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Bioefficacy of bio-control agents against eggs, larvae and pupa of fall armyworm *Spodoptera frugiperda* (J.E. Smith) on maize under laboratory conditions

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Abstract
The investigations were carried out on study of bioefficacy of biocontrol agents against Fall armyworm *Spodoptera frugiperda* (J. E. Smith) on maize under laboratory conditions (650 C and 25% RH) at Biocontrol Laboratory, Department of Agricultural Entomology, College of Agriculture, Pune during 2020- 2021. Bioefficacy of the test bioagents against eggs of FAW depicted as Azadirachtin and *S. carpocapsae*>*M. anisopliae* and *N. rileyi*>*B. bassiana* and *Bt*. Bioefficacy against 2nd instar larvae depicted as *Bt*> *N. rileyi*, *M. anisopliae* and Azardiractin >*S. carpocapsae* and *B. bassiana*. Bioefficacy against pupae depicted as Azardiractin and *S. carpocapsae*>*M. anisopliae* and *N. rileyi*> *B. bassiana* and *Bt*.

Keywords: Fall armyworm, *Spodoptera frugiperda*, bioefficacy, laboratory conditions

1. Introduction

Maize is the most important cereal crop in. Maize is consumed as food in Jammu and Kashmir, Rajasthan, Gujarat, Himachal Pradesh and Bihar predominantly by the tribal populations. Besides; it has wide use as fodder, both as green and silage. Now a day's maize production is hindered by several biotic and abiotic factors. Although about 141 insect pests causing varying damage to maize crop from sowing till harvesting but only about a dozen of these are quite serious and require control measures (Reddy and Trivedi, 2009). Moreover, during 2018, a new invasive pest, fall armyworm, *Spodoptera frugiperda* (Smith, 1797) [10] (Lepidoptera: Noctuidae) has been reported from Indian sub-continent with potential to cast a dark shadow on maize production in the region and making the farmers helpless. Chemical insecticides in agriculture are useful for protecting crop against pests and play the significant role to boost the production. To obviate the effects of chemical insecticides, there has been increased demand for the alternative and selective pest control agents particularly bioagents that in turn are silent workers from nature. Several biopesticides with novel mode of action are now available in the market and therefore, it is necessary to use safe, effective, ecologically sound biocontrol agents (Saxena and Ahmad, 1997) [8]. Amongst the bioagents and pathogens causing disease in insect pest are practically of more significant as they contribute epizootics. In view of aforesaid facts and moreover considering the economic importance of FAW, the present investigations were undertaken in laboratory conditions with the following objectives. To evaluate bioefficacy of biocontrol agents against fall armyworm, *Spodoptera frugiperda* (J. E. Smith) in laboratory conditions.

2. Materials and Methods

Studies were carried out to for testing efficacy of six test bioagents against *Spodoptera frugiperda* (J. E. Smith) in biocontrol laboratory, Department of Agricultural Entomology, College of Agriculture, Pune during the year 2020-2021. Culture of fall armyworm was obtained by collecting larvae from the infested maize field and was reared in laboratory. Larvae of FAW were reared on fresh maize leaves being the natural host.

Efficacy of six test bioagents were evaluated against life stages of FAW under laboratory conditions wherein, observations recorded in respect of egg, larval, and pupal stages. Completely randomized design is followed. Ten larva, eggs, pupa were taken for each replication and 3 replications is followed. Requisite amount of test bioagents were measured accurately with micropipette for the liquid formulations whereas weighed on electronic balance for talc formulations. Thereafter were mixed in the requisite volume of distilled water separately for each of the formulations. Then each solution was thoroughly stirred using wooden stick and used for further application.

2.1 Bioefficacy of test bioagents against eggs of FAW

Freshly laid ten eggs were kept on petriplates lined with filter paper. Then the respective test bioagents were sprayed using calibrated and standardized baby sprayer on the surface of eggs. In untreated check, the eggs were treated with distilled water. The treated petriplates were then dried under ceiling fan. Eggs prevailing on each of the petriplates were observed daily under the microscope up to 5DAT. Unhatched eggs were considered as sterile and/or dead. The data on percent mortality were computed and subjected to the arc sin transformation and statistical analysis thereafter.

2.2 Bioefficacy of test bioagents against larvae of FAW

The efficacy of test bioagents were evaluated on larvae by adopting the leaf dip method succulent maize leaves were brought and after thorough cleaning with water. The leaves were dipped in requisite concentration of bioagents for 10 seconds. The leaves were air dried under ceiling fan for 4 hr and then the leaves were placed in each plastic container. Ten larvae were randomly selected from nucleus culture and then were placed in each plastic container. Larval mortality was recorded after every 1, 3, 5 and 7 DAT. The moribund larvae were considered as dead. Mean larval mortality was computed for each of the larval instar. The data were subjected to the arc sin transformation and statistical analysis thereafter.

