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Efficacy of bio-pesticides against fall armyworm, *Spodoptera frugiperda* under laboratory condition

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Abstract
The fall armyworm, *Spodoptera frugiperda* (smith) (Lepdoptera: Noctuidae), is an economically serious and polyphagous pest and native to tropical to subtropical regions of America. It is widely distributed in India, causing significant damage to maize. It was noticed for the first time in the month of August, 2019 feeding on maize crop in Bhagalpur, Bihar. Being a new pest, there is need to find out the management strategy. Therefore, three different doses of microbial biopesticides along with one insecticide were tested for their efficacy against fall armyworm under laoboratory condition. The results revealed that Emamectin benzoate caused highest larval mortality 100 percent at 72 h after application. However, among biopesticides *Metarhizium anisopliae* @7ml/l caused 100 per cent at 96 h after application followed by *Beauveria bassiana* @7g/l (95% mortality). Other treatments caused more than 80 per cent mortality at 96 hrs after treatment application. It was concluded that larval mortality increased with an increase in doses of microbial pesticides and time interval. The biopesticide, *Metarhizium anisopliae* @7ml/l showed high efficacy against fall armyworm larvae can be used as components for integrated pest management plans for fall armyworm.

Keywords: fall armyworm, biopesticides, *Metarhizium anisopliae*, *Beauveria bassiana*, per cent mortality

Introduction
Maize (*Zea mays* L.) is one of the important cereal crops grown across the world as food for human consumption and feed for animals. There are various factors which are responsible for reduction of yield in maize, insects-pests are one among the major yield reducing factors. These insect pests cause damage to all plant parts, i.e., root, stem, leaf, grain and seeds. The invasive fall armyworm, *Spodoptera frugiperda*, native to America, causes severe economic losses in various crops such as maize, soybean, cotton (Nagoshi *et al.* 2007; Bueno *et al.* 2011) [1, 2]. In Asia, it was reported for the first time from India on maize during May 2018 (Sharanabasappa *et al.* 2018) [3]. Then, it has spread to different states of India on maize (Mahadevaswamy *et al.* 2018s; Sharanabasappa *et al.* 2018) [4, 5] and it was recorded for the first time on maize in Sabour, Bhagalpur, Bihar during August, 2019 (Reddy *et al.* 2020) [6]. It is the most destructive pest of maize. The caterpillars damage the leaves severely during the vegetative growth of plants. Although chemical control recommendations are available for protecting the crops from this pests, but there are many disadvantages in their use. Extensive use of chemical pesticides has resulted in wide spread insect resistance to pesticides and adverse effect on beneficial insects, wild life and human health throughout the world. Using bio-pesticides for the control of pests is an ideal alternative as it has long term effect, without any harmful effect on environment and animals. Keeping all facts in view, the experiment was conducted to test the efficacy of different doses of microbial bio-pesticides along with one insecticide under laboratory condition.

Materials and Methods
Experimental details
The experiment was laid out in a complete randomised design (CRD) with three replications in laboratory. There were seven treatments and one control. The treatments included two commercial biopesticides, *Beauveria bassiana* (Amit Biotech) and *Metarhizium anisopliae* (Green Life Biotech laboratory). The synthetic insecticide, Emamectin Benzoate (EM-1 of Dhanuka Agritech Limited Company) was used as check. Distilled water was used in control treatment.

The commercial bio-pesticides of different doses and synthetic insecticide were: T_1- *Beauveria bassiana* @ 3 g/l, T_2 - *Beauveria bassiana* @ 5 g/l, T_3 - *Beauveria bassiana* @ 7 g/l, T_4 -*Metarhizium anisopliae* @ 3 ml/ l, T_5 -*Metarhizium anisopliae* @ 3 ml/ l, T_6 *Metarhizium anisopliae* @ 3 ml/ l, T_7 -*Emamectin benzoate* 5 SG @ 0.4 g/ l and T_8 -Control.

Rearing of Fall armyworm larvae

Fall armyworm larvae were collected from an infested and unsprayed maize plot of maize section, Bihar Agricultural College, Sabour, Bhagalpur. Then larvae were brought to the laboratory and placed individually in ventilated plastic jars to avoid cannibalism and fed with maize leaves collected from 15–25-day-old maize plants. The pre-pupal stage was transferred to a plastic jar one-third filled with soil for pupation. The pupae were collected and placed in a moistened Petri dish in an oviposition cage. Sterile cotton soaked in a sugar solution (20%) was placed in a Petri dish inside the oviposition cage as a food source for the emerging adults. The wall of the oviposition cage was lined with wax paper as an oviposition media. After approximately 2–3 days, old egg batches were collected from the oviposition cages and placed in sterile plastic jars. Eggs were monitored daily for hatching; as soon as the first instars emerged, they were provided with tender and fresh maize leaves. Rearing was performed at room temperature.

