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Management strategies for pink stem borer, *Sesamia inferens* Walker (Noctuidae: Lepidoptera) infesting barnyard millet, *Echinochloa frumentacea* Link using botanicals

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Abstract
Barnyard millet also known as kudhiraivaali is known for its high nutrient content. Barnyard millet is being cultivated mostly as rainfed crop and it is ravaged by several pests. Of which, pink stem borer causes dead heart and white ear symptoms by boring into stem and peduncle region causing heavy economic loss. Hence, the present study was conducted for the management of pink stem borer, *Sesamia inferens* in barnyard millet with botanicals. The treatments were neem oil 3%, pongamia oil 3%, mahua oil 3%, citrus peel oil 3%, *Vitex negundo* leaf extract 5%, sweet flag rhizome extract 3% and neem seed kernel extract 5%. The above treatments were applied two times during the year 2020 at Central farm, Agricultural College and Research Institute, Madurai. Among the treatments, neem oil 3% (62.01%) was found to be the most effective followed by citrus peel oil 3% (60.74%), pongamia oil 3% (57.94%), mahua oil 3% (56.87%), *Vitex negundo* leaf extract 5% (54.72%) and neem seed kernel extract 5% (51.73%). Among all treatments sweet flag rhizome extract (50.22%) was found to be the least effective. With regard to yield, the neem oil 3% recorded the highest yield (7.34 q/ha) over control with the cost benefit ratio of 1:1.74 and sweet flag rhizome extract 3% was the least performing treatment with 11.50% increase in yield over control with the cost benefit ratio of 1:1.45.

Keywords: *Sesamia inferens*, *Echinochloa frumentacea*, botanicals, dead heart, white ear

Introduction
Barnyard millet (*Echinochloa frumentacea*) belongs to the family of Poaceae and it is a multi-purpose crop cultivated for both food and fodder [4]. It is a very good source of nutrients like proteins and dietary fibers. The grains are good source of carbohydrate, fiber and minerals like zinc and iron when compared to other major cereals [10]. The nutritional contents of barnyard millet per 100g of grains are 11.6g protein, 74.3g of carbohydrate, 5.8g of fat, 14mg of calcium, 15.2mg of iron, 14.7g of crude fiber, 121mg of phosphorus, 4.4mg of minerals and 300 k.cal of energy [1]. In the account of the grains with high nutrient content, the demand for this crop has been recently increased. Barnyard millet is infested by several insect pests like defoliators, stem borers and sap feeders. Among these, pink stem borer, *Sesamia inferens* (Noctuidae: Lepidoptera) is a serious pest attacking most of the millet crops [3]. In peninsular India, pink stem borer causes more damage throughout the year [11]. Adults lay eggs inside the leaf sheath in clusters. After hatching, the larva bores into the stem and feed inside. At panicle emergence stage, the infestation causes white chaffy panicles (white ear damage) [9]. Arundhati Sasmal (2018) [13] reported the management of pink stem borer in finger millet with seven different treatments including chemical and biological control methods. In this experiment, Cartap hydrochloride 4% GR @ 20 kg/ha applied as soil application at 30 days after sowing performed best against pink stem borer recording 3.2% dead heart, 4.9% white ear and highest incremental yield. Though many studies have been made for the management of pink stem borer in different crops, yet no studies were illustrated regarding their infestation and management in barnyard millet. Hence, the present study has been under taken to identify the suitable botanicals for the management of *S. inferens* in barnyard millet.

Materials and Methods
The experiment was conducted in the fields of Agricultural College and Research Institute, Madurai. The efficacy of botanicals were tested against pink stem borer in barnyard millet.

The variety MDU-1 of barnyard millet was used for this experiment. Totally seven botanicals *viz.*, neem oil 3%, pungamia oil 3%, mahua oil 3%, citrus peel extract 3%, sweet flag rhizome extract 3%, neem seed kernel extract 5% and *Vitex negundo* leaf extract 5% were tested against pink stem borer. Phorate 10 G @ 10 kg/ha was used as a standard check. The seeds were sown in the field during third week of January, 2020 with a plot size of 3x3 m with three replications. The spacing of 30x10 cm was maintained between plants. All the agronomic practices were followed properly and no plant protection chemicals were sprayed in the field.

