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Relative Toxicity of Some Insecticide Against *Pectinophora Gossypiella* (Saunders) In Laboratory

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Abstract: The experiment was conducted during the year 2019-20 in the Toxicology Laboratory of Department of Entomology, Dr. PDKV, Akola. The insecticides used as treatments included, Chlorantraniliprole 18.5% SC, Profenofos 50% EC, Thiodicarb 75% WP, Lambda cyhalothrin 5% EC, Fifronil 5% SC along with untreated control (for bioassay studies). Topical application method of bioassay as described by Kranthi *et al*., (2005) was followed. Toxicity studies revealed no considerable variations in log dose probit assay values for respective insecticides. However, it appears from the bioassay studies that sensitivity to Chlorantraniliprole 18.5% SC, Profenofos 50% EC, Thiodicarb 75 %WP, Lambda cyhalothrin 5% EC and Fifronil 5% SC in *P. gossypiella* populations, respectively, from Buldhana, Amravati & Buldhana, Yavatmal and Wardha and Wardha was found higher. In the present experiments the five insecticides tested have not shown difference in the trend of effectivity at LC_{50} or LC_{90} levels. For Akola, Washim, Amravati, Buldhana, Yavatmal and Wardha populations of *Pectinophora gossypiella* the relative toxicity trend (at LC_{90}) was [Chlorantraniliprole 18.5% SC] > [Profenofos 50% EC] > [Thiodicarb 75 %WP] > [Fifronil 5% SC] > [Lambda cyhalothrin 5 % EC]. The index of effectiveness, security index (SI) of insecticides was worked out by comparing of dose response with established field use rates. Security index (SI) indicate that insecticides Chlorantraniliprole 18.5% SC, Profenofos 50% EC, Thiodicarb 75 %WP, Lambda cyhalothrin 5 % EC, Fifronil 5% SC are in safe zone (S.I. > 1) and effective for irrespective of location for management of *P. gossypiella.* A, preferential sequence of insecticide selection for their application against *P. gossypiella* at different locations have been.

Keywords: Relative toxicity, security index (SI), Laboratory, Bioassay, *P. gossypiella*,

INTRODUCTION

Cotton the "King of fibres" or "White gold" is one of the most important commercial crop which plays a pivotal role in strengthening national economy of many countries. India ranks first in acreage of cotton cultivation in the world. In India cotton is cultivated on 122.29 lakh ha with production of 370 lakh bales per ha. In Maharashtra cotton crop is grown on 42.07 lakh ha with production of 85.00 lakh bales and productivity of 343.00 lint kg/ha (https://www.cotcorp.org.in. 25 june, 2019). Although, India maintaining the position of leading cotton producer in the world, China and United States has increased cotton production around 23% as compared to last year. Cotton yields primarily depend on weather, pests, diseases and management practices. Despite good monsoon season during last couple of years the average cotton productivity was declined to less than 500 kg lint per hectare.

Major constraint in attaining high production of seed cotton in India is mainly

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inflicted by the damage caused due to insect pests, especially the three bollworms of cotton. Meanwhile, the introduction of *Bt* cotton in 1983 solved the problem of bollworm complex in many cotton growing areas of the world, but soon after in 1996 the bollworm complex issue arose again and this time only pink bollworm displayed first time resistance against *Bt* cotton. During last three years the resurgence of pink bollworm *Pectinophora gossypiella (Saundars)* on all the popularly grown *Bt* cotton cultivars throughout the country has caused significant reduction in cotton productivity in major cotton growing states like Maharashtra, Gujrat, Andhra Pradesh, Telangana State and Panjab. In dryland areas of Vidarbha and Marathwada regions of Maharashtra the severe losses to the tune of 50-80% green boll damages were recorded (https://www.cotcorp.org.in. 27 june,2019). The review of literature suggests that the three bollworms of cotton viz., *Helicoverpa armigera* (Hub.), *Earias vittella* (Fab.) and *Pectinophora gossypiella* (Saunders) already showing many fold resistance against all conventional insecticide molecules (Kranthi et al. 2002) and have posed a serious threat to cotton productivity (Dhaliwal et al. 2006). Among the three bollworms, pink bollworm, *Pectinophora. gossypiella* is one of the most serious pests of cotton worldwide causing losses in both yield and quality of cotton. Growing threat to cotton productivity and development of resistance to conventional insecticide molecules drove farmers to move towards the newer chemistry insecticides to suppress *Pectinophora gossypiella* population on cotton as these new products proven to have an added advantage over the conventional insecticides due to their novel mode of action and low eco-toxicity. In view of long term indiscriminate use of some new insecticide formulation under label claim it is critical to evaluate their effectiveness (relative toxicity) before being they are used extensively in major cotton growing areas.

