Advances in Agricultural Technology & Plant Sciences
ISSN: 2640-6586

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Research Article

Volume 7 Issue 2

Eco-Friendly Practices for the Management of Fall Armyworm, *Spodoptera frugiperda* (J.E.Smith) in Maize

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Received Date: April 26, 2024; **Published Date:** July 19, 2024

Abstract

A study was conducted in the College Research Farm, Rajendranagar for two years 2020-21 and 2021-22 to evaluate various ecofriendly practices for the management of fall armyworm in maize. Two year pooled results revealed that among the biological and biorational methods, significantly least number of damaged plants plot-1 were seen in Trichocard+Bt plots (41.09 %) and pheromone (41.24%) and highest were seen in control plots (88.83%). Trichocard+Bt treatment (8.67 plot-1) and chemical treated plots (9.83 plot-1) recorded significantly highest no. of dead larvae, while pheromone plots (1.30) and control plot (0.00 and 2.30) recorded minimum dead larvae. Yield and benefit: cost ratio was significantly higher in Trichocards+Bt treated plots (2.79 t a-1 and 2.54 resp.) among the biological treatments and this was followed by the pheromone treatment (1.11 t a-1 and 2.19 resp.). Biological pest management methods have an important role to play in integrated pest management and have to be popularized among the farming community for better conservation of the ecosystem.

Keywords: Biopesticides; Eco friendly; Bt; Trichocards; Fall Armyworm; Maize

Abbreviations

FAW: Fall Armyworm; CC/Acre: Cubic Centre/Acre; HA: Hectare; BT: *Bacillus thuringiensis*.

Introduction

In India, maize is principally grown in two seasons, rainy (kharif) and winter (rabi). Kharif maize represents 83% of maize area in India, while rabi crop corresponds to 17% area. The crop is cultivated throughout the country and is infested by many insect pests and diseases. The fall armyworm is a severe pest causing huge losses to the farmers every year. FAW is a damaging transboundary pest that will continue to spread due to its biological characteristics and high volumes of trade between African countries [1]. Severe incidences of fall armyworm were reported from African countries such as Nigeria, Bénin, and Togo in 2016 [2]. The incursion of fall armyworm as an invasive pest into Asia was reported for the first time from India on maize during May 2018 [3]. In 2019 1.4 out of 6.2 lakh ha in Karnataka, 137 ha out of 32,000 ha in Andhra Pradesh, 200 out of 2700 ha in Tamil Nadu, 2000 ha in Nasik district in Maharashtra, 0.59 out of 7 lakhs ha in Rajasthan and 0.85 out of 11.3 lakh ha in Madhya Pradesh were infested by FAW [4]. The pest infests the crop a week after sowing, thereby causing 'window' like damage on the leaves while feeding in the whorls, then moves onto feeding in the cob. Since larvae feed voraciously on the growing point of the plant, severely infested plants remain stunted with no flowering. Although FAW larvae can feed on more than 80 species of plants, they prefer maize, as well as rice, cotton, groundnut, sorghum and vegetables. Farmers have been resorting to chemicals insecticides for its management. However, multiple sprays of insecticides may lead to the quick development of resistance as has occurred in other areas [5]. Several physical, chemical, and biological control strategies have been tried, but most are unsatisfactory for this destructive pest [6]. The pest has created food insecurity mainly among small land-holding farmers in Asia and Africa who grow maize as their main staple food [1,7]. Integrated pest management (IPM) approach was used to control FAW, including cultural control, chemical control, botanicals, push-pull farming system, biological control and indigenous knowledge [8]. Pesticide overuse has had negative effects on soil, water, air, and plant biomass, resulting in long-term environmental degradation, and an increase in cultivation costs [9]. Many workers have suggested the use of non-chemical alernatives for its management. Kushwaha UKS reported significant reduction in fall armyworm larval infestation in 0.15 g/plant grease-treated plots after 7-days of treatment application and the fields were free from the larvae after 14 days [10]. Trichogramma parasitoids could be high potential biocontrol agents for developing inundative biological control programs [11-13]. An integrated approach on the other hand can manage the pest better in addition to conserving natural enemies and soil fauna. Therefore, it is necessary to understand the efficacy of eco-friendly approaches for its management.