The pretreatment count was taken before every spray. Two sprays of botanicals were given on 35 and 50 days after sowing. The granules were applied in the leaf whorls and others were given as foliar spray. Botanicals were amalgamated with adhesive (soap oil) @ 2.0 ml per litre of spray fluid. The total number of tillers and number of dead hearts were counted in 10 randomly selected plants from each plot at 5, 10 and 15 days after spray. The percentage dead heart damage was calculated by using the following formula [6].

$$Dead\ heart\ (\%) = \frac{Damaged\ tillers\ with\ dead\ hearts}{Total\ no.of\ tillers} \times 100$$

At maturity stage, number of white ears and total number of ear heads were counted in each treatment plot and the percentage of white ear was calculated by [6],

$$White\ ear\ (\%) = \frac{Damaged\ tillers\ with\ dead\ hearts}{Total\ no.of\ tillers} \times 100$$

Untreated plot was maintained as a check. The percentage incidence in different treatments was compared by calculating the per cent control over the untreated check. The per cent reduction over control was calculated by,

$$Per\ cent\ reduction\ over\ untreated\ check = \frac{(C-T)}{C} \times 100$$

Where, C = per cent incidence in control plot; T= per cent incidence in treatment plot [11].

The ear heads were harvested from each plot and threshed separately. The individual plot grain yield was recorded and converted into yield/hectare. The data were analyzed and yield difference between plots were calculated. By comparing yield from different treatments, the per cent increase in yield over control was calculated by using the formula,

$$Increase\ in\ yield\ over\ untreated\ check = \frac{(T-C)}{C} \times 100$$

Where, T = yield from treatment plot, C = yield from control [12].

The economics of different treatments like cost of cultivation, net returns and cost benefit ratio were calculated based on the yield data and market price of barnyard millet using the following formula [14].

$$Cost\ Benefit\ ratio = \frac{Net\ returns}{Total\ cost}$$

Statistical analysis

The experiment was carried out using RBD with each treatment replicated three times. The data collected from each plot were processed to arcsine data transformation and square root data transformation. The data were analyzed using AGRES software to differentiate the transformed mean values by using Fisher's Least Significant Difference (LSD) at 5% probability level [5].

Results and Discussion

From the data collected after two sprays, the botanicals were less effective when compared to standard check. The result of the first spray are shown in table 1. In first spray, among the botanicals, the oils were found to be more effective when compared to other extracts.

The neem oil 3% was found to be significantly more effective when compared to other botanicals with 60.33% control over untreated check followed by citrus peel oil 3% (59.34%), pongamia oil 3% (55.79%), mahua oil 3% (52.48%), *Vitex negundo* leaf extract 5% (51.35%) and neem seed kernel extract 5% (46.30%). The sweet flag rhizome extract 3% was found to be less effective when compared to other treatments with the control of 43.88% over the untreated check.

The results after second spray also indicates that neem oil 3% was found to be most effective when compared to other botanicals with 63.32% control over untreated check followed by citrus peel oil 3% (61.86%), mahua oil 3% (60.29%), pongamia oil 3% (59.60%), *Vitex negundo* leaf extract 5% (57.31%) and neem seed kernel extract 5% (55.92%). Among all treatments sweet flag rhizome extract 3% was found to be less effective than other botanicals with 55.13% control over untreated check. (Table 2.)

The pooled per cent incidence and the yield data are given in table 3. From the pooled data the neem oil was found to be most effective than the other botanicals. The neem oil 3% controls pink stem borer with 62.01% reduction over untreated check.

Citrus peel oil 3% was the next best treatment with 60.74% followed by pongamia oil 3% (57.94%), mahua oil 3% (56.87%), *Vitex negundo* leaf extract 5% (54.72%) and neem seed kernel extract 5% (51.73%) over the untreated check. Among all the treatments neem oil 3% recorded highest yield (7.34 q/ha) than the other botanicals followed by citrus peel oil 3% (7.18 q/ha), pongamia oil 3% (6.92 q/ha), mahua oil 3% (6.78 q/ha), *Vitex negundo* leaf extract 5% (6.63 q/ha) and neem seed kernel extract 5% (6.62 q/ha).

With regard to cost benefit ratio neem oil recorded the maximum per cent increase in yield with maximum cost benefit ratio of 1:1.74. It was followed by mahua oil 3%, *Vitex negundo* leaf extract 5%, pongamia oil 3% and citrus peel oil 3% with 18.49, 13.53, 16.10 and 22.95 per cent increase in yield coupled with cost benefit ratio of 1:1.73, 1:1.71, 1:1.70 and 1:1.61 respectively and they were on par with each other. While, neem seed kernel extract 5% and sweet flag rhizome extract 3% showed 13.36 and 7.53 per cent increase in yield over control with the cost benefit ratio of 1:1.69 and 1:1.45 respectively.

