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Biological activities of *Morinda tinctoria* Plant Leaf Extract (Rubiaceae) Against *Spodoptera litura* (Lepidoptera: Noctuidae)

T. Chinnamani, S. Sethuraman and S. Senthilnathan

PG & Research Department of Zoology, Arignar Anna Government Arts College, Namakkal, India

Abstract

Antifeedant, larvicidal and ovicidal activities of various concentrations of *Morinda tinctoria* plant leaf different solvent crude extracts were studied against fourth instar larvae of *Spodoptera litura* and freshly laying *S. litura* eggs. The results observed in 12 and 24 hours antifeedant, larval mortality and then observed eggs mortality rate progressively increased in 0.625, 1.25, 2.5, 5% concentrations. The antifeedant activity of *Morinda tinctoria* showed significant antifeedant effect was recorded in ethyl acetate extract of 5% concentrations values of 51.30% at 12 hours and 83.10% at 24 hours. Following significant antifeedant effect was recorded in chloroform extract of 5% concentrations values of 39.50% at 12 hours and 70.32% at 24 hours and hexane in 38.20% at 12 hours and 67.70% at 24 hours for concentration at 5% respectively. Then the larvicidal activity is higher percentage values in ethyl acetate extract for maximum larval mortality was observed in 43.30% at 12 hours and 73.60% at 5% concentrations in 24 hours. Then the chloroform extracts values were recorded in 28.30% at 12 hours and 50.32% at 5% concentrations in 24 hours. The Following extract of hexane values at 33.30% in 12 hours and 53.20% in 24 hours at 5% concentration respectively. It was significant ovicidal effect was observed from ethyl acetate at 24 hours in 46.40% and 48 hours in 88.60% 5% concentrations and chloroform extract values were 24 hours in 33.43% and 48 hours in 43.43% at 5% concentrations and then the hexane extract values in 24 hours 43.40% and 48 hours 63.30% at 5 % respectively. Antifeedant, mortality of larvae and egg and more than 60% observed from ethyl acetate crude extract of *Morinda tinctoria* at 5% concentration and control of agricultural insect pest for *S. litura*.

Keywords: *Spodoptera litura, Morinda tinctoria* , Ovicidal activity, Larvicidal activity, Antifeedant activity

Introduction

Chemical pesticides dangerous, chemicals not degradable affected soil, water and air to be used for alternative way of search in the plant based pesticides the local name Indian Nona it is valuable medicinal plant and available all over India and other countries jeyasankar *et al*., 2012. The plants Rubiaceae family, scientific

name *Morinda tinctoria* and native of a plant South asia particularly India. It is on small tree growing plants for 5 to 10 meters tall and a plant leaf 15 to 25 cm long and with 3.5 to 5cm, flower tubular white and multi seed fruits Krishnappa, 2012; pavunraj *et al*., 2014. If the plant active substance is extracted as the glucoside as more product available medicinal off field Anandan *et al*., 2010. Botanical drugs and under dietary supplement to be derived from a broader variety of plant that are normally present in the human diet Bakavathiappan *et al*., 2012; Elumalai *et al*., 2004.

Phyto Para medical are a perfect fit for prophylactic used in order to prevent diseases. The screening under revolutions of medical plant mostly depends proper cultivation and collection of plant material follow bio extraction and derived the phytochemistry elumalai *et al.,* 2015; Balaraju *et al.,* 2011. Bioactive component production and use therapy of some diseases. The Indian sub continent of oldest civilization, main traditional health care system the development was supported by the derivatives compound of flora and fauna to landscaping Jeyasankar *et al.,* 2017. Reviews of medicinal plant including therapeutic potential and effect of acetylcholine esterase for peter from medicinal plant and other into the traditional use phytochemical profile and therapeutic potential of various parts of the plants, Baskar, 2009; elumalai *et al.,* 2014.

Many species of *Morinda* available in India of *Morinda tinctoria* predominantly grow Tamil Nadu. Phyto constituent present in different part of the *Morinda tinctoria* for leaves at Ursolic acid, Quercetin, Acacetine-7-glucopyranoside,ext. *Spodoptera litura* Fab for Asia polyphagous insect with adaptively live on many agriculture and horticulture and also more than 130 plants this insect to eat chinnamani *et al.,* 2018. *Spodoptera litura* cotton leaf worm species ranger covering of asia and africa, european, middle eastern respectively. Is insect egg circle flat under 0.6 mm in diameter play orange or pink color laid off batches and covered scales from the abdomen of the female moth and egg mass about 4-7 mm diameter Devanand *et al.,* 2008.

