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Eco-friendly management of pink stem borer *Sesamia inferens* walker in finger millet (*Eleusine coracana* Gaertn) in coastal Odisha

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Abstract
Field experiments on the eco-friendly management of pink stem borer in finger millet cv. *Bhairabi* revealed the superiority of foliar spray of Bt (*Bacillus thuringiensis*) @ 2g/L at 30 DAS and NSKE 5% at 35 DAS in arresting mean stem borer damage *i.e.* (13.93 &14.48%) dead heart and (11.63% & 11.89%) white ear head as against 22.82% & 20.68% dead heart and white ear head respectively in control. At vegetative and heading stages treatments resulted upto 39.0% and 44.0% reduction in borer damage in comparison to control. In grain yield point of view both the treatments yielded more than 20.0q/ha which is significantly higher than untreated control (11.68q/ha).

Keywords: Pink stem borer (*Sesamia inferens*), Bt (*Bacillus thuringiensis*), NSKE (Neem seed kernel extract)

1. Introduction
Millets represent a diverse group of small-seeded grasses grown for food, feed or forage (Lata *et al*., 2013; Lata, 2015) [12, 11]. They comprise about a dozen crop species that mainly originated in third world countries and were domesticated and cultivated by small farmers in semi arid and tropical regions. Millets are important by virtue of their contribution to biodiversity and the means of livelihood of the poor in various parts of the world (Belton and Taylor, 2004) [3].

Millets comprised of six major small-grained cereal crops, of which finger millet is considered as an economically important nutraceutical crop. Finger millet is a crucial ingredient for the diets of pregnant and lactating mothers and children as well for the economy of marginal farmers. Its grains are rich in protein, vitamins, minerals, fiber content and energy as compared to other cereals (Vadivoo *et al.*, 1998) [28]. Some genotypes of finger millet have been analyzed to contain calcium as high as 450 mg/100g of grains (Gupta *et al*., 2011; Kumar *et al*., 2014c) [5, 10] and hence, can be developed and used as preventive drug(s) against osteoporosis. It is also enriched with manganese, phosphorus and iron as well as useful amounts of copper and comparatively higher chromium, magnesium, molybdenum, zinc and selenium (Shashi *et al*., 2007; Tripathi and Platel, 2010) [20, 27]. Also, finger millet straw is excellent as animal fodder with up to a total of 60% digestible nutrients.

Finger millet crop previously being neglected but now gaining its importance in diet. Now both area expansion and yield improvement of finger millet is the need of the hour. Apart from the improvement in genetic attributes and agronomic practices some plant protection measures are also needed for enhancing yield in finger millet.

Among the insect pests associated with finger millet crop, pink stem borer, *Sesamia inferens* Walker (Noctuidae; Lepidoptera) is widely distributed and responsible for major yield loss. This is one of the most important insect pest of finger millet during *Rabi* and Summer season. Pink stem borer *S. inferens* Walker is a polyphagous pest attacking various graminaceous crops like sorghum, pearl millet, finger millet, wheat (Nagrajan,1989; Singh, 1986) [13, 23], rice (Banerjee & Pramanik, 1967; Khan *et al*., 1991) [2, 9], oats, barley, sugarcane and some grasses (Rao, 1983) [14]. Pink stem borer regularly attack finger millet crop in parts of Odisha, Karnataka, Tamil Nadu and Andhra Pradesh (Jagadish *et al*., 2008) [6].Pink stem borer causes extensive damage to the crop in the peninsular India throughout the year and across the country (Santosh *et al*., 2008) [18]. Egg laying of this insect occurs in clusters in between leaf

sheath and the whorl. After hatching the larvae enter into the stem, reach the soft tissues and start feeding which forms 'S' shaped tunnels filled with excreta inside the stem (*Sonali et al*., 2013) [25]. Infestation of pink stem borer after ear head emergence causes completely white, chaffy panicle called 'White ear head (WEH)' (Reddy *et al*., 2003) [16]

