**Eco-friendly management of Pink stem borer (*Sesamia inferens* Walker) in finger millet (*Eleusine coracana*Gaertn) in Andhra Pradesh, India**

**ABSTRACT**

Finger millet (*Eleusine coracana* Gaertn) is a nutri-cereal, known for its unique nutritional properties and climate resilience. In India, among various insect pests infesting finger millet, pink stem borer causes extensive damage to the crop in the peninsular India throughout the year and across the country. In the present scenario of growing importance of sustainable and eco-friendly agriculture, exploring effective and environmentally safe novel insecticides and microbial pesticides needs to be prioritized for management of pink stem borer in finger millet. Field studies were conducted at regional agricultural research station, Anakapalle, Andhra Pradesh to evaluate a novel eco-friendly insecticide, a botanical and few microbial pesticides for their efficacy against pink stem in finger millet during 2019-20 and 2020-21. The experiment was laid out in randomized block design with three replications. All the treatments were imposed as two foliar sprays at 15-20 days after sowing and again at 35-40 days after sowing and cumulative incidence of dead hearts and white ears were recorded up to 60 days after sowing. The cumulative data from the two consecutive years of study, revealed that emamectin benzoate @ 0.4 gl-1 is most effective in managing pink stem borer (2.5 per cent dead hearts and 2.8 per cent white ear heads), giving higher yield (29.4 quintals per hectare) and also achieving higher benefit cost ratio of 3.25. Among the botanicals and microbial pesticides tested, *M. anisopliae* @5 gl-1and *B.bassiana* @5 gl-1 proved to be the best at reducing the dead hearts to 3.9-4.3 per cent and white ear heads to 4.2-4.7 per cent. The cost economics reinforced the superiority of *M. anisopliae* and *B.bassiana* by obtaining benefit cost ratios of 3.08 and 2.98, respectively.

**Keywords**: finger millet, stem borer, management, cost economics

1. **INTRODUCTION**

Finger millet *Eleusine coracana* Gaertn is a nutri-cereal, known for its unique nutritional properties having high fiber (3.6 g/100 g), protein (7.6 g/100 g), calcium (410 mg/100g), iron (12.6mg/100g), potassium (314 mg/100g) content along with vitamins like niacin, thiamine, riboflavin and essential amino acids like tyrosine, cysteine, tryptophan and methionine.[1]Finger millet is also a climate resilient crop which can withstand vagaries of climate and can be cultivated in various ecological situations. From being a sparsely grown and input starved crop, finger millet is now gaining importance owing to increased awareness towards healthy diet. The emergence of Finger millet from "poor man's staple food" to "a nutrient rich cereal" has encouraged the need to explore this crop at a wider scale. To meet the market demand by achieving higher yields through eco-friendly and sustainable avenues, the growers should invariably resort to good variety, organic agronomic inputs and eco-friendly plant protection measures.

Among more than 50 insect pests associated with finger millet crop, pink stem borer, *Sesamia inferens* Walker (Noctuidae; Lepidoptera) is widely distributed in India and is responsible for yield loss in parts of Andhra Pradesh, Odisha, Karnataka and Tamil Nadu throughout the year[2, 3] The adult moth lays eggs in clusters in between leaf sheath and the whorl, from there the hatched larvae enter into the stem and start feeding forming ‘S’ shaped tunnels[4]. Infestation of pink stem borer after ear head emergence causes completely white, chaffy panicle called ‘White ear head (WEH)’ [5]. Losses to the extent of 10-15 per cent have been recorded due to incidence of pink stem borer in finger millet.