Larvae hairless variable color side of the body dark and light longitudinal bands. Larval instar candy basis of the capsule, ranging from 2.7 to 25 mm, body length range from 2.3 to 32 mm. Pupae is 15 to 20 mm long red color of the abdomen with two small spines. Adult moth grey brown body 15-20 mm long chinnamani *et al.,* 2021. We reported the antifeedant, larvicidal and ovicidal activities of physiological and behavioral effect of *Morinda tinctoria* plant leaf extract against *Spodoptera litura*.

Materials and methods

The selected plant of *Morinda tinctoria* were collected from kolli hills nearby place Namakkal district Tamil Nadu, India. Leaf were washed tap water and dried under room temperature after completed drying the plant materials powdered to use electrical blender. Thousand gram of leaf powder was extracted by using soxhlet extraction method and various solvents and then different polarity of ethyl acetate, chloroform and hexane. The crude extracts were collected in clean glass vials and storage at 4 degree Celsius.

Antifeedant assay

The insect feeding plant of castor leaf to use 4 cm diameter for wet in to the different concentration for 5%, 2.5 % 1.5 % and 0.625% crude extracts of *Morinda tinctoria* plant after 5 minutes are kept in to the single for *Spodoptera litera* was introduced on each petri dishes each activity experiment five replication were maintained Isman , 2000. 12 and 24 hours law feeding period was observed and recorded different values was calculated formula Abbott W.S 1925. Leaf disc no choice method.

$$\text{Antifeedant activity} = \frac{C - T}{C + T} X\ 100$$

Larvicidal assay

Studied for leaf disc no choice method for insect feeding plant of castor leaf 4 cm diameter with dipped 5 minutes air dried in different concentration at 5% 2.5% 1.25 and 0.625 crude extract of *Morinda tinctoria* plant. *Spodoptera litura* 4th instar larvae and leaf introduced every Petri dish each experiment were five replications maintained. After 12 and 24 hours a number of ravae died of recorded and calculated using the formula Abbott W.S 1925.

$$\text{Corrected mortality} = \frac{\text{mortality in treatment} - \text{ mortality in control}}{100 - \text{Control mortality}} X\ 100$$

Ovicidal activity

The freshly laid 25 individual eggs of *Spodoptera litura* separated and dip in various concentrations of plant crude extract and then following the antifeedant activity method. After this experiment 24 and 48 hours treatment activity was recorded the number of egg in controlled and hatch rate was assessed basis and calculated using Abbott formula.

$$\%OA = \frac{\%ELC - \%EHT}{100 - \%ELC} X100$$

Statistical analysis

All data analysis was carried out Microsoft Excel 2007 and one way anova was carried out for the experimental data from LSD was calculated and significant differences are marked with the different alphabets LC_{50}, LC_{90} using the SPSS 16.00.

Results and Discussion

Antifeedant, larvicidal and ovicidal activites of various concentrations to prepare *Morinda tinctoria* plant leaf different solvent crude extracts were studied against *Spodoptera litura.* The treatment on fourth instar larvae of *Spodoptera litura* and freshly laing eggs. The results of the total larval mortality rate progressively increased in different concentrations. The antifeedant activity of *Morinda tinctoria* showed significant antifeedant effect was recorded in ethyl acetate extract of 51.30, 37.14, 25.34, 17.23% at 12 hours and 83.10,

69.30, 48.40, 31.23, % at 24 hours and LC_{50} (LCL-UCL), LC_{70} (LCL-UCL), LC_{90} (LCL-UCL) X^2 value was recorded as 12 hours 4.60(3.81-6.05), 10.76(8.47-15.65)1.581 and 24 hours in 1.75(1.27-2.16), 5.81(4.99-7.29) 2.279 respectively.

