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RESEARCH NOTE

Evaluation of indigenous technologies against fall armyworm, *Spodoptera frugiperda* (J. E. Smith)

P. LIKHITHA, C. P. MALLAPUR AND P. S.TIPPANNAVAR

Department of Agricultural Entomology
College of Agriculture, Dharwad
University of Agricultural Sciences, Dharwad - 580005 (Karnataka), India
E-mail: pokalalikhitha96@gmail.com

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Abstract: The fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Noctuidae: Lepidoptera) has become a serious pest on maize in India and elsewhere. The rapid spread of this pest in Indian states and Asian countries might be due to its efficient ability to travel and migrate long distances in short time. Further, the pest has a wide range of hosts including several most important crops grown in India. In India, the pest is reported on maize from Karnataka during May-June, 2018. The studies on evaluation of indigenous technologies against fall armyworm, *Spodoptera frugiperda* under laboratory conditions revealed that among the indigenous technologies neem oil treatment exhibited highest mortality of 96.67 and 86.67 per cent of third and fourth instar larvae, respectively resulting in no pupal formation. The next best treatments to follow included pongamia oil (93.33 and 86.67% mortality of 3rd and 4th instar larvae, respectively) and GCKE + nimbecidine (86.67 and 76.67%) which lead to formation of deformed pupae as well the malformed adults. However, cow dung slurry and cow urine+ cow dung slurry treatments registered lower larval mortality of 10.0 and 13.33 per cent, respectively among the third instar larvae. While, chlorantraniliprole 18.5 SC being a chemical check treatment, excelled over all other treatments by causing cent per cent larval mortality at 96 hours of treatment imposition.

Key words: Fall armyworm, Indigenous technologies, Plant extract

Maize (*Zea mays*), the "Queen of cereals" is one of the utmost significant cereal crops in the global agriculture economy which is consumed equally as food for man and fodder for animals. It is being cultivated both in the tropical and subtropical climatic conditions of the world. The annual global production of this crop is 1016 million tons over an area of 184 million hectare with productivity of 5,520 kg per hectare (Anon., 2020). India is the fourth largest producer with a production of 27.15 million tons in an area of 9.60 million hectare at a productivity rate of 3,100 kg per hectare. Maize is grown in an area of 1.35 million hectare in Karnataka with the production of 3.75 million tonnes and the productivity is 2810 kg per hectare (Anon., 2020). FAW has developed resistance to several insecticides (Yu, 1991). From Northern Karnataka however, the pest has been reported to cause infestation ranging from 6.00 to 100 per cent on maize during *kharif* 2018 (Mallapur *et al.,* 2018).

The pest causes yield losses in maize to the tune of 8.3 - 20.6 million tons per year in the absence of management practices (Roger *et al*., 2017). Insecticide resistance in key insect pests has become a significant problem in crop production. So, there is a need for more effective and sustainable ways of management. This is made possible by the use of many indigenous technologies which are cost effective and eco-friendly. Indigenous Technical Knowledge (ITK) is a significant component of the indigenous knowledge base. Local or indigenous knowledge refers to the cumulative and complex bodies of knowledge, know-how practices and representations that are maintained and developed by local communities, who have long histories of interaction with the natural environment. Such knowledge is collectively owned, developed over several generations and subject to adaptation and imbedded in a community's way of life as means of survival (Borthakur and Singh, 2012). Adoption of ITK based crop protection measures is not only alternative to pesticides but also helps in restoring the biodiversity of natural enemies. But, there is a need to explore, verify, modify and scientifically validate these practices for their wider use and application. Considering above issues the current study was initiated to ascertain the efficacy of certain ITKs against the invasive pest, *S. frugiperda*.