For eco-friendly and effective management of pink stem borer infesting finger millet, need to be explored along with their timing of application. Focus on effective and environmentally safe insecticides with novel mode of action and certain microbial pesticides is to be prioritized as they play a vital role in conserving natural enemies, insecticide resistance management strategies and also combating chemical pollution, ecological adversities besides reducing human health hazards. Eco-friendly and microbial insecticides are crucial in modern pest management as they offer sustainable alternatives to chemical pesticides, reducing environmental pollution and harm to non-target species. They target specific pests, minimizing the disruption to beneficial insects and ecosystems. Microbial insecticides have a lower toxicity to humans and animals, promoting safer agricultural practices. These options help in managing pesticide resistance by offering different modes of action. The use of eco-friendly insecticides aligns with integrated pest management (IPM) principles, supporting long-term agricultural productivity and environmental health. In this backdrop, a study was conducted to evaluate the efficacy of certain eco-friendly bio-agents and novel pesticides in management of pink stem borer in finger millet.

**2.MATERIALS AND METHODS**

A field experiment was laid out at regional agricultural research station, Anakapalle, Andhra Pradesh to evaluate the efficacy of a novel eco-friendly insecticide, a botanical and few microbial pesticides against pink stem borer in finger millet during the years 2019-2020 and 2020-21.

**2.1 Cultivation of finger millet**: The finger millet variety VR 847 (Chaitanya) with duration of 110-115 days was grown in area of 0.03 ha adopting a spacing of 30cm x 10 cm in a randomized block design in three replications with seven treatments. The recommended package of practiceswas adopted with regard to crop production aspects. The NPK were applied in the ratio 24:12:8 with nitrogen in two splits as basal and at 30 days. Manual weeding was done twice and plant protection measures were taken up during crop growth stage as per the treatments.

**2.2Treatments imposed**: The treatments included a novel eco-friendly insecticide, Emamaectin benzoate, a botanical, neem oil and few microbial pesticides viz., *Metarrhizium anisopliae*, *Bacillus thuringiensis* and *Baueveria bassiana*. The zonal recommendation of monocrotophos was taken as a chemical check and an unsprayed treatment was taken as control check. The details of the seven treatments are given are presenter under Table1.

|  |
| --- |
| **Table1. Details of the treatments imposed**  |
| **Treatment number** | **Details** |
| T1(Microbial) | *Metarrhizium anisopliae* @ 5.0 gm/l  |
| T2(Microbial) | *Bacillus thuringiensis* @ 2.0 gm/l  |
| T3(Microbial) | *Baueveria bassiana* @ 5.0 gm/l  |
| T4(novel insecticide) | Emamectin benzoate@ 0.4 gm/l  |
| T5(Botanical) |  Neem oil @ 5.0 ml/l  |
| T6(chemical check) | Monocrotophos 36 SL@ 1.6ml/l  |
| T7(untreated check) | Unsprayed control check |

 All the treatments were imposed twice at 15-20 days after sowing followed by 35-40 days after sowing. The spraying was taken up using battery operated knapsack sprayer using 500 litres of spray fluid per acre after pink stem borer attaining economic threshold level of 5 per cent dead hearts initially.

**2.3 Pest data**: The pink stem borer damage in the form of either dead hearts or white ears were recorded. The number of total tillers and dead hearts (DH) were counted in 10 randomly selected hills from each treatment plots at fortnightly interval and the cumulative incidence was calculated. The cumulative percentage incidence of stem borer affected tillers (DH%) was calculated for each entry by computing the formula [6].

Percentage of dead heart (DH%) = [No of stem borer affected tillers (Dead heart)/ Total no of tillers in each entry] X 100

The number of total tillers and white ear head (WEH) were counted in 10 randomly selected hills from each treatment plots at finger maturity stage. The percentage of white ear head (WEH %) was also calculated for each entry by computing the formula.

 Percentage white ear head (WEH %) = [No of stem borer affected panicles/ Total no of panicles in each entry] X 100.

**2.4 Yield data**:

**Yield**: Plot wise and replication wise yield was recorded and the total yield per hectare was computed according to the following formula [7].