2.3 Bioefficacy of test bioagents against pupae of FAW

The efficacy of test bioagents were evaluated on pupae collected from the nucleus culture. Ten freshly pupae were kept on petriplates lined with filter paper. The bioagents were sprayed using calibrated and standardized baby sprayer. The pupae from untreated check were treated with distilled water. The observations on pupal mortality were recorded at 15 DAT on the basis of emergence of moths from pupae. The data were subjected to the arc sin transformation and statistical analysis thereafter.

3. Results and Discussion

3.1 Bioefficacy of test bioagents against eggs of FAW

Data in respect of mean egg mortality at 5 DAT reveals that all the six test bioagents were observed to be significantly superior over the untreated check. Amongst test bioagents, azadirachtin recorded highest egg mortality (81.33%) that was on par with *S. carpocapsae* (73.67%). Next promising treatments were *N. rileyi* (73.67%) and *M. anisopliae* (66%) which were at par with each other. Next treatments in the descending preference were *B. bassiana* (36.33%) and *Bt* (6.67%). In the present investigations, Azardirachtin and *S. carpocapsae* exhibited highest egg mortality whereas, *B. bassiana and Bt* shown lowest mortality. *M. anisopliae* and *N. rileyi* depicted moderate egg mortality. Herein, the findings for Azadirachtin are in confirmatory with that of findings reported by Trarore *et al*. (2019) [11] in respect of neem oil on *M. vitrata*. *S. carpocapsae* also exhibited significant mortality and the findings are in 37 agreement with that of reported by Kalia *et al*. (2014) [5] on eggs of *H. armigera* and *S. litura*. In the present findings, moderate mortality was exhibited by *M. anisopliae and B. bassiana* and these results are in confirmation with that of reported by Asi *et al*. (2013) [1].

Table 1: Bioefficacy of test bioagents against eggs of FAW

TN	Treatments	Egg mortality (at 5DAT)
T_1	*Metarhizium anisopliae* @ (1 x 108 cfu/ml) 5g / l	54.67(47.68)
T_2	*Beauveria bassiana* @ (1 x 108 cfu/ml) 5g / l	36.33(37.07)
T_3	*Nomuraea rileyi* @ (1 x 108 cfu/ml) 5g / l	66.00(54.34)
T_4	*Bacillus thuringiensis* @ (3.5% ES) 2ml / l	6.67(13.25)
T_5	*Steinernema carpocapsae* @ (10,0000 IJs) 4ml / l	73.67(59.15)
T_6	Azadirachtin @ (10,000 ppm) 2ml / l	81.33(64.43)
T_7	Untreated check	3.33(9.57)
	CD at 5%	7.40
	F Test	sig
	SE(m)±	2.44

3.2 Bioefficacy of test bioagents against second instar larvae

At 1 DAT, all the test bioagents were found to be non-significant with the untreated check exhibiting no harmful effect. At 3 DAT, Bt (20%) was found significantly superior over rest of the treatments followed by Azardirachtin (16.63%) and *N. rileyi* (13.33%) which were at par with each other followed by *M. anisopliae* (10%) followed by *S. carpocapsae* (6.67%) and *B. bassiana* (3.33%) and were on par. At 5 DAT, *Bt* (64.4%) remain to be promising treatment followed by *N. rileyi* (42.59), *M. anisopliae* (35.56%), Azardirachtin (31.11%) and *S. carpocapsae* (28.15%) which were on par followed by B. bassiana (21.48%). At 7 DAT, Bt (67.78) was the most effective treatment which however was at par with *N. rileyi* (60.37%), *M. anisopliae* (57.04%) and Azardirachtin (53.33%) followed by *S. Carpocapsae* (28.15%) and *B. bassiana* (24.81%) which were on par. In the present findings, Bt exhibited promising performance from 3 to 7 DAT. *N. rileyi*, *M. anisopliae* and Azardirachtin were found to be next best treatments during 3 to 7 DAT. *S. carpocapsae* and *B. bassiana* shown efficacy in almost in similar range. Findings in respect of Bt are in confirmatory with that reported by Sisodiya *et al.*

The observations recorded in respect of *N. rileyi* are on almost on similar lines with the findings reported by Espinel *et al*., (2008) [2]. The findings on *M. anisopliae* are in corroboration with that of Sisodiya *et al*. (2020) [9] on FAW. The observations recorded on Azardirachtin are on similar lines with that of reported by Joshi and Ramprasad *et al*. (2013) against S. *litura*. The findings in respect of *S. carpocapsae* are in confirmation with the results reported by Uma *et al*. (2006) [12] on *S. litura*. Relative lesser efficacy exhibited by *B. bassiana* is in agreement with the findings of Sisodiya *et al*. (2020) [9].