For effective management of stem borers infesting finger millet, effective chemicals and their timing of application is inevitable as this pest is an internal feeder and management at later stage offers narrow scope for chemical control (Ravinder and Jawala, 2015) [15]. Focus on effective and environmentally safe insecticides with novel mode of action is to be prioritized as they play a vital role in insecticide resistance management strategies. Botanicals like neem oil, neem leaf extract and NSKE has exhibited higher efficacy in deterring the oviposition of stem borer adults (Saranya and Samiayyan, 2017) [19]. Similarly, *Bt* products (James, 2002 and Siddalingaapa, 2010) [7, 22] also expressed moderate levels of efficacy in suppressing the stem borer larvae. Among various management strategies, chemical control has its own effectiveness due to its rapid knock down effect (Tende *et al*. 2010) [26]. But, over reliance on synthetic pesticides leads to ecological adversities besides human hazards. Thus, there is need of using more efficient insecticides against the pest and safe, eco-friendly alternatives to insecticidal control for safeguarding the natural enemies. Keeping these concept in view, the present investigation was carried out during Summer, 2016 to Summer, 2018.

2. Materials and Methods

Field experiments were carried out in randomized block design with three replications at Centre for Pulses Research (OUAT), Berhampur under the supervision of All India Co-Ordinated Research Project on Small Millets during Summer 2016, 2017 and 2018 to test the efficacy of different eco-friendly approaches *viz*., bio-control agents, botanical pesticides, biopesticides against pink stem borer (*Sesamia inferens* Walker) in finger millet cv. *Bhairabi* under irrigated condition. Line sowing of seeds was done during 2nd week of January in 20 m^2 plots at 22.5 cm row to row spacing. A week after emergence, thinning was done to maintain plant population at 10cm plant to plant spacing. Fertilizers were applied at 50:25:25 kg NPK/ha and crop was grown following all recommended agronomic practices. The experiment constituted of seven treatments and the details of the treatments are as follows

T_1 : Release of *Trichogramma chelonis* as biocontrol agent at 50000/- per hectare at 7 days interval (3 times released starting from 30 DAS)
T_2 : Foliar spray of neem pesticide 0.03% (300ppm) @ 5ml./L of water at 30 DAS.
T_3 : Foliar spray of *Bt* (*Bacillus thuringiensis*)@ 2g/L of water at 30 DAS.
T_4 : Spraying of NSKE 5% at 15 DAS
T_5 : Spraying of NSKE 5% at 25 DAS
T_6 : Spraying of NSKE 5% at 35 DAS
T_7 : Untreated Control

Observations on stem borer damage was recorded from 10 randomly selected plants from each plot at 45 DAS for dead heart (DH) and at 70 DAS for white ear head (WEH) incidence. At vegetative stage dead heart damage was estimated by counting total tillers and the infested ones and at heading stage white ear head damage was accessed by counting the total panicle bearing tillers and the damaged ones. Plot wise grain yield was recorded leaving two border rows from all sides. Data generated were then subjected to statistical analysis after stable transformation for drawing meaningful conclusion.

3. Results and Discussion

Pink Stem borer is considered as the major insect pest in all millet growing areas of Odisha. During the period of investigation, the mean borer damage at an intensity of 22.82% DH and 20.68% WEH was recorded at vegetative and reproductive stage respectively.

3.1 Effect of different eco-friendly treatments against Pink stem borer (*Sesamia inferens*)

Pink stem borer inflicts heavy damage to finger millet crop in the state as well as country with 4-5 generations per year (Shyam Prasad *et al*.,2015) [22]. Comparatively the severity is more in late *rabi/summer* season during which the field experiments were carried out. Mean Borer damage to the tune of 22.82% DH and 20.68% WEH was recorded at vegetative and reproductive stages respectively over 03 years of experiment. The data presented in Table 1 revealed the year wise cumulative effect of application of different treatments against pink stem borer during *summer*, 2016-18. The application of treatments bring about significant difference in stem borer damage in the treated plots over the years. NSKE 5%, a botanical insecticide sprayed at 35 DAS(days after sowing) and Spraying of *Bacillus thuringiensis* (*Bt*) @ 1 kg/ha at 30 DAS exhibited better performance in arresting the stem borer damage at tillering as well as heading stage of finger millet over 03 years of experiment.

