.98bcd (26.50)	33.88b (31.08)	36.74b (35.78)
S. Em. ±	Treatment (T)		1.66	1.63	1.51	1.85	2.33	1.77	1.50	1.74
F test (T)			Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
C. V. (%)			11.01	9.63	7.19	8.13	15.84	10.46	7.95	8.66

Note: 1. Figures in parenthesis are retransformed values and those outside are arc sine transformed values
2. Treatment mean(s) with the letter(s) in common are not significant by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance

The larval mortality was recorded highest in all the treatments at 120 hrs after imposition of treatments. The data showed that the highest mortality of 2nd and 3rd instar larvae were observed in the treatment of *M. anisopliae* (AAU Strain - 2×10^9) (57.56% and 50.63%), which was remained at par with *M. anisopliae* (AAU Strain - 2×10^8) (55.50% and 48.45%), *M. anisopliae* (NBAIR Strain - 2×10^9) (53.33% and 48.12%) and *M. anisopliae* (NBAIR Strain - 2×10^8) (52.48% and 46.62%). Whereas, the treatment of *N. rileyi* (AAU Strain - 2×10^9) (42.92% and 35.78%), *N. rileyi* (AAU Strain - 2×10^8) (41.59% and 33.49%), *M. anisopliae* (AAU Strain - 2×10^7) (39.13% and 31.08%) and *M. anisopliae* (NBAIR Strain - 2×10^7) (38.29% and 29.47%) were found mediocre in their efficacy. The treatment of *B. bassiana* (AAU Strain - 2×10^9) (29.31% and 21.42%) was found next best treatment in their efficacy, followed by treatment of *B. bassiana* (AAU Strain - 2×10^8) (27.57% and 20.48%), *N. rileyi* (AAU Strain - 2×10^7) (24.86% and 19.62%) and *B. bassiana* (AAU Strain – 2×10^7) (24.04% and 13.82%). *B. bassiana* (AAU Strain - 2×10^7) was found least effective against 2nd and 3rd instar larvae of *S. frugiperda*. Overall, *M. anisopliae* (AAU Strain - 2×10^9) was found best entomopathogenic fungi by recording highest larval mortality of second and third instar larvae of *S. frugiperda*, followed by *M. anisopliae* (AAU Strain - 2×10^8), *M. anisopliae* (NBAIR Strain - 2×10^9) and *M. anisopliae* (NBAIR Strain- 2×10^8).

Entomopathogenic bacteria

All the evaluated different strains of entomopathogenic bacteria were found significantly superior by causing higher mortality of *S. frugiperda* larvae to the control in both the instars (Table 2). The mortality data of 2nd and 3rd instar larvae at 48 hrs after imposition of the treatment indicated that the highest larval mortality was observed in the treatment of *B. thuringiensis* (AAU Strain @ 3ml) (39.14% and 37.72%). However, it was remained at par with the treatment of *B. thuringiensis* (AAU Strain @ 2 ml) (36.07% and 34.93%). Further, the treatment of *B. thuringiensis* (NBAIR Strain @ 3 ml) (26.62% and 24.98%) and *B. thuringiensis* (NBAIR Strain @ 2 ml) (24.04% and 24.04%) were at par with each other and found next best treatment, followed by treatment of *B. thuringiensis* (AAU Strain @ 1 ml) (16.34% and 16.27%). The lowest mortality of 2nd and 3rd instar were recorded in the treatment of *B. thuringiensis* (NBAIR Strain @ 1 ml) (10.35% and 9.99%). At 72 hrs after imposition of treatments, *B. thuringiensis* (AAU Strain @ 3 ml) (46.62% and 43.28%) showed highest mortality of 2nd and 3rd instar larvae, respectively. Nonetheless, it was found at par with the treatment of *B. thuringiensis* (AAU Strain @ 2 ml) (42.92% and 40.97%). Whereas, the treatment of *B. thuringiensis* (NBAIR Strain @ 3 ml) (33.23% and 31.74%) and *B. thuringiensis* (NBAIR Strain @ 2 ml) (32.69% and 30.72%) were found mediocre in their efficacy. The treatment of *B. thuringiensis* (AAU Strain @ 1 ml) and *B. thuringiensis* (NBAIR Strain @ 1 ml) caused 24.85% and 20.71% mortality of 2nd instar larvae, while 22.62% and 15.56% mortality of 3rd instar larvae, respectively and found least effective against *S. frugiperda*.