Table 2: Bioefficacy of test bioagents against second instar larva

TN	Treatments	Percent Mortality at days after treatment			
		1 DAT	3 DAT	5 DAT	7 DAT
T_1	*Metarhizium anisopliae* @ (1 x 108 cfu/ml) 5g / l	0.00 (2.87)*	10.00 (18.43)	35.56 (36.29)	57.04 (49.05)
T_2	*Beauveria bassiana* @ (1 x 108 cfu/ml) 5g / l	0.00 (2.87)	3.33 (8.06)	21.48 (27.61)	24.81 (29.82)
T_3	*Nomuraea rileyi* @ (1 x 108 cfu/ml) 5g / l	3.33 (8.06)	16.61 (23.86)	42.59 (40.69)	60.37 (51.06
T_4	*Bacillus thuringiensis* @ (3.5% ES) 2ml / l	13.33 (20.85)	24.81 (29.32)	64.44 (53.41)	67.78 (55.42)
T_5	*Steinernema carpocapsae* @ (10,0000 IJs) 4ml / l	0.00 (2.87)	6.67 (13.25)	28.15 (31.83)	28.15 (31.83)
T_6	Azadirachtin @ (10,000 ppm) 2ml / l	10.00 (18.43)	13.31 (21.49)	31.11 (33.89)	53.33 (46.92)
T_7	Untreated check	3.33 (8.85)	3.33 (8.06)	6.67 (13.25)	6.67 (13.25)
	CD at 5%	-	4.06	9.27	8.88
	F Test	NS	Sig.	Sig.	Sig
	SE(m)±	3.56	4.67	3.05	2.92

3.3 Bioefficacy of the test bioagents against pupa of FAW

Table 3: Bioefficacy of the test bioagents against pupa of FAW

TN	Treatments	Adult emergence (15 DAT)
T_1	*Metarhizium anisopliae* @ (1 x 108 cfu/ml) 5g / l	86.67(68.86)
T_2	*Beauveria bassiana* @ (1 x 108 cfu/ml) 5g / l	90.00(71.57)
T_3	*Nomuraea rileyi* @ (1 x 108 cfu/ml) 5g / l	83.33(66.14)
T_4	*Bacillus thuringiensis* @ (3.5% ES) 2ml / l	96.67(83.66)
T_5	*Steinernema carpocapsae* @ (10,0000 IJs) 4ml / l	73.33(59.00)
T_6	Azadirachtin @ (10,000 ppm) 2ml / l	70.00(56.79)
T_7	Untreated check	100.00(89.71)
	CD at 5%	8.59
	F Test	sig
	SE(m)±	2.83

All the six test bioagents were observed to be significantly superior over the untreated check. Amongst test bioagents, Azadirachtin recorded the lowest adult emergence (70%) that was on par with *S. carpocapsae* (73.33%) followed by *N. rileyi* (83.33%) and *M. anisopliae* (86.67%) which were at par followed by *B. bassaina* (71.57%) and Bt (96.67%). In the present studies, Azardirachtin and *S. carpocapsae* exhibited the lowest emergence whereas, *B. bassaina* and Bt recorded highest emergence. In comparison, *M. anisopliae* and *N. rileyi* showed the moderate emergence. Herein, the findings in respect of Azardirachtin are in confirmatory with that reported by Jucelio *et al.* (2020) [4] in respect of 47 neem oil on FAW. *S. carpocapsae* also exhibited significant pupal mortality and the findings are in corroboration with that of reported by Raultson *et al.* (1992) [6]. The findings in respect of N. rileyi, *M. anisopliae* and *B. bassaina* are in confirmation with that of reported by Asi *et al.* (2013) [1].

4. Summary and Conclusions

In respect of egg and pupal stage, Azardiractin and *S. carpocapsae* exhibited highest efficacy; *M. anisopliae* and *N. rileyi* depicted moderate bioefficacy; *B. bassiana* and Bt showed lowest efficacy. The trend of bioefficacy in larval stage depicted that Bt was found the most promising treatment exhibiting more than 80 per cent mortality in 2nd instar More or less similar observations are depicted in respect of *N. rileyi*, *M. anisopliae* and Azardiractin. *S. carpocapsae* and *B. bassiana* assumed to be least effective against 2nd instar larvae.

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