Insect culture: Egg masses of fall armyworm were collected from the field and reared to get nucleus culture. The caterpillars were reared up to adult stage. Further, a pair of freshly emerged adult moths were released into wooden cage (36 cm × 36 cm × 36 cm size) for oviposition where in provision were made with 10 per cent honey solution as food and fresh tender maize leaves were provided inside the cage for oviposition. The cut end of leaves was covered with a wet cotton wad for maintaining turgidity and freshness. Freshly laid eggs were kept in rearing boxes provided with wet blotting paper at the bottom to protect the eggs from desiccation. After two days when eggs turn to black purple colour, they were provided with fresh maize leaves as food for neonate larvae. The neonate larvae were released on leaves with the help of soft hair brush and kept in a rearing box whose cap were covered with muslin cloth in order to facilitate aeration. The food was changed after every 24 hours.

Agniastra: *Ipomea* (besaram) leaves (200 g), 100 gm chilli, 100 gm garlic and 100 g neem leaves were crushed in 200 ml cow urine. The suspension was boiled for 5 times till it becomes half and then the squeezed extract was filtered and stored in glass or plastic bottles for further use (Anon., 2018).

Brahmastra: Neem leaves (300 g) were crushed in 1 litre cow urine. 200 g custard apple leaves, 200 g papaya leaves, 200 g pomegranate leaves and 200 g guava leaves were crushed in water. Both mixtures were combined and boiled for 5 times or till it becomes half. After 24 hours, it was squeezed and filtered to get the final extract which can be stored in bottles for 6 months (Anon., 2018).

Garlic chilli kerosene extract (GCKE): Garlic (100 g) and 100 g green chilli were grinded into paste separately and soaked in 100 ml kerosene overnight (12 hrs). Then the liquid extract was separated using filter and 60 g of soap solution was added. All ingredients were mixed thoroughly and the concentration obtained was 50 per cent and the required concentration was prepared by diluting with water. The extract was stirred well before using.

Aqueous plant extracts: Plant extracts were prepared by crushing 100 g plant part with 100 ml of water. The extract was filtered through fine muslin cloth and then the volume was made up to 200 ml by adding water to filtered extract. This product was with 50 per cent concentration and the desired concentration was prepared by adding distilled water.

Other products: The cow dung slurry was made by mixing 1 part of cow dung with 10 parts of water. While, cow urine + cow dung slurry was prepared by mixing cow urine and cow dung slurry in 1:1 ratio.

Treatment imposition: The tender maize leaves were immersed in treatment solutions for a minute and later shade dried. The treated leaves were then given as food for the 3rd instar larvae which were reared in cavity trays. However, application of wood ash, cow dung slurry and cow urine + cow dung slurry to the leaf whorls was made on the maize seedlings raised in polythene bags with one seedling in each bag. Thirty seedlings were taken for each treatment @ ten plants for each replication. At 20 days after sowing (DAS), one larva was allowed to feed on each seedling and the treatments were imposed. Based on the preliminary studies conducted on third instar larvae, six treatments which performed better were selected for evaluation against the late 4th instar larvae in a similar fashion as that of third instar larvae. Both the experiments (with 3rd and 4th instar larvae) were conducted in completely randomized design (CRD) with 3 replications. Thirty 4th instar larvae of fall armyworm were used for each treatment @ 10 larvae for each replication. The observations were made on larval mortality in each treatment at 12, 24, 48, 78 and 96 hrs after treatment application and were converted into percentage. The values were subjected to angular transformation before statistical analysis. In addition to larval mortality, the per cent pupation and adult emergence including observations on deformation of pupae and adults were recorded.