Application of bio-pesticides and insecticides to fall armyworm larvae

Leaf dip bioassay method was employed. A fresh, uniform sized maize leaf bit of 5-6 cm in length of hybrid 3355 from 25 days old crop. Leaves were immersed in aqueous bio-pesticide solution for 10 seconds. For control, distilled water was used. Treated leaf bits were air dried and were transferred to plastics vials and secured.

Ten 3rd instar larvae were released into vials containing the treated leaves. The maize leaves were changed every 2nd day. Larval mortality were assessed at the interval of 24, 48,72 and 96 h after treatment application. A larva was considered dead if it could not right itself after being placed on its dorsal surface. The above experiment was repeated and the mortality (%) was assessed corrected by using equation (1) and the data were corrected by using Abbott's (1925) [7] equation (2).

$$\text{Percentage of mortality} = \frac{\text{Number of dead larvae}}{\text{Number of larvae introduced}} \times 100 \ldots . (1)$$

$$\text{Corrected percentage of mortality} = \left(1 - \frac{\text{n T after treatment}}{\text{n C after treatment}}\right) \times 100 \ldots (2)$$

Where, n = larval population, T = treatment, C = control

The data on percent mortality was subjected to angular transformation.

Results and Discussion

24 hrs after treatment application

The data in the Table 1 clearly indicated that significantly highest percent mortality was observed in the treatment Emamectin benzoate @ 0.4g/l (73.33) which was at par with the treatment *Metarhizium anisopliae* @7ml/l (68.33). The next best treatment was *Metarhizium anisopliae* @ 5ml/l caused 61.67 percent mortality. The treatment *Metarhizium anisopliae* @ 3ml/l and *Beauveria bassiana* @ 7g/l showed 33.33 and 30 percent mortality, respectively. However, the other treatment caused 25.00 and 11.67 percent mortality in *Beauveria bassiana* @ 5g/l and *Beauveria bassiana* @ 3g/l, respectively.

48hrs after treatment application

It is apparent from the Table1 that the highest mortality was recorded in the treatment Emamectin benzoate @ 0.4g/l (91.67% mortality) which was followed by the treatment *Metarhizium anisopliae* @ 7ml/l (80% mortality). The next best treatment was *Metarhizium anisopliae* @ 5ml/l caused 75.00 percent mortality. The treatment *Metarhizium anisopliae* @3ml/l and *Beauveria bassiana* @ 7g/l were at par with each other showed 65.33 and 63.33 per cent mortality, respectively whereas, the treatment *Beauveria bassiana* @5g/l and *Beauveria bassiana* @3g/l recorded 43.33 and 35.00 percent mortality, respectively.

72 hrs after treatment application

It is quite clear from the Table 1 the treatment Emamectin benzoate 5SG @ 0.4g/l recorded maximum mortality (100%) which was followed by the treatment *Metarhizium anisopliae* @ 7ml/l (95.67% mortality). The treatment *Metarhizium anisopliae* @ 5ml/l showed 86.33 percent mortality which was at par with the treatment *Beauveria bassiana* @7g/l (85.67% mortality). The treatment *Metarhizium anisopliae* @3ml/l caused 78.67 per cent mortality and in parity with *Beauveria bassiana* @ 5gl/l (75% mortality). While, *Beauveria bassiana* @ 3g/l caused least mortality (61.67%) among all the treatments.

96 hrs after treatment application:

The experimental results presented in Table 1 revealed that per cent mortality ranged from 77.00 to 100 at 96 hrs after treatment application. Apart from the treatment Emamectin benzoate 5SG @ 0.4g/l, at this time interval *Metarhizium anisopliae* @ 7ml/l reached highest mortality (100) per cent followed by *Beauveria bassiana* @7g/l (95% mortality). Remaining treatment caused more than 80 per cent mortality. The treatment *Beauveria bassiana* @3g/l caused least mortality (77%) among all the treatments.

Comparative performance of the treatment application

There were significant differences among the treatments in causing mortality to fall armyworm larvae at 24hrs, 48hrs, 72hrs and 96 hrs after treatment application. The efficacy of different bio-pesticides was evaluated against fall armyworm and the data obtained with regards to percentage of mortality of fall armyworm larvae are presented in Table 1.