Yield, kg/ha = Factor × Seed yield (per plot)

Where,

Where, Factor = $\frac{10000}{Net plot size},m^{2}$

**Benefit cost ratio:** Benefit cost ratio (B: C ratio) was calculated with respect to different treatments for management of pink stem borer in finger millet, as per the formula given [7].

$$B:C ratio=\frac{Gross returns}{Cost of cultivation}$$

**2.5 Statistical Analysis:** The experiments have been replicated thrice during three subsequent years.The data from field experiments was screened by ANOVA (analysis of variance) after getting transformed into √x+0.5 using AGRES. Pooled RBD ANOVA was done using Microsoft excel. Critical difference was calculated at 5% probability level and treatments mean values were compared using Duncan’s Multiple Range Test[8].

**3. RESULTS**

Field experiments to evaluate the efficacy of a novel eco-friendly insecticide, a botanical and few microbial pesticides against pink stem borer in finger millet were conducted for two consecutive years and the data was statistically analysed. The results obtained are presented here under.

**3.1Efficacy of treatments on incidence of pink stem borer:** The pink stem borer damage in the form of either dead hearts or white ear heads in finger millet were recorded at fortnightly interval and the cumulative incidence was calculated.

As presented in table 2, the pooled mean cumulative dead heart incidence was least (2.5 per cent) in plots treated with emamectin benzoate, a novel eco-friendly molecule. The next best treatments were microbials, *M. anisopliae*, which recorded 3.9 per cent incidence of dead hearts as a pooled mean for two years and which was closely followed by, *B.bassiana*, recording 4.3 per cent incidence of dead hearts. The plots treated with the chemical check, monocrotophos fared better (5.7 per cent dead hearts) compared to another microbial *B.thuringiensis* (6.7 per cent) and neem oil(botanical) which recorded 8.9 per cent pooled cumulative incidence of dead hearts. The unsprayed control check recorded, the highest of 16.7 per cent pooled cumulative incidence of dead hearts. Comparing the results in the form of per cent reduction in damage, the novel insecticide, emamectin benzoate, recorded highest of 85 per cent, followed by, *M. anisopliae* (76.6 per cent) and *B.bassiana* (74.2 per cent).

 With regard to white ear heads, the cumulative incidence for two consecutive years is presented in table 2 along with the pooled mean and per cent reduction in damage. In plots treated with emamectin benzoate,pooled mean cumulative white ear heads incidence was least (2.8 per cent) followed by *M. anisopliae*, which recorded 4.2 per cent incidence of white ear heads as a pooled mean for two years. These were closely followed by, *B.bassiana* (4.7 per cent) and *B.thuringiensis* (6.9 per cent). The chemical check, monocrotophos performed better (5.8 per cent white ear heads) compared to neem oil, which recorded 8.0 per cent pooled cumulative incidence of white ear heads. The unsprayed check recorded the highest of 15.9 per cent pooled cumulative incidence of white ear heads. The results indicate that the novel insecticide, emamectin benzoate, recorded significantly highest of 82.4 per cent reduction in white ear heads. Among the microbial pesticides *M. anisopliae* (73.6 per cent) was the most superior closely followed by*B.bassiana* (70.4 per cent). The subsequent treatments were the chemical check, monocrotophos (63.5 per cent), *B.thuringiensis* (56.6 per cent) and neem oil, which recorded 49.7 per cent reduction in white ear heads compared to unsprayed check.

**3.2 Grain Yield and cost economics of treatments against pink stem borer in finger millet:**

 The data on grain yields obtained in different treatments, plot wise and replication wise was recorded and the total yield per hectare was calculated for each treatment. The cost economics were worked out, by computing the treatment-wise cost of insecticides, cost of cultivation like land preparation, seed, fertilizer, labour wages and weed control. The income generated and benefit cost ratios of the respective treatments were also calculated. The yields obtained, cost of cultivation, income generated and benefit cost ratios of various treatments are presented in table 3.