Larval mortality: The larval mortality was very low initially up to 24 hours after treatment imposition in all the indigenous material treatments but however the mortality rate has shown a gradual increase from 48 hours onwards (Table 1). Among the indigenous technologies, relatively higher larval mortality of third instar larvae was revealed in neem oil (96.67%) at 96 hours after treatment imposition, followed by pongamia oil (93.33%) and GCKE+ nimbecidine (86.67%) treatments. While, cow dung slurry (10%), cow urine + cow dung slurry (13.33%) and cow urine (33.33%) treatments exhibited significantly lower larval mortality. However, the insecticidal treatment, chlorantraniliprole recorded cent per cent larval mortality. No mortality of late fourth instar larvae was recorded in any of the selected indigenous treatments up to 24 hours of treatment imposition. However, neem oil has shown the highest mortality of 86.66 per cent followed by pongamia oil (83.33%) and GCKE+ nimbecidine (76.67%) at 96 hours after treatment imposition. Agniastra (66.66%) and parthenium extract (63.33%) treatments registered significantly lower larval mortality of fourth instar larvae (Table 2). The highest larval mortality recorded in neem oil treatment is due to the presence of azadirachtin which acts as anti-feedant leading to continuous starvation and ultimate death of the larvae. These results are in line with the findings of Tavares *et al*. (2010) who could record the larval mortality of fall armyworm up to 86.66 per cent when treated with neem oil. Similarly, the pongamia oil contains active components such as karanjin, glabarin, pongamol and pinnatin which possess highly repulsive, antifeedant and growth retarding properties which may result in higher larval mortality. The combination of GCKE

Table 1. Evaluation of indigenous technologies against 3rd instar larvae of fall armyworm under laboratory conditions

S.No.	Treatments	Dosage	Larval mortality (%) at				
			12 h	24 h	48 h	72 h	96 h
T_{1}	Wood ash	2 g/plant	0 (0.00)^{d}	13.33 (21.41)^{d}	23.33 (28.88)^{d}	26.66 (31.09)^{gh}	26.67 (31.09)^{j}
T_{2}	Cow dung slurry	2.5 ml/plant	10 (18.43)^{b}	10 (18.43)^{e}	10 (18.43)^{f}	10 (18.43)^{j}	10 (18.43)^{l}
T_{3}	Cow urine+ Cow dung slurry	2.5 ml/plant	0 (0.00)^{c}	0 (0.00)^{h}	6.66 (14.95)^{g}	13.33 (21.41)^{j}	13.33 (21.41)^{k}
T_{4}	Neem oil	5 ml/l	6.67 (14.95)^{d}	23.33 (28.88)^{b}	36.66 (37.27)^{b}	86.66 (68.59)^{b}	96.66 (79.50)^{b}
T_{5}	Brahmastra	20 ml/l	0 (0.00)^{d}	0 (0.00)^{h}	6.66 (14.95)^{g}	30 (33.21)^{fg}	46.67 (43.09)^{gh}
T_{6}	Pongamia oil	5 ml/l	0 (0.00)^{d}	16.67 (24.09)^{c}	33.33 (35.26)^{c}	83.33 (65.91)^{bc}	93.33 (75.05)^{c}
T_{7}	Agniastra	20 ml/l	0 (0.00)^{d}	10 (18.43)^{e}	23.33 (28.88)^{d}	66.66 (54.74)^{d}	76.67 (61.12)^{e}
T_{8}	Garlic-Chilli Kerosene extract	5 ml/l	0 (0.00)^{d}	0 (0.00)^{h}	6.67 (14.95)^{g}	23.33 (28.88)^{hi}	43.33 (41.17)^{h}
T_{9}	Detergent water	10 g/l	0 (0.00)^{d}	6.67 (14.95)^{f}	6.67 (14.95)^{g}	20 (26.57)^{i}	36.67 (37.27)^{i}
T_{10}	Cow urine + *Vitex negundo*	(50 ml/l+ (50 ml/l)	0 (0.00)^{d}	0 (0.00)^{h}	13.33 (21.41)^{e}	33.33 (35.26)^{f}	50 (45.00)^{fg}
T_{11}	GCKE + Nimbecidine	(5 ml/l) +(2.5 ml/l)	6.67 (14.95)^{c}	16.67 (24.09)^{c}	33.33 (35.26)^{c}	80 (63.43)^{c}	86.67 68.86)^{d}
T_{12}	Cow urine	100 ml/l	0 (0.00)^{d}	0 (0.00)^{h}	6.67 (14.95)^{g}	26.67 (31.09)^{gh}	33.33 (35.26)^{i}
T_{13}	Parthenium extract	100 ml/l	6.67 (14.95)^{c}	13.33 (21.41)^{d}	23.33 (28.88)^{d}	56.67 (48.83)^{e}	73.33 (58.93)^{e}
T_{14}	Ginger-Garlic extract	10 ml/l	0 (0.00)^{d}	3.33 (10.50)^{g}	13.33 (21.41)^{e}	23.33 (28.88)^{hi}	53.33 (46.91)^{f}
T_{15}	Chlorantraniliprole 18.5SC	0.2 ml/l	13.33 (21.41)^{a}	40 (39.23)^{a}	73.33 (58.93)^{a}	100 (90.00)^{a}	100 (90.00)^{a}
T_{16}	Untreated control	-	0 (0.00)^{d}	0 (0.00)^{h}	0 (0.00)^{h}	3.33 (6.14)^{k}	3.33 (10.50)^{m}
S. Em. ±0.13		0.21	0.38	1.80	0.72		
C. D. @ 1 %		0.70	0.84	1.48	5.99	2.80	
C. V. (%)		3.95	2.73	2.76	4.59	2.80	