Table 1: Evaluation of certain botanicals against pink stem borer, *Sesamia inferens* incidence in barnyard millet (First spray)

	Treatments	Recommended Dose /ha	*Pre-treatment	*Per cent incidence				Per cent control over untreated check
				5 DAS	10 DAS	15 DAS	Mean	
T_1	Neem oil (*Azadirachta indica*)	15 L	17.51 (24.73)	11.01 (19.37)^{b}	13.51 (21.55)^{b}	16.46 (23.92)^{b}	13.66 (21.68)^{b}	60.33
T_2	Pongamia oil (*Pungamia pinnata*)	15 L	18.07 (25.15)	13.31 (21.38)^{cd}	13.92 (21.90)^{b}	18.43 (25.42)^{cd}	15.22 (22.95)^{cd}	55.79
T_3	Mahua oil (*Madhuca indica*)	15 L	17.41 (24.65)	12.10 (20.35)^{bcd}	13.76 (21.76)^{b}	17.73 (24.90)^{bc}	16.36 (23.85)^{de}	52.48
T_4	Citrus peel oil (*Citrus limon*)	15 L	17.49 (24.71)	11.49 (19.80)^{bc}	13.58 (21.62)^{b}	16.95 (24.30)^{b}	14.00 (21.97)^{bc}	59.34
T_5	Sweet flag rhizome extract (*Acorus calamus*)	15 L	17.93 (25.04)	17.41 (24.65)^{e}	19.46 (26.17)^{d}	21.13 (27.35)^{f}	19.33 (26.07)^{f}	43.88
T_6	Neem seed kernel extract (NSKE)	25 L	18.60 (25.54)	16.30 (23.80)^{e}	18.93 (25.78)^{d}	20.24 (26.73)^{ef}	18.49 (25.46)^{f}	46.30
T_7	*Vitex negundo* leaf extract (*Vitex negundo*)	25 L	18.50 (25.46)	13.95 (21.92)^{d}	16.77 (24.17)^{c}	19.54 (26.22)^{de}	16.75 (24.15)^{e}	51.35
T_8	Standard check Phorate 10 G	10 kg	17.87 (25.00)	4.47 (12.20)^{a}	6.48 (14.74)^{a}	9.19 (17.64)^{a}	6.71 (15.01)^{a}	80.51
T_9	Untreated check	-	18.85 (25.72)	26.64 (31.06)^{f}	34.31 (35.84)^{e}	42.34 (40.58)^{g}	34.43 (35.91)^{g}	-
SEd			NS	0.76	0.70	0.57	0.50	
CD (0.05%)				1.62	1.48	1.20	1.06	

NS – Non significant
*Each value is the mean of three replications
Figures in the parentheses are arcsine transformed values
In a column, mean values followed by the similar alphabets are not significantly different (P<0.05)

Table 2. Evaluation of certain botanicals against pink stem borer, *Sesamia inferens* incidence in barnyard millet (Second spray)

	Treatments	Recommended Dose /ha	*Pre-treatment	*Per cent incidence				Per cent control over untreated check
				5 DAS	10 DAS	15 DAS	Mean	
T_1	Neem oil (*Azadirachta indica*)	15 L	16.46 (23.92)^{b}	11.01 (19.37)^{b}	13.51 (21.55)^{b}	16.46 (23.92)^{b}	16.36 (23.85)^{b}	63.32
T_2	Pongamia oil (*Pungamia pinnata*)	15 L	18.43 (25.42)^{cd}	13.31 (21.38)^{cd}	13.92 (21.90)^{bcd}	18.43 (25.42)^{cd}	18.02 (25.11)^{cd}	59.60
T_3	Mahua oil (*Madhuca indica*)	15 L	17.73 (24.90)^{bc}	12.10 (20.35)^{cd}	13.76 (21.76)^{bc}	17.73 (24.90)^{bc}	17.71 (24.88)^{c}	60.29
T_4	Citrus peel oil (*Citrus limon*)	15 L	16.95 (24.30)^{b}	11.49 (19.80)^{bc}	13.58 (21.62)^{b}	16.95 (24.30)^{bc}	17.01 (24.35)^{bc}	61.86
T_5	Sweet flag rhizome extract (*Acorus calamus*)	15 L	21.13 (27.35)^{f}	17.41 (24.65)^{e}	19.46 (26.17)^{e}	21.13 (27.35)^{e}	20.01 (26.56)^{e}	55.13
T_6	Neem seed kernel extract (NSKE)	25 L	20.24 (26.73)^{ef}	16.30 (23.80)^{e}	18.93 (25.78)^{de}	20.24 (26.73)^{e}	19.66 (26.31)^{e}	55.92
T_7	*Vitex negundo* leaf extract (*Vitex negundo*)	25 L	19.54 (26.22)^{de}	13.95 (21.92)^{de}	16.77 (24.17)^{cde}	19.54 (26.22)^{de}	19.04 (25.86)^{de}	57.31
T_8	Standard check Phorate 10 G	10 kg	9.19 (17.64)^{a}	7.29 (15.66)^{a}	7.52 (15.91)^{a}	8.18 (16.61)^{a}	7.66 (16.06)^{a}	82.83
T_9	Untreated check	-	42.34 (40.58)^{g}	26.64 (31.06)^{f}	34.31 (35.84)^{f}	42.34 (40.58)^{f}	44.60 (41.88)^{f}	-
SEd			0.57	0.49	0.64	0.50	0.39	
CD (0.05%)			1.20	1.03	1.36	1.06	0.83	