 The incremental yield over unsprayed control ranged from highest of 10.3 quintals per hectare to lowest of 4.4 quintals per hectare. Pooled grain yield for the two years reinforced the supremacy of emamectin benzoate, which registered highest yield of 29.4 quintals per hectare, however it was statistically on par with yields obtained with *M. anisopliae* (27.8 quintals per hectare) and *B.bassiana* (26.9 quintals per hectare). The chemical check, monocrotophos registered next highest yield of 24.3 quintals per hectare and it was on par with *B.thuringiensis*(24.1 quintals per hectare) and neem oil (23.5 quintals per hectare). The unsprayed control recorded least grain yield of 19.1 quintals per hectare.

Based on the yields, the income generated was also highest in emamectin benzoate (Rs.88200) followed by *M. anisopliae*(Rs.83400), *B.bassiana* (Rs.80700), monocrotophos (Rs.72900), *B.thuringiensis* (Rs.72300) and neem oil (Rs.70500). The least income of Rs.57300 was obtained in the unsprayed control owing to the lowest yield.The benefit cost ratios obtained also upheld the most effective treatment as the novel insecticide, emamectin benzoate achieving highest benefit cost ratio of 3.25. The microbial pesticides, *M. anisopliae* and *B.bassiana* were also proved to be highly economical registering benefit cost ratios of 3.08 and 2.98, respectively. The chemical check, monocrotophos registered benefit cost ratio of 2.72 followed by *B.thuringiensis*(2.66) and neem oil (2.55), while the unsprayed control registered least benefit cost ratio of 2.30.

**4. DISCUSSION**

 The pooled mean cumulative dead heart incidence was least (2.5 per cent) in plots treated with emamectin benzoate, a novel eco-friendly molecule. The efficacy of emamectin benzoate in has been proved widely in maize and millets by against stem borers when tested along with other conventional insecticides[9,10,11, 12]. The next best treatments were the microbial pesticides, *M. anisopliae* and *B.bassiana,* which recorded 3.9 per cent and 4.3 per cent incidence of dead hearts as a pooled mean for two years. Due to their specificity, effectiveness, easily affordable, quickly decomposing nature and less resurgence, bio-pesticides have an edge over conventional pesticides in pest management and their efficacy of microbial pesticides against stem borers has been reported[13,14,15].Grain yield is the manifestation of efficacy of different treatments when compared to unsprayed control. Pooled grain yield for the two years reinforced the supremacy of emamectin benzoate, which registered highest yield of 29.4 quintals per hectare, however it was statistically on par with yields obtained with *M. anisopliae* (27.8 quintals per hectare) and *B.bassiana* (26.9 quintals per hectare). The benefit cost ratios obtained also upheld the most effective treatment as the novel insecticide, emamectin benzoate achieving highest benefit cost ratio of 3.25. There are reports in consensus with the other findings stating reporting high benefit cost ratio with emamectin benzoate [16,17,18,19]. The microbial pesticides, *M. anisopliae* and *B.bassiana* were also proved to be highly economical registering benefit cost ratios of 3.08 and 2.98, respectively. In concurrence with the results of the present study, reports suggest efficacy of*M. anisopliae* and *B.bassiana* against stem borer and proved to be much viable economically[20,21,22,23].

**5. CONCLUSION**

The cumulative data from the two consecutive years of study, it can be interpreted that a novel eco-friendly insecticide, emamectin benzoate @ 0.4 gl-1 is most effective in managing pink stem borer(2.5 per cent dead hearts and 2.8 per cent white ear heads), giving higher yield (29.4 quintals per hectare) and also achieving higher benefit cost ratio of 3.25. Among the botanicals and microbial pesticides tested, *M. anisopliae* @5 gl-1and *B.bassiana* @5 gl-1 proved to be the best at reducing the dead hearts to 3.9-4.3 per cent and white ear heads to 4.2-4.7 per cent. The cost economics reinforced the superiority of *M. anisopliae* and *B.bassiana* by obtaining benefit cost ratios of 3.08 and 2.98, respectively.