Material and Methods

Study Site

The experiment was laid out in a randomized block design with 10 treatments in the College Farm, Rajendranagar, Telangana, India during rabi season November-March of two years 2020–21 and 2021–22 with variety DHM 117. The crop was sown in the first week of November both the years. Size of each replication plot was 40 m2.

Treatments were Applied One Week after Sowing and they Included:

T1 Trichogramma chilonis cards @ 1 cc/acre +NBAIR Bt 2% @ 2.0 ml L^{-1}.

T2 Trichogramma chilonis cards@ 1 cc/acre +Metarhizium anisopliae NBAIR -Ma 35, 0.5%@ 5.0 g/Litre.

T3 Trichogramma chilonis cards@ 1 cc/acre + Beauveria bassiana NBAIR -Bb 45, 0.5% @ 5.0g/Litre.

T4 Trichogramma chilonis cards @1 cc/acre +EPN H. indica NBAIR H38 @ 4.0 kg/acre spray in whorls.

T5 Trichogramma chilonis cards @1 cc/acre + Pseudomonas fluorescens (Pf DWD 1%)@ 20.0 ml/L.

T6 Trichogramma chilonis cards @1 cc/acre +NBAIR SpfrNPV @ 2.0 ml/L.

T7 Trichogramma chilonis cards @ 1 cc/acre

T8 Pheromones @15 traps/acre (installed one week after planting and the lures were replaced every 21 days).

T9 Insecticidal check (Emamectin benzoate 0.40 g/L).

T10 Untreated check (control)

The biopesticidal and chemical treatments were sprayed 4 times starting from a week after and Trichocards were pinned for four times one week before each of the sprays. Observations on number of egg patches/plot, number of larvae/plot, number of damaged plants/plot, number of dead larvae (due to bacteria/virus/fungus)/plot, egg parasitization (%) and larval parasitization (%), number of predators/plant and yield were taken.

Results and Discussions

Pooled results of two years revealed that damaged plants/plot (%) were least (35.18) in the chemical treatment, Tc cards+Bt (41.09) and Pheromone plots (41.24), while Tc+Ma and Tc+Bb treatments recorded 63.65 and 73.64% respectively and rest of the treatments recorded between 83.33 and 88.83%. Similarly, dead larvae/plot were maximum in the chemical treatment (9.83) and in the Tc cards+Bt treatment (8.83) and they were on par. It was minimum (0.00) in the Tc cards plot and control plots, while rest of the treatments registered 1.30–7.67 dead larvae/plot. The microbial treatments were found to be safer to predators which were noticed in higher numbers in the Trichocard released plots (54.83)/plot and control plots (61.67/plot) while the biopesticides recorded 25.00–29.33/plot and least number of predators were recorded in the chemical treated plot (12.50/plot). The control plot however was safest to the beneficials (61.67/plot). Egg parasitisation (%) was affected in the chemical plots (12.67%) while rest of the plots registered 22.33–57.50% parasitisation indicating their safety to the parastioids and predators. It was maximum in the Trichocard released plots (57.50%).

Treatments	Percentage of damaged plants plot-1	Number of dead larvae plot-1	Number of predators plot-1	Egg parasitisation (%)	Yield (t a-1)	B:C ratio
Tc cards @ 1 cc a^{-1}+NBAIR Bt 2% @2 ml L^{-1}	41.09 (39.62)a	8.83 (3.04)ab	26.67 (5.05)cde	22.33 (4.70)e	2.88b	2.54
Tc cards @ 1 cc a^{-1}+NBAIR Ma 35 @ 5 ml L^{-1}	63.65 (53.41)b	6.33 (2.61)bc	29.33 (5.14)c	43.00 (6.25)b	1.43 d	1.29
Tc cards @ 1 cc a^{-1} +NBAIR Bb 45 @ 5 ml L^{-1}	73.64 (60.49)b	6.33 (2.61)bc	25.00 (5.36)e	22.33 (4.70)e	1.61d	1.78
Tc cards @ 1cc/a+NBAIR H38 whorl application @ 4 kg a^{-1}	83.33 (68.97)c	1.33 (1.34)d	26.00 (5.15)de	38.83 (6.13)c	1.34de	0.16
Tc cards @ 1 cc a^{-1}+Pseudomonas fluorescens 1% Pf @ 20 g L^{-1}	91.07 (73.87)c	5.00 (2.29) c	28.33 (7.43)cd	27.17 (5.20)d	1.43 d	1.34
Tc cards @ 1 cc a^{-1}+NBAIR Spfr NPV @ 2 ml L^{-1}	84.91 (70.24)c	7.67 (2.85)ab	26.00 (3.60)de	38.83 (6.13)c	2.17c	1.82
Tc cards @ 1 cc a^{-1}	88.54 (75.60)c	0.00 (0.71)e	54.83 (7.88)b	57.50 (7.21)a	1.02f	1.47
Pheromone traps @ 15 a^{-1}	41.24 (39.82)a	1.30 (1.32)d	28.33 (7.43)cd	43.00 (6.25)b	1.11 ef	2.19
Emamectin Benzoate @ 0.4 g L^{-1} spray	35.18 (35.40)a	9.83 (3.19)a	12.50 (5.05)f	12.67 (3.55)f	3.27 a	4.42
Control	88.83 (75.84)c	0.00 (0.71)e	61.67 (5.14)a	38.83 (6.13)c	0.62 g	-
CD 0.05	7.40	0.54	0.29	1.37	3.10	-

