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Ecofriendly management of *Spodoptera frugiperda* in maize

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Abstract
Maize is a major field crop used as staple food and as fodder, but its nutrition quality and production is threatened by the major insect pest like Fall armyworm, *Spodoptera frugiperda*. An experimental study "Ecofriendly management of *Spodoptera frugiperda* in Maize" was carried out at the Department of Agricultural Entomology, VNMKV, Parbhani during *Rabi* 2021-22. Efficacy of biopesticides were studied using split plot design with three main treatments- seed treatment with cyantraniliprole+ thiamethoxam @ 6ml/kg of seeds, granular application with carbofuran 3G @ 33kg/ha and without treatment and five sub treatments- azadirachtin 3000 ppm, *Beauveria bassiana*, *Metarhizium anisopliae*, *Beauveria bassiana* + *Metarhizium anisopliae* and untreated against larval population Fall armyworm *Spodoptera frugiperda*. The results of fall armyworm larval population (No. of larvae/10 plants) at the end of three sprays showed that the main treatment, granular application with carbofuran (2.03) recorded the minimum larval population of *S. frugiperda* and main treatment, without treatment (3.23) recorded the maximum larval population. In sub treatments, *Metarhizium anisopliae* (1.51) showed the best result with the minimum larval population, which was at par with *Beauveria bassiana* (1.64) and maximum larval population was recorded in untreated (5.98). Application of biopesticides prevent the residual toxicity effects caused by chemical pesticides when it is consumed as fodder and it is considered as ecofriendly.

Keywords: Fall armyworm, *Metarhizium anisopliae*, *Beauveria bassiana*, carbofuran 3G

Introduction
Maize, *Zea mays* Linn. is a Poaceae family cereal crop, known as "queen of cereal" because of its inherent high genetic yield potentials. It is originated in Central Mexico and is currently one of the most extensively distributed crops of the world. In India major maize producing states are Karnataka, Andhra Pradesh, Maharashtra, Bihar, Punjab and Haryana. During the year 2020-21, in India Maize was cultivated on 9.86 million hectares, which produced 31.51 million tonnes with productivity of 3195 kg/hectare. In Maharashtra Maize was cultivated under 0.87 million hectares of land, which produced 1.1 million tonnes of Maize with productivity of 3000 kg/hectare (Anonymous, 2021) [2]. About 250 species of insect and mite pests have been reported damaging this crop out of which only few pests are of economic importance which threaten to reduce the product of this crop. It is attacked by a number of insect pest at various stages of development, from sowing to maturity, causing damage to all plant parts. Fall armyworm *Spodoptera frugiperda,* is a new destructive insect pest recently reported in India during the year 2018 has now gained a major pest importance causing damage to the crop at all the growing stages and the yield losses range up to 73 per cent (Kumar *et al.*, 2018) [4]. Maize crop is used for human consumption as well as fodder purpose. The chemical insecticides used to control insect pests causes adverse effects like insecticide resistance, effects natural enemies, effect of residual toxicity and environmental risks. Also, the chemical residues left in the plant after using insecticides will impair the health of animal when it is fed as fodder. Hence, to overcome all these major problems use of biopesticides is necessary and found to be safer and best alternative option to chemical insecticides as they are ecofriendly in nature and can be easily integrated with other pest management tactics.

Most widely used biopesticides are living organisms and plant- based pesticides, which are toxic for the pest of interest. Microbial pesticides, contain microorganisms as the active ingredient which are specific for its targeted pest. Among which entomopathogenic fungi like *Metarhizium anisopliae* and *Beauveria bassiana* plays important role in decreasing pest load by providing host defense mechanism against variety of crop insect pests. *M. anisopliae* and *B. bassiana* are promising biopesticides that are widely used in different crops and have been identified as endophytes in Maize. Hence, they can be utilized for managing pest in Maize. Application of *Metarhizium* and *Beauveria* in the moist condition helps them to colonize rapidly in the environment, so *kharif* crop duration is considered as most suitable condition for the growth of microorganisms. These microorganisms grow, multiply and resides in the field, the residues present in field helps in controlling the pest population in the following *Rabi* season. Botanical pesticide is any chemical or disinfectant that is derived from plants. Botanicals such as azadirachtin showed higher efficacy in preventing the growth of insects as they provide a valuable source of active chemical compounds. The use of these biopesticides is usually less harm to environment and has lower residual effects, resulting in least development of resistance against pests. Therefore, ecofriendly insect pest management is required as it is safer to environment. Hence, present investigation was carried out to study the ecofriendly management of *Spodoptera frugiperda* in Maize.