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Table 2. Efficacy of treatments against pink stem borer incidence in finger millet

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment detail | Cumulative Incidence of dead hearts(%) | Reduction of dead hearts over control (%) | Cumulative Incidence of white ear heads(%) | Reduction of white ear heads over control (%) |
| 2019-2020 | 2020-2021 | Pooled Mean | 2019-2020 | 2020-2021 | Pooled Mean |
| *Metarrhizium anisopliae* @ 5.0 gm/l  | 3.6(10.8) | 4.2(11.5) | 3.9(11.1) | 76.6 | 3.7(11.2) | 4.6(12.6) | 4.2(11.5) | 73.6 |
| *Bacillus thuringiensis*@ 2.0 gm/l  | 7.0(15.1) | 6.4(14.5) | 6.7(14.5) | 59.9 | 7.2(15.4) | 6.7(15.0) | 6.9(15.2) | 56.6 |
| *Baueveria bassiana* @ 5.0 gm/l  | 3.9(11.6) | 4.7(12.1) | 4.3(11.8) | 74.2 | 4.3(12.3) | 5.1(13.1) | 4.7(12.6) | 70.4 |
| Emamectin benzoate@ 0.4 gm/l  | 2.2(8.2) | 2.8(8.7) | 2.5(8.6) | 85.0 | 2.4(8.6) | 3.3(10.4) | 2.8(9.3) | 82.4 |
|  Neem oil @ 5.0 ml/l  | 8.5(16.3) | 9.3(17.7) | 8.9(17.2) | 46.7 | 7.4(15.3) | 8.6(17.0) | 8.0(16.7) | 49.7 |
| Monocrotophos 36 SL@ 1.6ml/l (chemical check) | 5.3(12.3) | 6.1(14.2) | 5.7(14.0) | 65.8 | 6.3(14.2) | 5.3(13.4) | 5.8(13.9) | 63.5 |
| Unsprayed control check | 17.8(25.1) | 15.6(23.2) | 16.7(24.3) |  | 16.3(23.8) | 15.4(22.6) | 15.9(23.4) |  |
| SE(m) ± | 0.38 | 0.41 | 0.42 |  | 0.39 | 0.37 | 0.40 |  |
| CD(p=0.05) | 1.2 | 1.3 | 1.4 |  | 1.4 | 1.2 | 1.3 |  |

Figures in parenthesis are arc sine transformed values

Table 3. Grain yield and cost economics in different treatments evaluated against pink stem borer incidence in finger millet

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Treatment detail | Grain yield(quintal ha-1) | Incremental Yield over control (quintal ha-1) | Total Income\*(Rs ha-1) | Total Cost of Cultivation(Rs ha-1) | BC ratio |
| 2019-2020 | 2020-2021 | Mean |
| *Metarrhizium anisopliae* @ 5.0 gm/l  | 27.2 | 28.4 | 27.8 | 8.7 | 83400 | 27000 | 3.08 |
| *Bacillus thuringiensis* @ 2.0 gm/l  | 21.5 | 26.7 | 24.1 | 5.0 | 72300 | 27200 | 2.66 |
| *Baueveria bassiana* @ 5.0 gm/l  | 26.6 | 27.2 | 26.9 | 7.8 | 80700 | 27000 | 2.98 |
| Emamectin benzoate@ 0.4 gm/l  | 28.2 | 30.6 | 29.4 | 10.3 | 88200 | 27160 | 3.25 |
|  Neem oil @ 5.0 ml/l  | 21.4 | 25.6 | 23.5 | 4.4 | 70500 | 27700 | 2.55 |
| Monocrotophos 36 SL@ 1.6ml/l (chemical check) | 25.2 | 23.4 | 24.3 | 5.2 | 72900 | 26800 | 2.72 |
| Unsprayed control check | 17.8 | 20.4 | 19.1 |  | 57300 | 25000 | 2.30 |
| SE(m) ± | 0.36 | 0.39 | 0.42 |  |  |  |  |
| CD | 3.2 | 3.1 | 3.4 |  |  |  |  |

 \* The market price of Ragi was taken as Rs.30 per kg.