Selling price of maize varied from ₹1200-Rs.160 t^{-1} based on the quality of the cob.

Table 1: Efficacy of Various Treatments on Fall Armyworm in Maize.

Yield was higher in the Trichocards+Bt treated plots (2.79 t/acre) among the biologicals, while the rest of the treatments recorded yield between 1.02–2.17 t/acre. Control plot recorded least yield (0.62 t/acre). A study of the economics of the experiment revealed that Benefit: Cost ratio was highest in the Tc cards+Bt treatment (2.54) followed by the pheromone trap treatment (2.19), while it ranged between 0.16–1.82 in the others. The chemical treatment however recorded 4.42 B:C ratio.

Similar results were reported by Ramanujam B, et al. [14] who observed 68 and 69% reduction of FAW infestation and 55 and 62% increase in yield in the plots treated with M. anisopliae ICAR-NBAIR Ma-35 or B. bassiana ICAR-NBAIR Bb-45, respectively, during 2018. In 2019, 70 and 76% reduction of FAW infestation and 44 and 55% increase in yield were observed in the plots treated with these two entomofungal agents. Dhobi CB, et al. [15] found lowest larval population (1.81 larvae 10 plants-1 and 2.03 larvae 10 plants-1), minimum plant damage (15.34% and 17.70%) and cob damage (15.19% and 15.19%) in the plot treated with Nomuraea rileyi 1% WP @ 40 g 10 L water-1 and it was at par with *Bacillus thuringiensis* var kurstaki 1% WG @ 20 g 10 L water-1, respectively. Of the tested biopesticides, the highest grain and fodder yield was recorded from the plot treated with N. rileyi 1% WP (2957 and 4069 kg ha-1) and followed by *B. thuringiensis* (2932 and 4033 kg ha^{-1}). Ochoa MJ, et al. [16] reported that among the pathogens, B*. thuringiensis, M. anisopliae* and *B. bassiana* could cause significant mortality in FAW populations and help to reduce leaf defoliation in crops. However, Sharanabasappa D, et al. [17] found that chlorantraniliprole 18.5 SC followed by Emamectin benzoate 5SG, spinetoram 11.7 SC, flubendiamide 480 SC, indoxacarb 14.5 SC, lambda cyhalothrin 5 EC and novaluron 10 EC were most effective for the management of FAW in maize.