Following significant antifeedant effect was recorded in chloroform extract of 39.50, 28.72, 17.50, 10.42 at 12 hours and 70.32, 50.38 31.40, 20.54 at 24 hours and LC_{50} (LCL-UCL), LC_{70} (LCL-UCL), LC_{90} (LCL-UCL) X^2 value was recorded as 12 hours 6.00 (4.88-8.38), 12.31 (9.51-18.70) 2.529 and 24 hours in 2.95 (2.52-3.48), 7.26 (6.17-9.09) 2.511 respectively. Hexane extract value in 38.20, 23.23, 17.34, 9.32 at 12 hours and 67.70, 44.30, 29.40, 18.23 % at 24 hours for different concentration at 5, 2.5, 1.25, 0.625% and LC_{50} (LCL-UCL), LC_{70} (LCL-UCL), LC_{90} (LCL-UCL) X^2 value was recorded as 12 hours in 6.32 (5.12-8.89), 12.57(9.69-19.12)1.404 and 24 hours in 3.28 (2.82-3.86), 7.62(6.46-9.75) 1.503 respectively.

Then the larvicidal activity is higher percentage values in ethyl acetate extract for maximum larval mortality was observed in 43.30, 31.44, 20.44, 17.63 at 12 hours and 73.60, 51.66, 38.40, 27.43 % at 24 hours and LC_{50} (LCL-UCL), LC_{70} (LCL-UCL), LC_{90} (LCL-UCL) X^2 was recorded as 12 hours values 5.79 (4.59-8.60), 13.15(9.81-21.77)0.639 and 24 hours values 2.53 (2.06-3.05), 7.28 (6.08-9.38) 0.790 respectively.

Then the chloroform extracts values were recorded in 28.30, 21.22, 13.20, 10.32% at 12 hours and 50.32, 35.21, 28.40, 19.24 at 24 hours and LC_{50} (LCL-UCL), LC_{70} (LCL-UCL), LC_{90} (LCL-UCL) X^2 was recorded as 12 hours values in 8.54 (6.29-16.14), 17.05 (11.83-35.30)0.918 and 24 hours values in 4.80(3.88-6.71), 11.83 (9.01-18.60) 1.030 respectively. The Following extract of hexane values at 33.30, 23.13, 18.24, 10.22 in 12 hours and 53.20, 34.20, 23.20, 16.13 in 24 hours at 5, 2.5, 1.25, and 0.625% concentration and LC_{50} (LCL-UCL), LC_{70} (LCL-UCL), LC_{90} (LCL-UCL) X^2 was recorded as 12 hours values in 7.43 (5.67-12.41), 15.30 (11.00-28.09) 1.671 and 24 hours values in 4.52 (3.81-5.73), 10.02 (8.09-13.82) 0.644 respectively.

It was significant ovicidal effect was observed from ethyl acetate at 24 hours in 46.40, 34.56, 27.5, 17.30 % and 48 hours in 88.60, 61.6, 44.60, 28.46% and LC_{50} (LCL-UCL), LC_{70} (LCL-UCL), LC_{90} (LCL-UCL) X^2 was recorded as 24 hours values 1.81 (1.45-2.15), 5.08 (4.44-6.05) 1.888 and 7.34 (5.68-11.76), 14.76 (10.79-25.82) 0.742 at 48 hours respectively. Chloroform extract values were 24 hours in 33.43, 21.32, 16.30, 10.22 % and 48 hours in 43.43, 32.21, 27.46, 21.24 and then LC_{50} (LCL-UCL), LC_{70} (LCL-UCL), LC_{90} (LCL-UCL) X^2 was recorded as 24 hours values in 7.34 (5.68-11.76), 14.76 (10.79-25.82) 0.742 and 6.12 (4.57-11.19), 15.71(10.83-33.34) 0.398 at 48 hours respectively.