The treatment Emamectin benzoate @ 0.4g/l caused highest mortality 73.33%, 91.67% and 100% at 24hrs, 48hrs and 72hrs, respectively. *Metarhizium anisopliae* @ 7ml/l caused 95.67 per cent mortality at 72 hours after treatment application and mortality per cent reached 100 per cent at 96 hrs after treatment application. The next best treatment recorded was *Beauveria bassiana* @7g/l (95% mortality). Other treatments caused more than 80 per cent mortality at 96 hrs after treatment application. There was no mortality observed in control. It was concluded that larval mortality increased with an increase in doses of microbial pesticides and time interval. Karthi *et al.* (2019) [8] found the similar results that the fungal mycotoxins of *M. anisopliae* and *B. bassiana* significantly reduce the development of lepidopteran pests. Denisse *et al.* (2016) [9] found that applications of entomopathogens including fungi like *Beauveria bassiana* (Bals.) as alternative against chemical insecticides and

assessed its pathogenicity against fall armyworm larvae. efficacy of different insecticides against fall armyworm, *Spodoptera frugiperda* infesting maize. Spinetoram 11.7 SC,0.117%, emamectin benzoate 5SG, 0.0025%, chlorantraniliprole 18,5 EC, 0.006% and thiodicarb 75 WP,0.11% were found more effective in minimizing the larval population, plant and cob damage in maize which also reflected on grain and fodder yield as well (Chimweta *et al.* 2020) [10]. Dhobi *et al.* (2020) [11] determined the efficacy of different biopesticides against the fall armyworm, *Spodoptera frugiperda* in maize (GAYMH-1) and found that the lowest larval population (1.81 larvae /10 plants and 2.03 larvae /10 plants), minimum plant damage (15.34% and 17.70%) and cob damage (15.19% and 15.19%) with *Nomuraea rileyi* 1% WP @ 40 g/10 lit water and it was at par with *Bacillus thuringiensis* var. kurstaki 1% WG @ 20 g/10 lit water, respectively.

Table 1: Mean percentage of cumulative mortality of fall armyworm larvae at 24, 48, 72 and 96 hrs after application of treatment.

Treatments	Mortality percentage of fall armyworm larvae			
	24hrs	48hrs	72hrs	96 hrs
T_1 - *Beauveria bassiana*@ 3 g/l	11.67 (19.89)	35.00 (36.24)	61.67 (51.81)	77.00 (61.37)
T_2 - *Beauveria bassiana* @ 5 g/l	25.00 (29.93)	43.33 (41.12)	75.00 (60.67)	84.00 (66.48)
T_3 - *Beauveria bassiana* @ 7 g/l	30.00 (33.16)	63.33 (52.91)	85.67 (67.85)	95.00 (79.55)
T_4 - *Metarhizium anisopliae* @ 3 ml/ l	33.33 (35.25)	65.00 (53.76)	78.67 (62.85)	83.67 (65.05)
T_5 - *Metarhizium anisopliae* @ 3 ml/ l	61.67 (51.78)	75.00 (60.07)	86.33 (68.98)	91.67 (76.26)
T_6 - *Metarhizium anisopliae* @ 3 ml/ l	68.33 (55.85)	80.00 (63.55)	95.67 (78.26)	100.00 (90.00)
T_7 - *Emamectin benzoate* 5 SG @ 0.4 g/ l	73.33 (58.93)	91.67 (73.40)	100.00 (90.00)	100.00 (90.00)
T_8 - Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
SEm (±)	0.99	1.32	1.48	1.97
CD (p=0.05)	3.05	4.08	4.57	6.10
CV (%)	8.49	8.48	7.55	8.97

Figures in parentheses are angular transformed values.

Conclusion

The efficacy of different bio-pesticides was evaluated against fall armyworm under laboratory condition and the result indicated that the treatment Emamectin benzoate @ 0.4g/l caused highest mortality (100%) at 72 hours after treatment application. While, *Metarhizium anisopliae* @ 7ml/l caused 100.00 per cent mortality followed by the treatment *Beauveria bassiana* @7g/l (95% mortality) at 96 hrs after treatment application. Other treatments caused more than 80 per cent mortality at 96 hrs after treatment application. There was no mortality observed in control. It was concluded that larval mortality increased with an increase in doses of microbial pesticides and time interval.

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