NS – Non significant
*Each value is the mean of three replication
Figures in the parentheses are arcsine transformed values
In a column, mean values followed by the similar alphabets are not significantly different (P<0.05)

Table 3: Impact of botanicals on pink stem borer, *S. inferens* infestation and yield of barnyard millet

	Botanicals	Percentage incidence (pooled mean)	Cumulative per cent reduction over control	Cost of botanicals (Rs./ha)	Total cost of protection (Rs./ha)	Yield (q/ha)	Per cent increase in yield over control	Gross return (Rs.)	Net benefit /ha (Rs.)	Increased net return over control (Rs./ha)	C:B ratio
T_1	Neem oil @ 3%	15.01 (22.78)^{b}	62.01	3000	24000	7.34 (2.71)^{ab}	25.68	41839	17839	8458	1:1.74
T_2	Pongamia oil @ 3%	16.62 (24.05)^{c}	57.94	1800	22800	6.92 (2.63)^{cd}	18.49	38646	15846	6465	1:1.70
T_3	Mahua oil @ 3%	17.04	56.87	1800	22800	6.78	16.10	39455	16655	7274	1:1.73

		(24.37)^{cd}				(2.60)^{de}					
T_4	Citrus peel oil @3%	15.51 (23.18)^{b}	60.74	4500	25500	7.18 (2.68)^{bc}	22.95	40926	15426	6045	1:1.61
T_5	Sweet flag rhizome extract @ 3%	19.67 (26.32)^{e}	50.22	3750	24750	6.28 (2.51)^{f}	7.53	35821	11071	1690	1:1.45
T_6	Neem seed kernel extract @ 5%	19.07 (25.89)^{e}	51.73	1300	22300	6.62 (2.57)^{e}	13.36	37711	15411	6030	1:1.69
T_7	*Vitex negundo* leaf extract @ 5%	17.89 (25.02)^{d}	54.72	1100	22100	6.63 (2.58)^{de}	13.53	37821	15721	7440	1:1.71
T_8	Standard check Phorate 10 G	7.28 (15.65)^{a}	81.57	1150	22150	7.57 (2.75)^{a}	29.62	43125	20975	11594	1:1.95
T_9	Untreated check	39.51 (38.93)^{f}	-	-	21000	5.84 (2.42)^{g}	-	30381	9381		
	SEd	0.376				0.027					
	CD (0.05%)	0.798				0.058					

Value in the parentheses are square root transformations.
In a column, means followed by same letter are not significantly different at P < 0.05 as per LSD.
Selling price of barnyard millet – Rs. 5700/q.
Cost of cultivation excluding cost of botanicals – Rs. 21000.

Similarly, Mishra [7] carried out an experiment on eco-friendly management of pink stem borer in finger millet. The results revealed that Bt @ 2g/L at 30 DAS and NSKE 5% at 35 DAS controls pink stem borer effectively with the yield of more than 20 q/ha. Sahu and Deole [12] tested the bio efficacy of biorational insecticides against pink stem borer on maize. Emamectin benzoate 5% SG was found to be best with minimum number of pin holes which was on par with spinosad 45% SC, chlorantraniliprole 18.5% SC and *Bacillus thuringiencis.* Karanj oil was the least effective in controlling pink stem borer. Sasmal [13] has done an experiment on management of pink stem borer in finger millet. The treatments tested were *Trichogranma chilonis*, neem oil 300 ppm, foliar spray of Bt, fipronil 0.3% G, cartap hydrochloride 4% GR and carbofuran 5% GR. Cartap hydrochloride was better performing in reducing the per cent incidence with high yield (7.9 q/ha). The neem oil 300 ppm was found to be the least performing treatment when compared to other treatments. Choudhary [2] assessed the efficacy of neem-based insecticides for yellow stem borer in rice. The results revealed that nimbicidine @ 5ml/l was most effective against yellow stem borer followed by neem oil @ 5ml/l. Ogah [8] evaluated neem seed kernel extracts in management of rice stem borers. The neem seed kernel extracts and synthetic insecticides were compared, NSKE plots showed more natural enemy population when compared to carbofuran treatment. NSKE was found to be suitable alternative in conserving natural enemies.

Conclusion

In the present study, among all the treatments, neem oil 3% (62.01% reduction over control) and citrus peel extract 3% (60.74% reduction over control) were better performing in controlling the pink stem borer infestation at field level with cost benefit ratio of 1:1.74 and 1:1.61 respectively. Hence neem oil 3% would be suggested for the economical control of pink stem borer.

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