The hexane extract values in 24 hours 43.40, 31.23, 23.34, 16.42 % and 48 hours 63.30, 44.30, 32.10, 23.24 % at 5, 2.5, 1.25, and 0.625% and LC_{50} (LCL-UCL), LC_{70} (LCL-UCL), LC_{90} (LCL-UCL) X^2 was recorded as 24 hours values 5.77(4.57-8.66), 13.2(9.86-22.24) 0.887 and 48 hours values for 3.39(2.83-4.19), 8.87 (7.21-12.07) 0.790 respectively. Antifeedant, mortality of larvae and egg and more than 60% observed from ethyl acetate crude extract of *Morinda tinctoria* at 5% concentration and control of agricultural insect pest

for *S. litura*. India is agricultural country and more than 80 % of population dependent on agriculture Negi, 2016. The insect pest causes of losses of 120 billions of dollars worldwide and reduced the per year yield losses of 20 to 40 percentage of worldwide and India is approximately 18 % of food grain losses due to pathogen in insect pest to losses of plants cultivations and yield Siva, 2015; baskar *et al.,* 2011.

To control the insect pest to different chemical pesticides are used and then chemical pesticides in polluting the environment causes illness and effects on non target organism and developing resistance and resurgence of the insect pest chinnamani *et al.,*2020. Alternative pesticides natural sources of the pest control including plant source. The antifeedant, larvicidal and ovicidal activities for used in botanical pesticities of insect pest management in many countries us polyphagous insect pest for *Spodoptera litura* Krishnappa *et al.,* 2010

Recently meny researchers reported potanical compound and medicinal plant, essential oils and also the plant resources and antifeedant properties against *Spodoptera litura* devan *et al*., 2008 by leaf disc no choice method which included in the leaf extract of some plants significant on the effect was also recorded. It was interesting to note from the present study at different solvent extract from different concentration studded were on the antifeedant activity, larvicidal activity and ovicidal activity. Plant extract source of active and therapeutic purposes have been used for thousands of years, plant extract and other derivatives compound eluted for different pest control programmed Baskar *et al*., 2011. In this study *Morinda tinctoria* plant leaf were extracted by hexane, chloroform and ethyl acetate to develop insecticide and pesticide to control of *Spodoptera litura* Lavae chinnamani *et al.,* 2016.

Table. 1 Antifeedant activity of *Morinda tinctoria* plants leaf extract against *Spodoptera litura*

Different solvent extract	Con. (%)	Antifeedant activity		LC_{50} (LCL-UCL)	LC_{90} (LCL-UCL)	X^2	LC_{50} (LCL-UCL)	LC_{90} (LCL-UCL)	X^2
		12hrs	24hrs	12hrs			24hrs		
Hexane	5	38.20±2.30	67.70±4.30	6.32 (5.12-8.89)	12.57 (9.69-19.12)	1.404	3.28 (2.82-3.86)	7.62 (6.46-9.75)	1.503
	2.5	23.23±3.22	44.30±2.40						
	1.25	17.34±2.40	29.40±3.23						
	0.62	9.32±3.44	18.23±2.22						
Chloroform	5	39.50±4.54	70.32±3.23	6.00 (4.88-8.38)	12.31 (9.51-18.70)	2.529	2.95 (2.52-3.48)	7.26 (6.17-9.09)	2.511
	2.5	28.72±5.45	50.38±3.25						
	1.25	17.50±4.33	31.40±3.25						
	0.62	10.42±3.33	20.54±4.34						
Ethyl acetate	5	51.30±3.20	83.10±3.20	4.60 (3.81-6.05)	10.76 (8.47-15.65)	1.581	1.75 (1.27-2.16)	5.81 (4.99-7.29)	2.279
	2.5	37.14±3.22	69.30±5.30						
	1.25	25.34±4.20	48.40±4.53						
	0.62	17.23±5.21	31.23±2.34						

Values are mean ±Standard deviation of five replications and $LC_{50,}$ LC_{90} to use SPSS 16.00 software.

Table. 2 Larvicidal activity of *Morinda tinctoria* plants leaf extract against *Spodoptera litura*