Methodology

The present investigation was laid out in split plot design with three replications at Department of Agricultural Entomology, College of Agriculture, VNMKV, Parbhani during *Rabi* 2021-22. The maize variety Dhanlaxmi (32D12) was sown in plot size of 3.6m x 4.8m with 60 x 20 cm spacing. Efficacy of biopesticides were studied with three main treatments- seed treatment with cyantraniliprole+ thiamethoxam @ 6ml/kg of seeds, granular application with carbofuran 3G @ 33kg/ha and without treatment and five sub treatments- azadirachtin 3000ppm, *Beauveria bassiana*, *Metarhizium anisopliae*, *Beauveria bassiana* + *Metarhizium anisopliae* and untreated against larval population Fall armyworm *Spodoptera frugiperda*. For seed treatment, required quantity of insecticide Cyantraniliprole+ Thiamethoxam @6ml/ kg of seed was taken and mixed with seeds before the sowing of seeds. For without seed treatment, no other insecticide was applied other than the sub treatments. For granular application, required quantity of insecticide Carbofuran 3G @33kg/ha was applied to the soil around the plant on 15th day after the germination of seeds. Sub treatments were imposed at the appearance of major insect pest on Maize and the remaining sprays were given with an interval of 15 days. The larval population of Fall armyworm was recorded on ten randomly chosen plants in each plot. Observation was recorded as number of larvae per 10 plants. Pre count of insect pest was recorded on one day before each spray and post counts were recorded on 3, 7 and 14 days after each spray. Observation recorded on 14th day is considered as the pre count of subsequent sprays. The data obtained from the field experiment was averaged and then subjected to statistical analysis.

Results and Discussion

Efficacy of biopesticides against larval population of Fall armyworm *Spodoptera frugiperda* in Maize

The observations presented in the table 1 revealed that,

First spray

The pre-count of larval population of Fall armyworm, *Spodoptera frugiperda* per ten plants showed that the main treatment, granular application with carbofuran (2.95) was superior over other two main treatments. The next best main treatment was seed treatment with cyantraniliprole+ thiamethoxam (3.44) which was at par with the main treatment, without treatment (3.76). In sub treatment, the pre-count of larval population of Fall armyworm *Spodoptera frugiperda* per ten plants was non-significant showing even distribution of plant infestation before spraying.

The observations reported on the larval population of Fall armyworm per ten plants at three days after spraying showed that the main treatment, granular application with carbofuran (2.6) was superior over the main treatment, seed treatment with cyantraniliprole+ thiamethoxam (3.23) which was at par with the main treatment, without treatment (3.55). In sub treatment, *Metarhizium* anisopliae (2.96) recorded the minimum larval population of Fall armyworm and it was at par with the azadirachtin 3000ppm (3.0), *Beauveria bassiana* (3.02) and *Beauveria bassiana*+ *Metarhizium anisopliae* (3.02). The untreated recorded the maximum number of larval population (3.62).

The observations reported on the larval population of Fall armyworm per ten plants at seven days after spraying showed that the main treatment, granular application with carbofuran (2.15) was superior over rest of two main treatments seed treatment with cyantraniliprole+ thiamethoxam and without treatment. Maximum larval population was recorded in main treatment, without treatment (3.32). In sub treatment, *Metarhizium* anisopliae (2.36) recorded the minimum larval population of Fall armyworm and it was at par with the *Beauveria bassiana* (2.4), azadirachtin 3000ppm (2.53) and *Beauveria bassiana*+ *Metarhizium anisopliae* (2.62). The untreated recorded the maximum number of larval population (3.96).

The observations reported on the larval population of Fall armyworm per ten plants at fourteen days after spraying showed that the main treatment, granular application with carbofuran (2.41) was superior over rest of two main treatments seed treatment with cyantraniliprole+ thiamethoxam and without treatment. Maximum larval population was recorded in main treatment, without treatment (3.65). In sub treatment, *Metarhizium* anisopliae (2.58) recorded the minimum larval population of Fall armyworm and it was at par with the *Beauveria bassiana* (2.67), *Beauveria bassiana*+ *Metarhizium anisopliae* (2.91) and azadirachtin 3000ppm (2.93). The untreated recorded the maximum number of larval population (4.29).