Sauphanor et al. (1998) enumerated superiority of insecticides in terms of safety and effectiveness by estimating security index. Security index (SI), is an index that determines the effectiveness of chemical when applied at field dose which is calculated by using field recommended dose and LC_{90} of the insecticides obtained from the log probit assay. If the threshold value is ≥1; it is considered to be effective against the target pest. In the context of insecticide resistance, determination of this threshold value for *Pectinophora gossypiella* populations of various locations could give a clear picture of sensitivity to insecticides that can be useful for selecting proper insecticides.

MATERIALS AND METHODS

Experimental details

a)	Type of Experiment	:	Laboratory Experiment
b)	Test insect	:	*Pectinophora gossypiella* (Saundars) (Lepidoptera: Gelechiidae)
c)	Season	:	Kharif, 2019
d)	No. of insecticides used	:	05
e)	No. of replications	:	03
f)	Laboratory conditions	:	Ambient
g)	No. of location	:	06 (six districts viz, Akola, Buldana, Washim, Yavatmal, Amravati & Wardha)

The materials used and methodology followed in the present investigations are described under respective subheads.

Materials Used

Test insect

Fourth instar larvae of *Pectinophora. gossypiella* from unsprayed cotton fields were used for the experimentations.

Food for test insect

Cotton seeds from freshly dissected cotton bolls were used as food of the test insect

Insecticides used for treatments and their availability

The details of insecticides used in the experiment and their availability are given in Table 1.

Table 1: Insecticides used and their availability

Sr. No	*Insecticides*	*Trade Name*	*Manufactured by*	*Recommended dose*
1	Fipronil 5% SC	Regent	Bayer	15ml /10 L water
2	Thiodicarb 75 WP	Larvin	Bayer	20gm /10 L water
3	Chlorantraniliprole 18.5 SC	Coragen	EL Dupont India Pvt .Ltd (BASF)	3ml /10 L water
4	Lambda cyhalothrin 5 % EC	Reeva	Rallis India limited a TATA enterprice	10ml /10 L water
5	Profenophos 50 EC	Curacron	Excel crop care limited	20ml /10 L water

Plastic and glass wares used

1. Plastic containers (25cm diameter and 10 cm height) with rubber band for larval rearing, 2. Plastic jars (16 cm diameter and 18 cm height) as incubation chamber, 3. Measuring cylinder, 4. Conical flasks (250ml), 5. Glass beljars (15cm diameter and 25cm height) for adult mating and oviposition, 6. Glass beakers (250ml), 7. Glass petriplates (50ml), 8. Glass test tubes (25ml), 9. Plastic boxes (10cm height X 16cm width X 25cm length) for persistence studies as well as fruit dip bioassay, 10. Plastic boxes (3.5cm height X 6.5cm width X 8cm length) for larval dip bioassay, etc.

Chemicals used

1. Sodium hypochlorite solution (0.2%) in water for disinfection of tools and table tops, 2. Formaldehyde solution (2%) for disinfection of insect rearing room and 3. Alcohol (70%) solution in water for disinfection of brushes, scissors and washing of hands, etc.

Equipment's used

1. Refrigerator (Make Godrej, 170 Lit.), 2. Hot air oven (Lab Hosp. Make), 3. Digital balance (Contact make, 500 g capacity), 4. Digital camera (Fujifilm Fine Pix, AX-500 14 Mp). 5.Accupippettee (Cap.1 to 1000 µl), etc. 6. Air conditioner 7. Humiditifier

Other material and accessories used

1. Camel hair brush, 2. Honey (Dabur), 3. Muslin cloth, 4. Absorbent cotton, 5. Cotton thread, 6. Needle, 7. Forceps, 8. Hand lens (10x), 9. Scissor, 10. Paper towel, 11. Tissue paper, 12. Black paper sheets, 13. Sterile distilled water,14. Glass marking pens, 15. Fresh okra fruits as larval food, etc.

METHODOLOGY ADOPTED

Growing of cotton

Sowing of cotton (Variety- First Class) in isolation was under taken in the field of Department of Entomology by following recommended tillage practices. In order to ensure continuous and fresh availability of food throughout the experimental period, staggered sowing of cotton seeds was followed. Since the crop is served as food source for *Pectinophora gossypiella,* every precaution was taken to keep the plot free from insecticide contamination and possible drifts from neighboring plots. The fresh tender seeds of cotton bolls (after dissection in laboratory) from this plot were used for feeding *Pectinophora gossypiella* larvae in the laboratory during the course of the investigations,

Collection of Pectinophora gossypiella larvae for bioassay

Large number of infected / green bolls were collected from the unsprayed cotton fields of farmer's in Akola, Buldana, Washim, Yavatmal, Amravati and Wardha districts. They were manually dissected to collect *Pectinophora gossypiella* larvae. They were maintained in appendop vial tubes (38 mm diameter) on fresh wet cotton seeds obtained from the green cotton bolls from the food plot of the insect. The fourth instar larvae from these collections were used for bioassay purpose to determine the relative toxicity and security indices of different insecticides for the respective locations.