Figures in parenthesis are arcsine transformed values, means in the columns followed by same alphabet do not differ significantly by DMRT (p=0.01). GCKE: Garlic-Chilli Kerosene extract

Table 2. Evaluation of selected indigenous technologies against 4th instar larvae of fall armyworm under laboratory conditions

S. No.	Treatments	Dosage	Larval mortality (%) at				
			12 h	24 h	48 h	72 h	96 h
T_1	Neem oil	5 ml/l	0 (0.00)^{b}	0 (0.00)^{b}	46.33 (43.09)^{b}	73.33 (31.09)^{b}	86.66 (68.87)^{b}
T_2	Pongamia oil	5 ml/l	0 (0.00)^{b}	0 (0.00)^{b}	48.33 (41.16)^{b}	66.66 (54.74)^{c}	83.33 (65.91)^{c}
T_3	Agniastra	20 ml/l	0 (0.00)^{b}	0 (0.00)^{b}	0 (0.00)^{d}	46.66 (43.09)^{e}	66.66 (54.74)e
T_4	GCKE + Nimbecidine	(5 ml/l) + (2.5ml/l)	0 (0.00)^{b}	0 (0.00)^{b}	43.33 (41.16)^{b}	60 (50.77)^{d}	76.66 (58.91)^{d}
T_5	Parthenium extract	100 ml/l	0 (0.00)^{b}	0 (0.00)^{b}	0 (0.00)^{d}	33.33 (35.26)^{f}	63.33 (52.73)^{f}
T_6	Chlorantraniliprole 18.5 SC (Standard check)	0.2 ml/l	6.67 (14.96)^{a}	33.33 (35.26)^{a}	66.66 (54.74)^{a}	83.33 (66.14)^{a}	96.66 (81.39)^{a}
T_7	Untreated control	-	0 (0.00)^{b}	0 (0.00)^{b}	3.33 (10.00)^{c}	6.67 (14.76)^{g}	6.67 (14.76)^{g}
S.Em. ± 0.02		0.07	0.66	1.12	0.75		
C. D. @ 1 %		0.13	0.32	2.80	4.72	3.15	
C. V. (%)		2.34	2.64	4.23	4.19	2.29	

Figures in parenthesis are arcsine transformed values, means in the columns followed by same alphabet do not differ significantly by DMRT (p=0.01).

GCKE: Garlic-Chilli Kerosene extract

and nimbecidine also recorded significant mortality because of the components like allyl disulphide present in garlic along with capsaicin of chilli together with kerosene exhibiting anti-feedant and repulsive reaction of fall armyworm larvae. The azadirachtin present in nimbecidine also acts as anti-feeding agent against the larvae. These findings are supported by Khan and Ram (2016) who stated that the combined application of GCKE (0.05%) + nimbecidine (2.5 ml/lit) was found highly effective against *Helicoverpa armigera*. The lower larval mortality recorded in case of cow dung slurry, cow urine + cow dung slurry and cow urine treatments may be due to lack of higher insecticidal properties which can inflict larval mortality of this noxious pest. According to the reports of Kumari and Chandla (2010), cow urine alone is not effective against insect pests unless it is mixed with any of the botanical extract.