Different solvent extract	Con. (%)	Larvicidal activity		LC_{50} (LCL-UCL)	LC_{90} (LCL-UCL)	X^2	LC_{50} (LCL-UCL)	LC_{90} (LCL-UCL)	X^2
		12hrs	24hrs	12hrs			24hrs		
Hexane	5	33.30±2.10	53.20±3.20	7.43 (5.67-12.41)	15.30 (11.00-28.09)	1.671	4.52 (3.81-5.73)	10.02 (8.09-13.82)	0.644
	2.5	23.13±2.12	34.20±1.40						
	1.25	18.24±1.20	23.20±1.45						
	0.62	10.22±4.24	16.13±2.12						
Chloroform	5	28.30±2.34	50.32±2.12	8.54 (6.29-16.14)	17.05 (11.83-35.30)	0.918	4.80 (3.88-6.71)	11.83 (9.01-18.60)	1.030
	2.5	21.22±1.35	35.21±1.44						
	1.25	13.20±6.63	28.40±5.21						
	0.62	10.32±2.53	19.24±4.55						
Ethyl acetate	5	43.30±2.50	73.60±5.86	5.79 (4.59-8.60)	13.15 (9.81-21.77)	0.639	2.53 (2.06-3.05)	7.28 (6.08-9.38)	0.790
	2.5	31.44±6.52	51.66±5.67						
	1.25	20.44±5.40	38.40±3.24						
	0.62	17.63±2.21	27.43±6.63						

Values are mean ±Standard deviation of five replications and LC_{50}, LC_{90} to use SPSS 16.00 software.

Table. 3 Ovicidal activity of *Morinda tinctoria* plants leaf extract against *Spodoptera litura*

Different solvent extract	Con. (%)	Ovicidal activity		LC_{50} (LCL-UCL)	LC_{90} (LCL-UCL)	X^2	LC_{50} (LCL-UCL)	LC_{90} (LCL-UCL)	X^2
		24 hrs	48 hrs	12hrs			24hrs		
Hexane	5	43.40±2.32	63.30±6.32	5.77 (4.57-8.66)	13.27 (9.86-22.24)	0.887	3.39 (2.83-4.19)	8.87 (7.21-12.07)	0.790
	2.5	31.23±3.42	44.30±6.32						
	1.25	23.34±4.26	32.10±4.22						
	0.62	16.42±5.44	23.24±3.54						
Chloroform	5	33.43±4.32	43.43±2.42	7.34 (5.68-11.76)	14.76 (10.79-25.82)	0.742	6.12 (4.57-11.19)	15.71 (10.83-33.34)	0.398
	2.5	21.32±5.35	32.21±4.24						
	1.25	16.30±2.43	27.46±5.43						
	0.62	10.22±5.43	21.24±3.54						
Ethyl acetate	5	46.40±4.36	88.60±5.46	5.28 (4.20-7.76)	12.79 (9.53-21.23)	1.911	1.81 (1.45-2.15)	5.08 (4.44-6.05)	1.888
	2.5	34.56±4.32	61.66±5.54						
	1.25	27.54±5.55	44.65±3.26						
	0.62	17.33±2.61	28.46±6.43						

Values are mean ±Standard deviation of five replications and LC_{50}, LC_{90} to use SPSS 16.00 software.

REFERENCE

Abbott W. S. 1925. A method of computing the effectiveness of an insecticide, *Journal of Economic Entomology*, 18: 265-266.

Anandan A, Krishnappa K, Mathivanan T, Elumalai K, Govindarajan, M. 2010. Bioefficacy of Hyptis suaveolens and Melochia chorcorifolia against the armyworm, Spodoptera litura (Fab.) (Lepidoptera: Noctuidae). *International Journal of Current Research*; 4:117-121. 48.

Bakavathiappan G, Baskaran S, Pavaraj M, and Jeyaparvathi S. 2012. Effect of *Calotropis procera* leaf extract on *Spodoptera litura* (Fab.) *Journal of Biopesticides*, 5:135-138.

Balaraju K, Ezhil Vendan S, Ignacimuthu S, and Kyungseok P. 2011. Antifeedant and larvicidal activities of *Swertia chirata* Buch-Ham. ex Wall. against *Helicoverpa armigera* Hubner and *Spodoptera litura* Fab. *Journal of Elixir Social Science*, 31**:** 1902-1905.

Baskar k, Kingsley S, Vendan S. E, Paulraj M. G, Duraipandiyan V and Ignacimuthu S. 2009. Antifeedant, larvicital and pupicidal activities of *Atalantia monophylla* (L) correa against *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae). Chemosphere, 75:355-359.

Baskar K, Sasikumar S, Muthu C, Kingsley S, Ignacimuthu S. 2011. Bioefficacy of Aristolochia tagala Cham against *Spodoptera litura* Fab. (Lepidoptera: Noctuidae). Saudi Journal of Biological Sciences, 18:23–27.