Bacillus thuringiensis Bt is a gram-positive endospore-forming bacterium that synthesizes a wide range of toxins with different chemical structures, modes of action and biological targets. The bioinsecticide formulations based on spores and toxin crystals of Btk and Bti are the most sprayed in organic and conventional farming, and in natural areas (e.g. forests, swamps). It is generally accepted that once ingested by insect larvae, the toxin crystals are dissolved by the midgut alkaline pH, releasing ~ 130 kDa pro-toxins that are then processed by digestive proteases into smaller, soluble, active toxin fragments of ~ 60–70 kDa [18,19]. Active toxins bind to specific receptors of midgut epithelial cells, eliciting pores formation in the cell membrane, cell lysis and gut epithelium disorganization [20]. This allows gut bacteria, including Bt, to colonize the haemocoel, and leads to rapid septicaemia and death [21]. Its efficacy on many phytophagous Lepidopterans has been widely documented by many workers. On the other hand, Trichogramma sp is widely known to parasitise eggs of Lepidopterous insects. The parasitoid targets the egg stages of Fall Armyworm. A combination of Bt + Trichocards can help to manage both the egg and larval stages. Integrating two ecofriendly methods render better results in pest management than a single tactic. The only consideration during the process was that the methods should be synergistic and their harmonious combination would yield better pest control with least disturbance to the environment. Thus integrated pest management strategies can nullify all the negative impacts of chemical insecticides on the crops, soil and the environment, when used. They are safe to the non-target beings (both microbes and macrobes) in the soil, water sources and on the plants. They help to maintain the biodiversity of insects and microbes in the field intact. Bt toxin addition did not significantly alter the abundances of potential microbial phytopathogenic taxa and did not reduce soil microbiome diversity and stability [22].

Science workers have reported Bt formulations to be quite safe to non-target insects. Many researchers support Bt application as a safer alternative to chemical insecticides, especially in organic farming [23]. Babin A, et al. reported that doses upto those recommended for field application (∼ 106 Colony Forming Unit (CFU)/g fly medium) did not impact fly development, while no fly emerged at ≥ 1000-fold this dose [24].

Doses between 10- to 100-fold the recommended one increased developmental time and decreased adult emergence rates in a dose-dependent manner, with species- and strain-specific effect amplitudes. The impacts of Btk formulations on the development of D. melanogaster are consistent with growing evidence suggesting partial specific targeting of Bt. [25,26]. Field studies of transgenic crops have failed to demonstrate significant detrimental impacts of Bt on related nontarget organisms or their predators. Because chemical insecticides are generally used less frequently on Bt crops, it is likely that such crops will benefit non-target populations, especially those of parasitoids and predators that control insect pests. In fact, studies in the U.S., China, and elsewhere have documented larger populations of predatory bugs, spiders, and ants, and enhanced biodiversity of beneficial insects in Bt cotton fields as compared with conventional fields treated with chemical insecticides. Similar results have been reported in Bt versus sprayed conventional potato fields. Studies examining the impact of Bt formulations in aquatic environments have failed to show adverse effects. Similarly, field studies of forest applications of Bt sprays have shown that the impact is restricted to moths and butterflies and appears to be transient for many non-target organisms. Laboratory tests also have failed to show toxicity of Bt to birds, fish, and invertebrates, including earthworms. However, Belousova ME, et al. [27] reported that Bt strains can affect indigenous microorganisms, such as bacteria and fungi, and further establish complex relationships with local plants, ranging from a mostly beneficial demeanor, to pathogenesis-like plant colonization. By exerting a direct effect on target insects, Bt can indirectly affect other organisms in the food chain.

Use of biopesticides and their combination treatments usually incurs lesser input costs than chemical treatments. Reported that IPM approach had performed chemical treatment in terms of net profit by more than 80% since in 1992, net profits were higher by 500-1000$ in the IPM programme compare to the chemical treatment, while in 1993 the chemical treatment outperformed by 300$ [28]. Bacillus and other biopesticides have the potential to revolutionize pest control markets in India. 11% of the true Biopesticide market in India is slated to touch over $2.5 billion in 2024. Europe is fast-tracking biopesticides, but in India, biological crop protection remains largely unexplored. Unlike the chemical crop protection sector, the introduction of patented biological products in the last two decades has been minimal [29]. However, with increase in land under organic farming, Biopesticides especially *Bacillus thuringiensis* have a larger role to play in Indian agriculture.

Conclusion

The present work was carried out to understand the impact of biopesticides and biorational methods on the fall armyworm on maize and highlighted their safety to the natural enemies and the ecosystem. Though these eco-safe methods had a lesser B:C ratio when compared to the chemical insecticide treatment, they definitely form important tools of the integrated pest management programme considering ecosystem survival. They definitely stand chance of being used as part of the integrated pest management programme.

Acknowledgements

The authors are highly grateful to National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru, India for providing financial assistance and biopesticide samples for the experiment.

Conflict of Interests

The authors declare that there are no conflicts of interests or financial interests.

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