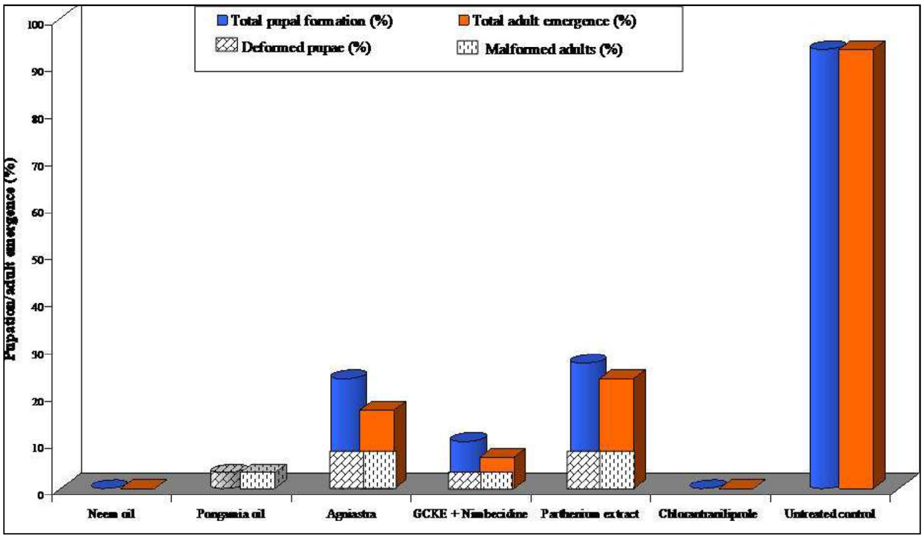

Fig. 1. Impact of various indigenous technologies on pupation and adult emergence of fall armyworm

Pupation: Neem oil treatment did not allow any larvae to undergo pupation due to very high larval mortality. Relatively lower per cent of pupation was noticed in pongamia oil (3.33%) and GCKE + nimbecidine (10%) treatments because of higher larval mortality observed in these treatments. However, significantly higher amount of pupation was recorded in agniastra (23.33%) and parthenium extract (26.67%) treatments. Deformed pupal formation could be observed in treatments like pongamia oil (3.33%), GCKE + nimbecidine (6.67%), agniastra (10%) and parthenium extract (10%) treatments. This could be due to reduced feeding capacity of the larvae and probably, the lack of proper nutrients in such pupae resulted in the formation of abnormal pupae. As per the reports of Barbosa *et al*. (2018), application of plant oils caused the formation of deformed pupae and abnormal adults of fall armyworm. Further, Shahriari and Sahebzde (2017) also reported that diallyl disulfide compounds present in GCKE interrupt in larval digestion by lowering the activity of digestive enzymes indicating significant effect on intermediary metabolism.

Adult emergence: No adult emergence was noticed in neem oil treatment as there was no pupal formation. Relatively lower adult emergence was noticed in pongamia oil (3.33%) and GCKE + nimbecidine (6.67%) treatments due to lower per cent of pupation recorded in these treatments. Emergence of deformed adults noticed in pongamia oil (3.33%), GCKE + nimbecidine (6.67%), agniastra (10%) and parthenium extract (10%) treatments could be due to abnormal pupae leading to emergence of such abnormal adults (Fig. 1). Similarly, Barbosa *et al*. (2018) also reported that the application of plant oils caused the emergence of deformed adults of fall armyworm.

In conclusion, the laboratory studies revealed the higher effectiveness of neem oil, pongamia oil and GCKE + nimbecidine treatments on fall armyworm by inflicting higher larval mortality in 3rd and 4th instar larvae and further leading to formation of abnormal pupae and deformed adults. Cow dung slurry and cow urine+ cow dung slurry treatments shown least impact by registering lower larval mortality.

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