3.1.1 Summer, 2016

Stem borer damage to the tune of 18.31% at vegetative stage and 12.49% in reproductive stage were recorded in control plots during *summer*, 2016 (Table 1). During vegetative stage of the crop, the superiority of foliar spray of NSKE 5% at 35 DAS and foliar spray of *Bacillus thuringiensis* (*Bt*) @ 1 kg/ha at 30 DAS was observed with low incidence of DH(dead heart) *viz*., 9.20&10.62% respectively over 18.31% DH in control. Next to these best treatments, foliar spray of NSKE at 25 DAS was also found effective in suppressing the pest damage with a record of 11.21% as against 18.31% in control. All the three treatments are found statistically at par with each other. All the other treatments were also found effective against stem borer with less DH incidence (11.21-13.08%) over control. During reproductive stage of the crop, similar effects as in vegetative stage were noticed with *lowest incidence of* 5.37-5.85 per cent WEH as against 12.49% in control. Throughout the season both the treatments were successfully able to reduce the stem borer damage with a record of 42-50% during vegetative stage and 53-57% during heading stage of the crop over untreated control.

3.1.2 Summer, 2017

Result of the second season trial presented in Table 1 further strengthened our finding that, foliar spray of NSKE 5% at 35 DAS and foliar spray of *Bacillus thuringiensis* (*Bt*) @ 1kg/ha at 30 DAS were observed with low incidence of DH(dead heart) *viz*., 13.06 &15.07% respectively over 27.03% in control during vegetative stage of the crop. Both the treatments were found statistically at par with each other.

During reproductive stage of the crop, similar effects as in vegetative stage were noticed with *lowest incidence of* 12.03&14.34% WEH respectively as against 23.20% in control. Throughout the season pest reduction of 44-52% in vegetative stage and 38-48% in reproductive stage was observed over untreated control.

3.1.3 Summer, 2018

During Summer 2018, same trend of performance was observed which again strengthened the findings where foliar spray of NSKE 5% at 35 DAS and foliar spray of *Bacillus thuringiensis* (Bt) @ 1kg/ha at 30 DAS was observed with low incidence of DH (dead heart) *viz*., 11.83 & 14.42% respectively as against 23.45% in untreated control. During reproductive stage of the crop, similar effects as in vegetative stage were noticed with *lowest incidence of* 12.03-14.34 per cent WEH as against 23.20% in control. Throughout the season pest reduction of 44-52% in vegetative stage and 38-48% in reproductive stage was observed over untreated control.

3.1.4 Pooled analysis of stem borer damage in Summer 2016, Summer 2017 and Summer 2018

Pooled data of three seasons trial on stem borer damage in cv. *Bhairabi* presented in Table 1 revealed severe borer damage at both vegetative and reproductive stage of the crop. At vegetative stage mean borer damage 22.82% DH in control plot as against 20.68% WEH at the heading stage.

During three years of experiment, heavy incidence of stem borer were observed throughout the crop growth stage, which helps in drawing suitable conclusion for management of this notorious insectpest of finger millet during Summer season. During the maximum tillering stage(Vegetative stage), the stem borer damage varied from 13.93 to 19.33 as against 22.82 in untreated control. The lowest being in plots receiving foliar spray of Bt (*Bacillus thuringiensis*) @ 2g/L of water at 30 DAS which remained on par with that of foliar spray of NSKE 5% at 35 DAS (13.93 & 14.48% DH) resulting in about 37.00-39.00% decline in dead heart damage. Both the best treatments were closely followed by foliar spary of NSKE 5% at 25 DAS (16.22% DH). Almost all other treatments were found with significantly lower borer damage over control.

White earhead damage recorded at pre-harvest was minimal in plots with receiving foliar spray of Bt (*Bacillus thuringiensis*) @ 2g/L at 30 DAS and foliar spary of NSKE 5% at 35 DAS (11.63 & 11.89% WEH) resulting about 43.00-44.00% decline in white earhead damage. Apart from these, foliar spray of neem pesticide 0.03% (300ppm)@ 5ml./l of water at 30 DAS and NSKE 5% at 25 DAS *viz.*,14.29 & 15.52% WEH respectively as against 20.68% in control were considered as next best treatments in arresting the stem borer damage at heading stage.