The treatment of *B. thuringiensis* (AAU Strain @ 3 ml) (59.35% and 52.20%) and *B. thuringiensis* (AAU Strain @ 2 ml) (55.63% and 48.78%) were at par with each other and continued its superiority against 2nd and 3rd instar larvae, respectively after 96 hrs of treatment.

Table 2: Bio-efficacy of different strains of entomopathogenic bacteria against larvae of fall armyworm, *S. frugiperda* under laboratory condition

Tr. No.	Treatments	Dosage (ml)	Corrected larval mortality (%) at indicated instars and hours							
			2nd instar				3rd instar			
			48	72	96	120	48	72	96	120
T_1	*Bacillus thuringiensis* (AAU Strain)	1	23.84 (16.34)	29.90 (24.85)	36.08 (34.68)	39.34 (40.19)	23.79 (16.27)	28.40 (22.62)	32.35 (28.63)	36.52 (35.41)
T_2	*Bacillus thuringiensis* (AAU Strain)	2	36.91 (36.07)	40.93 (42.92)	48.23 (55.63)	52.00 (62.10)	36.23 (34.93)	39.80 (40.97)	44.30 (48.78)	49.35 (57.56)
T_3	*Bacillus thuringiensis* (AAU Strain)	3	38.73 (39.14)	43.06 (46.62)	50.39 (59.35)	53.52 (64.65)	37.89 (37.72)	41.14 (43.28)	46.26 (52.20)	50.19 (59.01)
T_4	*Bacillus thuringiensis* (NBAIR Strain)	1	18.77 (10.35)	27.07 (20.71)	29.99 (24.98)	33.06 (29.76)	18.43 (9.99)	23.23 (15.56)	26.55 (19.98)	30.28 (25.42)
T_5	*Bacillus thuringiensis* (NBAIR Strain)	2	29.36 (24.04)	34.87 (32.69)	42.12 (44.98)	44.98 (49.97)	29.36 (24.04)	33.66 (30.72)	38.07 (38.02)	42.78 (46.13)
T_6	*Bacillus thuringiensis* (NBAIR Strain)	3	31.06 (26.62)	35.20 (33.23)	42.30 (45.29)	45.74 (51.29)	29.99 (24.98)	34.29 (31.74)	38.73 (39.14)	43.25 (46.95)
S. Em. ±	Treatment (T)		1.29	1.61	1.78	1.96	1.53	1.61	1.72	1.96
C. D. at 5%	T		3.96	4.96	5.48	6.05	4.71	4.97	5.29	6.03
C. V. (%)			7.48	7.93	7.41	7.60	9.04	8.36	7.89	8.06

Note: Figures in parenthesis are retransformed values and those outside are arc sine transformed values

Whereas, the treatment of *B. thuringiensis* (NBAIR Strain @ 3 ml) (45.29% and 39.14%) was found at par with *B. thuringiensis* (NBAIR Strain @ 2 ml) (44.98% and 38.02%) and established as next best treatment, followed by *B. thuringiensis* (AAU Strain @ 1 ml) (34.68% and 28.63%). Further, the lowest mortality of 2nd and 3rd instar larvae were recorded in the treatment of *B. thuringiensis* (NBAIR Strain @ 1 ml) (24.98% and 19.98%, respectively).

Significantly the highest mortality of 2nd and 3rd instar larvae were observed in the treatment of *B. thuringiensis* (AAU Strain @ 3 ml) (64.65% and 59.01%) after 120 hrs. Nevertheless, it was remained at par with the treatment of *B. thuringiensis* (AAU Strain @ 2 ml) (62.10% and 57.56%). While, the treatment of *B. thuringiensis* (NBAIR Strain @ 3 ml) (51.29% and 46.95%) was found as next best treatment. However, it was found at par with treatment of *B. thuringiensis* (NBAIR Strain @ 2 ml) (49.97% and 46.13%) and *B. thuringiensis* (AAU Strain @ 1 ml) (40.19% and 35.41%). *B. thuringiensis* (NBAIR Strain @ 1 ml) caused 29.76% mortality of 2nd instar larvae, 25.42% mortality of 3rd instar larvae and found least effective against larvae of *S. frugiperda*.

Thus, *B. thuringiensis* (AAU Strain @ 3 ml) was found best entomopathogenic bacteria by recording highest larval mortality of 2nd as well as 3rd instar larvae of *S. frugiperda* and remained equally effective as *B. thuringiensis* (AAU Strain @ 2 ml).