Chinnamani T, Jeyasankar A. and Elumalai. K. 2020. *Solanum pseudocapsicum* L. a Potential pesticide against *Helicoverpa armigera* (Hub.) and *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae). *Asian J. Agric. Res*., 14: 19-27.

Chinnamani T, Premalatha S. and Jeyasankar A. 2021. Evaluation Of Mosquitocidal Properties Of Some Plants Extracts Against Important Mosquito Vectors. *International Journal of International Journal of Multidisciplinary Educational Research*, 10, Issue:6(3),.

Chinnamani T, Sivakami R. and Jeyasankar A. 2016. Antifeedant, larvicidal and growth regulatory activities of fractions isolated from ethyl acetate extract of *Pseudocalymma alliaceum* against *Spodoptera litura* Fabricius and *Helicoverpa armigera* Hübner (Lepidotera: Noctuidae). *International Journal of Advanced Research in Biological Sciences*, 3 (9): 98-107.

Chinnamani T. and Jeyasankar A. 2018. Screening of plant extracts for antifeedant activity against *Spodoptera litura* and *Helicoverpa armigera* (Lepidoptera: Noctuidae). *Insight Bacteriology*, 7:1-6.

Devanand P, Rani P.U. 2008. Biological potency of certain plant extracts in management of two Lepidopteran pests of Ricinus communis L. *Journal of Biopesticides*; 1(2): 70-176. 47.

Elumalai A, Backiyaraj M, Kasinathan D, Mathivanan T, Krishnappa K, and Elumalai K. 2015. Pesticidal activity of *Rivina humilis* L. (Phytolaccaceae) against important agricultural pest. *Journal of Coastal Life Medicine*, 3 (5): 389-394.

Elumalai K, Jeyasankar A, Raja N, Ignacimuthu S. 2004. Evaluation of certain plant extracts for deterrent activity against tobacco armyworm, *Spodoptera litura* (Fabricius). *Indian Journal of Ecology*; 31(1):8-10. 46.

Isman M. B. 2000. Plant essential oils for pest and disease management. *Crop Protect*. 19:603-608.

Jeyasankar A, and Chinnamani T**.** 2017. Chemical composition and growth inhibitory activities of *Solonum pseudocapsicum* against *Spodoptera litura* and *Helicoverpa armigera* (Lepidoptera: Noctuidae). *International Journal of Entomology Research*,2(5): 60-68.

Jeyasankar A., Premalatha S. and Elumalai K. 2012. Biological activities of *Solanum pseudocapsicum* (Solanaceae) against cotton bollworm *Helicoverpa armigera* (Hübner) and armyworm *Spodoptera litura* (Fab.) (Lepidoptera:Noctuidae). *Asian Pacific Journal of Biomedicine*, 2: 98-986.

Krishnappa K, Anandan A, Mathivanan T, Elumalai K, Govindarajan M. 2010. Antifeedant activity of volatile oil of Tagetes patula against armyworm, *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae). *International Journal of Current Research*; 4:109-112. 49.

Krishnappa K, and Elumalai K. 2012. Larvicidal and ovicidal activities of *Chloroxylon swietenia* (Rutaceae) essential oils against *Spodoptera litura* (Lepidoptera: Noctuidae) and their chemical compositions. *International Journal of Current Research in Life Sciences*, 1 (1): 003-007.

Negi P, Bhupendra R, Singh and Negi D. S. 2016. Antifeedant Activity of Extracts & Isolated Compounds of Two Himalayan Plants against A Polyphagous Pest *Spodoptera litura*. *Octa Journal of Biosciences*, 4(1):33-35.

Pavunraj K, Baskar K, Janarthanan S, and Arumugam M. 2014. Phytopesticidal effects of *Spilanthes acmella* (L.) Murr. leaves on three economically important lepidopteran insect pests. *Journal of Coastal Life Medicine*, 2 (7): 549-554.

Siva C, and Santhosh Kumar M. 2015. Pesticidal activity of eco-friendly synthesized silver nanoparticles using *Aristolochia indica* extract against *Helicoverpa armigera* Hubner.*International Journal of Advanced Scientific and Technical Research*, 5 (2): 197-226.