3.1.5 Grain yield

Grain yield, which is manifestation of cumulative impact of different treatments over control. Pooled grain yield data of three seasons trial with cv. *Bhairabi* presented in Table 1 revealed that all the eco-friendly treatments showed higher grain yield over control with a record of 13.68- 21.52 q/ha as against 11.60 q/ha in control. Supremacy of foliar spray of NSKE 5% at 35 DAS and foliar spray of Bt (*Bacillus thuringiensis*) @ 2g/L of water at 30 DAS was reaffirmed with a record of 20.20-21.52 q/ha resulting in 74.13 to 85.51% higher yield over control. Foliar spray of NSKE 5% at 25 DAS (18.57q/ha) yielded next to the best treatments and identified as second most effective treatment.

3.1.6 Economics

The economics of various treatments were computed basing on the cost of insecticides and other cost of production like seed, fertilizer, labour wage, cost of ploughing, irrigation etc. The cost of insecticides were calculated (Table- 2). The cost of production of different treatments, mean yield, gross return and net return per ha, increased net return over control and B:C ratio were calculated (Table-2). The highest cost of insecticides was found in T_4, T_5 and T_6 (Rs 2000/-/ha), followed by T_3 (Rs 1440/-/ha) then T_2 (Rs 1200/-/ha), and lowest in T_1(Rs 525/-/ha). The total cost of production excluding cost of insecticides was Rs 28000/- per ha in all the treatments. The net return was computed by deducting the cost of production from the gross return obtained by selling the grains @ Rs 29/- per kg. The highest net return over control and B:C ratio was found in T_6 (Rs 26768/-, 2.08), followed by T_3 (Rs 23,500/-, 1.99) and lowest in T_1 (Rs 5507/-, 1.39). So, from the economics study, it was clearly found that T_6, *i:e*, foliar spray of NSKE 5% at 35 DAS is a better management option for farmers as they will get higher net return and profit.

4. Discussions

Relative superiority of neem formulations and *Bacillus thuringiensis* formulations were assessed on different crops. The results of this study reveals that the plots treated with foliar spray of Bt (*Bacillus thuringiensis*) @ 2g/L at 30 DAS and NSKE 5% at 35 DAS had the lowest percentage dead hearts and white ear heads incidence. It has already been established that NSKE exhibited higher efficacy in dettering oviposition of stem borer adults [20]. Similarly Bt (*Bacillus thuringiensis*) [7] and NSKE [4] express moderate levels of efficacy in supressing the damage by stem borer larva, which is well established through this investigation.

The current findings are in close accordance with the findings of Aboubakary *et al*., 2008 [1] , they revealed that application of neem seed extract application at transplanting and at 30, 45, 60, 75, 90, and 105 DAT considerably reduced losses due to the stem borer *Sesamia cretica* in transplanted sorghum in Africa. Similarly, Antifeedant activity of commercial formulation of neem against neonate larvae of maize stem borer was also documented by Ganguli *et al.*, (1998) [4]. Regarding Bt formulations, the present finding is in close accordance with Kandalkar and Men (2006) [8] who revealed the significant superiority of *B. thuringiensis* at one to three sprays than untreated control in case of leaf injury and in case of peduncle damage, application of two sprays of *B. thuringiensis* (at 1kg ha^{-1}) on 25^{th} and 35^{th} day was on par with three sprays of both endosulfan and *B. thuringiensis* against stem borer in sorghum.

Shojai *et al*. (1995) [25] studied the field efficiency of the parasitoids along with Bt, *B. thuringiensis* subsp. Kurustaki in the control of *Sesamia cretica* concluded that the application of parasitoids along with application of microbial insecticide (BT) and cultural methods gave very good result in Integrated pest management (IPM) of the borer.

5. Conclusion

Thus, considering all the facts and figures discussed in the present study, it is evident that overall impact of the foliar spray of Bt (*Bacillus thuringiensis*) @ 2g/L at 30 DAS and NSKE 5% at 35 DAS may be recommended for integration

into the IPM system in finger millet.

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Table 1: Pooled Mean (Three years data) of different eco-friendly treatments against pink stem borer infestation in finger millet *cv*. Bhairabi during *Summer*, 2016- 2018.