In nut shell, it is deduced that among evaluated different strains of entomopathogenic fungi, *M. anisopliae* (AAU Strain - 2×10^9) is found most effective treatment by recording highest larval mortality of *S. frugiperda* under laboratory condition. However, it remained equally effective as *M. anisopliae* (AAU Strain - 2×10^8), *M. anisopliae* (NBAIR Strain - 2×10^9) and *M. anisopliae* (NBAIR Strain - 2×10^8). While among evaluated different strains of entomopathogenic bacteria, *B. thuringiensis* (AAU Strain @ 3 ml) was found most effective by recording highest larval mortality of 2nd and 3rd instar larvae of *S. frugiperda* and remained equally effective as *B. thuringiensis* (AAU Strain @ 2 ml).

This study is in accordance with the findings of Ramanujam *et al.* (2020) [9] they found that all evaluated strains were effective against larvae of *S. frugiperda* with larval mortality ranged from 10.7% to 67.8% and treatment of *M. anisopliae* ICAR-NBAIR Ma-35 (67.8%) caused highest larval mortality. Hernandez (1988) [10] reported the larval mortality of *S. frugiperda* with *B. thuringiensis* sub species *Bt kenyae*, *Bt aizawai*, and *Bt kurstaki* (3 x 10^7 cells/ml) were 100%, 80% and 70%, respectively. Polanczyk *et al.* (2000) [11] found that *Bt thuringiensis* 4412 and *Bt aizawai* HD 68 strains containing 3 x 10^8 cells/ml induced 100% and 80.4% larval mortality, respectively.

Conclusion

Among different entomopathogenic fungi evaluated, AAU strain of *M. anisopliae* @ $2x10^9$ conidia/ml showed the highest larval mortality of fall armyworm. The same strain also registered the significant larval mortality @ 2 x 10^8 conidia/ml. In case of entomopathogenic bacteria, AAU strain of *Bacillus thuringiensis* showed the significant larval mortality against 2nd and 3rd instar larvae when spore-crystal mixture was tested @ 3 ml. The present study indicates the significant efficacy of native strains of different entomopathogens against fall armyworm as compared to non-native strains. Thus, the native strains of entomopathogenic fungi and bacteria could be utilized for the eco-friendly management fall armyworm *S. frugiperda.*

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References

1. Goergen G, Kumar PL, Sankung SB, Togola A, Tamò M. First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera, Noctuidae), a new alien invasive pest in West and Central

Africa. Plos One 2016;11(10):1-9.
2. Sharanabasappa, Kalleshwaraswamy CM, Asokan R, Swamy HM, Maruthi MS, Pavithra HB, *et al*. First report of the fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), an alien invasive pest on maize in India. Pest Management in Horticultural Ecosystems 2018;14(1):23-29.
3. Sisodiya DB, Raghunandan BL, Bhatt NA, Verma HS, Shewale CP, Timbadiya BG, *et al*. The fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae); first report of new invasive pest in maize fields of Gujarat, India. Journal of Entomology and Zoology Studies 2018;6(5):2089-2091.
4. Day R, Abrahams P, Bateman M, Beale T, Clottey V, Cock M, *et al*. Fall armyworm: impacts and implications for Africa. Outlooks Pest Management 2017;28:196-201
5. Lacey LA, Frutos R, Kaya HK, Vails P. Insect pathogens as biological control agents: Do they have future? Biological Control 2001;21(3):230-248.
6. Anand R, Tiwary BN. Pathogenicity of entomopathogenic fungi to eggs and larvae of Spodoptera litura, the common cutworm. Biocontrol Science and Technology 2009;19(9):919-929.
7. Nguyen N, Borgemeister C, Poehling H, Zimmermann G. Laboratory investigations on the potential of entomopathogenic fungi for biocontrol of *Helicoverpa armigera* (Lepidoptera: Noctuidae) larvae and pupae. Biocontrol Science and Technology 2007;17(12):853-864.
8. Abbott WS. A method of computing effectiveness of an insecticide. Journal of Economic Entomology 1925;18(2):265-267.
9. Ramanujam B, Poornesha B, Shylesha AN. Effect of entomopathogenic fungi against invasive pest *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) in maize. Egyptian Journal of Biological Pest Control 2020;30(100):1-5.
10. Hernandez JLL. Evaluation de la toxicite de *Bacillus thuringiensis* sur *Spodoptera frugiperda.* Entomophaga 1988;33(2):163-171.
11. Polanczyk RA, Piresda Silva RF, Fiuza LM. Effectiveness of *Bacillus thuringiensis* strain against *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Brazillian Journal of Microbiology 2000;31(3):165-167.