Second spray

The observations reported on the larval population of Fall armyworm per ten plants at three days after spraying showed that the main treatment, granular application with carbofuran (2.2) was superior over other two main treatments seed treatment with cyantraniliprole+ thiamethoxam and without treatment. Maximum larval population was recorded in main treatment, without treatment (3.43). In sub treatment, *Metarhizium* anisopliae (2.2) recorded the minimum larval population of Fall armyworm and it was at par with the *Beauveria bassiana* (2.36). The *Beauveria bassiana* (2.36) was at par with the *Beauveria bassiana*+ *Metarhizium anisopliae* (2.62) and azadirachtin 3000ppm (2.62). The untreated recorded the maximum number of larval population (4.51).

The observations reported on the larval population of Fall armyworm per ten plants at seven days after spraying showed that the main treatment, granular application with carbofuran (2.0) was superior over other two main treatments seed treatment with cyantraniliprole+ thiamethoxam and without treatment. The main treatment, without treatment recorded the maximum larval population (3.16). In sub treatment, *Metarhizium* anisopliae (1.78) recorded the minimum larval population of Fall armyworm and it was at par with the *Beauveria bassiana* (1.96). The next best treatment was *Beauveria bassiana*+ *Metarhizium anisopliae* (2.27) which was at par with the azadirachtin 3000ppm (2.31). The untreated recorded the maximum number of larval population (4.76).

The observations reported on the larval population of Fall armyworm per ten plants at fourteen days after spraying showed that the main treatment, granular application with carbofuran (2.31) was superior over other two main treatments seed treatment with cyantraniliprole+ thiamethoxam and without treatment. Maximum larval population (3.43) was recorded in main treatment, without treatment. In sub treatment, *Metarhizium* anisopliae (2.07) recorded the minimum larval population of Fall armyworm and it was at par with the *Beauveria bassiana* (2.27) and superior over other treatments. The *Beauveria bassiana* (2.27) was at par with *Beauveria bassiana*+ *Metarhizium anisopliae* (2.53), which was at par with azadirachtin 3000ppm (2.58). The untreated recorded the maximum number of larval population (5.09).

Third spray

The observations reported on the larval population of Fall armyworm per ten plants at three days after spraying showed that the main treatment, granular application with carbofuran (2.09) was superior over rest of two main treatments seed treatment with cyantraniliprole+ thiamethoxam and without treatment. Maximum larval population was recorded in main treatment, without treatment (3.23). In sub treatment, *Metarhizium* anisopliae (1.73) recorded the minimum larval population of Fall armyworm and it was at par with the *Beauveria bassiana* (1.93). The next best treatment was *Beauveria bassiana*+ *Metarhizium anisopliae* (2.22) and it was at par with the azadirachtin 3000ppm (2.24). The untreated recorded the maximum number of larval population (5.38).

The observations reported on the larval population of Fall armyworm per ten plants at seven days after spraying showed that the main treatment, granular application with carbofuran (1.84) was superior over rest of two main treatments seed treatment with cyantraniliprole+ thiamethoxam and without treatment. The maximum larval population was recorded in main treatment, without treatment (3.03). In sub treatment, *Metarhizium* anisopliae (1.29) recorded the minimum larval population of Fall armyworm and it was at par with the *Beauveria bassiana* (1.51). The next best treatment was *Beauveria bassiana*+ *Metarhizium anisopliae* (1.8) which was at par with azadirachtin 3000ppm (1.87). The untreated recorded the maximum number of larval population (5.76).

The observations reported on the larval population of Fall armyworm per ten plants at fourteen days after spraying showed that the main treatment, granular application with carbofuran (2.03) was superior over rest of two main treatments seed treatment with cyantraniliprole+ thiamethoxam and without treatment. The maximum larval population (3.23) was recorded in main treatment, without treatment. In sub treatment, *Metarhizium* anisopliae (1.51) recorded the minimum larval population of Fall armyworm and it was at par with the *Beauveria bassiana* (1.64). The next best treatment was *Beauveria bassiana*+ *Metarhizium anisopliae* (2.0) and it was at par with the azadirachtin 3000ppm (2.07). The untreated recorded the maximum number of larval population (5.98).