Treatment	% DH				%WEH				Yield(q/ha)			
	2016	2017	2018	Pooled Mean	2016	2017	2018	Pooled Mean	2016	2017	2018	Pooled Mean
T_1- Release of *Trichogramma chelonis* as biocontrol agent at 50000/- per hectare at 7 days interval (3 times released starting from 30 DAS)	13.08 (3.68)	24.40 (4.99)	20.49 (4.57)	19.33 (4.45)	9.28 (3.12)	21.73 (4.71)	21.14 (4.64)	17.40 (4.23)	14.60	13.49	12.96	13.68
T_2- Foliar spray of neem pesticide 0.03%(300ppm)@ 5ml./l of water at 30 DAS	11.35 (3.58)	19.03 (4.80)	18.72 (4.37)	17.54 (4.24)	6.05 (2.56)	18.39 (4.30)	19.29 (4.35)	14.29 (3.84)	17.63	14.87	14.54	15.68
T_3- Foliar spray of *Bt* (*Bacillus thuringiensis*) @ 2g/L of water at 30 DAS	9.20 (3.25)	15.07 (4.61)	11.83 (3.50)	13.93 (3.80)	5.85 (2.52)	14.34 (4.01)	13.64 (3.75)	11.89 (3.52)	21.80	19.53	19.26	20.20
T_4- Spraying of NSKE 5% at 15 DAS	12.43 (3.59)	21.86 (4.87)	19.97 (4.51)	18.53 (4.37)	6.68 (2.66)	19.39 (4.46)	19.98 (4.52)	15.52 (4.00)	16.70	15.45	15.12	15.75
T_5- Spraying of NSKE 5% at 25 DAS	11.21 (3.42)	17.41 (4.64)	16.42 (4.10)	16.22 (4.09)	5.58 (2.46)	16.47 (4.08)	18.21 (4.32)	13.12 (3.69)	19.20	17.80	17.14	18.57
T_6- Spraying of NSKE 5% at 35 DAS	10.62 (3.34)	13.06 (4.35)	14.42 (3.85)	14.48 (3.87)	5.37 (2.42)	12.03 (3.68)	16.78 (4.15)	11.63 (3.48)	22.60	21.06	20.90	21.52
T_7- Untreated control	18.31 (4.33)	27.03 (5.22)	23.45 (4.89)	22.82 (4.82)	12.49 (3.61)	23.20 (4.87)	25.84 (5.12)	20.68 (4.60)	12.27	11.60	10.93	11.60
S.E.(m)± C.D.$_{(0.05)}$	0.100 0.31	0.073 0.23	0.093 0.29	0.102 0.31	0.078 0.24	0.116 0.36	0.105 0.32	0.104 0.32	0.483 1.48	0.584 1.77	0.351 1.08	0.722 2.22

*Figures in parentheses are square root transformed values

Table 2: Economics of Treatments against management of pink stem borer in finger millet at CPR, Berhampur

Treatment	Cost of PP chemicals /ha	Total cost of production (excluding PP chemicals cost)	Total cost of production	Mean yield (q/ha)	Gross return(Rs) @ Rs 29/- per kg grain of finger millet	Net return/ha (Rs.)	Increased net return over control	B:C ratio
T_1- Release of *Trichogramma chelonis* as biocontrol agent at 50000/- per hectare at 7 days interval (3 times released starting from 30 DAS)	525/-	28000/-	28525/-	13.68	39672/-	11147/-	5507/-	1.39
T_2- Foliar spray of neem pesticide 0.03%(300ppm)@ 5ml./l of water	1200/-	28000/-	29200/-	15.68	45472/-	16272/-	10632/-	1.55
T_3- Foliar spray of Bt (*Bacillus thuringiensis*) @ 2ml/L of water	1440/-	28000/-	29440/-	20.20	58580/-	29140/-	23500/-	1.99
T_4- Spraying of NSKE 5% at 15 DAS	2000/-	28000/-	30000/-	15.75	45675/-	15675/-	10035/-	1.52
T_5- Spraying of NSKE 5% at 25 DAS	2000/-	28000/-	30000/-	18.57	53853/-	23853/-	18213/-	1.79
T_6- Spraying of NSKE 5% at 35 DAS	2000/-	28000/-	30000/-	21.52	62408/-	32408/-	26768/-	2.08
T_7- Untreated control	-	28000/-	28000/-	11.60	33640/-	5640/-		1.20

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