The result from the above three sprays revealed that, the main treatment granular application with carbofuran (2.03 larvae/10 plants) recorded the minimum larval population of *S. frugiperda* at the end of sprays. Similarly, the sub treatment, *Metarhizium anisopliae* (1.51 larvae/10 plants) showed the best result with the minimum larval population of *S. frugiperda* at the end of three sprays and it was at par with the sub treatment, *Beauveria bassiana* (1.64 larvae/10 plants).

Table 1: Efficacy of biopesticides against larval population of fall armyworm *Spodoptera frugiperda* on maize

Treatments	No. of larvae per ten plants									
	First Spray				Second Spray			Third Spray		
	Pre-count	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS
Main Treatment										
M_1- Seed treatment with Cyantraniliprole+ Thiamethoxam@ 6ml/kg	3.44	3.23	2.85	3.16	2.96	2.68	2.99	2.79	2.47	2.67
M_2-Granular application with carbofuran 3G @ 33kg/ha	2.95	2.60	2.15	2.41	2.20	2.0	2.31	2.09	1.84	2.03
M_3-Without seed treatment	3.76	3.55	3.32	3.65	3.43	3.16	3.43	3.23	3.03	3.23
S.Em±	0.09	0.09	0.08	0.08	0.08	0.07	0.06	0.08	0.06	0.07
C.D. at 5%	0.36	0.34	0.31	0.32	0.32	0.30	0.26	0.32	0.26	0.29
Sub Treatment										
T_1-Azadirachtin 3000ppm	3.36	3.0	2.53	2.93	2.62	2.31	2.58	2.24	1.87	2.07
T_2-*Beauveria bassiana*	3.36	3.02	2.4	2.67	2.36	1.96	2.27	1.93	1.51	1.64
T_3-*Metarhizium anisopliae*	3.38	2.96	2.36	2.58	2.2	1.78	2.07	1.73	1.29	1.51
T_4- *Beauveria bassiana*+ *Metarhizium anisopliae*	3.38	3.02	2.62	2.91	2.62	2.27	2.53	2.22	1.8	2.0
T_5-Untreated	3.44	3.62	3.96	4.29	4.51	4.76	5.09	5.38	5.76	5.98
S.Em±	0.14	0.13	0.11	0.12	0.11	0.08	0.10	0.09	0.07	0.08
C.D. at 5%	NS	0.36	0.32	0.36	0.33	0.25	0.29	0.26	0.22	0.23
Interaction (MxT)										
S.Em±	0.23	0.22	0.19	0.21	0.19	0.15	0.17	0.15	0.13	0.13
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	3.38	3.12	2.77	3.08	2.86	2.61	2.90	2.70	2.44	2.64

The result findings by earlier researchers were like Dhobi *et al.* (2020) [3] concluded that the treatments *B. bassiana* 5% WP (2.42 larvae/10 plants), azadirachtin 1500 ppm (2.46 larvae/10 plants) and next best treatment *M. anisopliae* 1.15% WP (2.78 larvae/10 plants) were effective in controlling the damage caused by Fall armyworm, *S. frugiperda*. All the treatments were found to be best compared to control (6.79 larvae/10 plants) in reducing the plant damage caused by the Fall armyworm, *Spodoptera frugiperda*.

Suthar *et al.* (2020) [6] concluded that the granular insecticides were effective against Fall armyworm in Maize. The carbofuran (1.96 larvae/10 plants) found to be more effective treatment compared over the control (6.58 larvae/10 plants) against the Fall armyworm in Maize.

Shinde *et al.* (2021) [5] reported that the mean of larvae per plant of Fall armyworm, *S. frugiperda* controlled in the treatments *M. anisopliae* (1.1 larvae/plant), *B. bassiana* (1.16 larvae/plant) and carbofuran (1.33 larvae/plant) were found to be effective in controlling the damage compared to untreated control (2.46 larvae/plant).

Ahir *et al.* (2021) [1] reported that the treatments *B. bassiana* (0.67 larvae/plant), *M. anisopliae* (0.73 larvae/plant) and azadirachtin 10000 ppm (0.97 larvae/plant) were found to effective over the untreated control (1.52 larvae/plant) in controlling the *S. frugiperda*.

Conclusion

Carbofuran showed the best results in managing larval population among the main treatments. *Metarhizium anisopliae* and *Beauveria bassiana* are the two biopesticides that potentially reduced the larval population of Fall armyworm. Hence, biopesticides can be used for managing major insect pests of Maize. Biopesticides can be the better alternative option to chemical insecticides for eco-friendly management.

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