Relative toxicity studies

Preparation of insecticide doses: The stock solution was prepared by adding formulated insecticides

in distilled water from which 5-6 concentrations were prepared and used for bioassay.

Insecticide bioassay: Topical application method of bioassay as described by Kranthi et al. (2002) was followed. The *Pectinophora gossypiella* larvae were starved for 2 h prior to the exposure with insecticide treatment. About 10-12 starved fourth instar larvae from appendop vial tube were taken in a petri dish (100 mm diameter) lined at its base with a tissue paper. The application of insecticide dose was made using a small hand sprayer (50ml capacity) which was calibrated earlier (to 0.15 ml per spray). The spraying was so adjusted as to uniformly covers all the larvae, seeds (food) and wet the bottom tissue paper in the petri dish. The larvae were kept in the same condition for 12 h and transferred in appendop vials containing fresh normal food and allowed to feed at ambient conditions in the laboratory. Fresh food was supplied to the larvae as and when required. A control (without treatment) was also maintained. About 10-12, fourth instar larvae from each location were used per treatment (concentration) and each treatment replicated thrice with appropriate labelling and marking for respective locations.

For relative toxicity studies of insecticides at different stages of cotton crop, the infected / green bolls were collected at 90, 120 and 150 days phonological stages of cotton crop grown at Entomology field and *Pectinophora gossypiella* larvae from these bolls were dissected out and used for bioassay as described earlier.

Recording of observations: The larval mortality observations in each insecticide concentration for respective location were recorded at 24 h interval up to 72 hours. The moribund larvae or larvae which were not responded to gentle touch of the camel hair brush were considered as dead. The corrected larval mortality data (Abbott, 1925) in each insecticide treatment was subjected to Probit analysis as per Finney (1971) for determination of LC_{50} values, further verified using a software (EPA Probit) available in the Department for ascertaining LC_{50} values from which relative toxicities of different insecticides were determined as per Mankar and Kulkarni, (2019) as under

$$Relative\,Toxicity\,(RT) = \frac{LC_{50}\ of\ less\ toxic\ compount}{LC_{50}\ of\ more\ toxic\ compound}$$

The LC_{90} values obtained from the probit equation were used to calculate security index (SI) of different insecticides as per Sauphanor *et al.* (1998) as below

$$Security\,Index\,(SI) = \frac{Recommended\ field\ rate\ as\ per\ CIBRC\ of\ product}{LC_{90}\ of\ the\ same\ product\ in\ experiment}$$

Insecticides with ≥ 1 Security Index values were considered as effective while those < 1 was considered as high risk insecticides.

Plate 1: Bolls damaged by *P. gossypiella*

RESULTS

Toxicity of Insecticides to *Pectinophora gossypiella* Populations from Different Locations

Toxicity of Chlorantraniliprole 18.5 % SC

The results of the laboratory bioassay studies on toxicity of Chlorantraniliprole 18.5 % SC to *P. gossypiella* populations from Akola, Washim, Amravati, Buldhana, Yavatmal and Wardha locations are presented in Table 1 The results revealed that Chlorantraniliprole 18.5 % SC at LC_{50} (range of 0.013 % to 0.015 %) and LC_{90} (range of 0.067 to 0.095**)** levels is more or less equally toxic to *Pectinophora gossypiella* populations collected from all these locations. However, *Pectinophora gossypiella* populations from Buldhana location at LC_{50} and Amravati location at LC_{90} levels, shown more susceptibility to Chlorantraniliprole. It was observed that *P. gossypiella* population from Akola at LC_{50} and LC_{90} levels showing less susceptibility to Chlorantraniliprole 18.5 % SC as compared to *Pectinophora gossypiella* populations collected from rest of the locations. The slope of Probit test for all the six geographical locations was in the range of 1.56 to 1.91 which indicated

Table 1: Toxicity of Chlorantraniliprole 18.5 % SC to *Pectinophora gossypiella* populations from different locations

Location	*LC_{50} (%)*	*Fiducial limits at LC_{50}*	*LC_{90} (%)*	*Fiducial limits at LC_{90}*	*Slope ± SE*	*Chi square*
Akola	0.015	0.008-0.021	0.095	0.057-0.390	1.60±0.41	1.16
Washim	0.014	0.008-0.020	0.079	0.051-0.246	1.72±0.42	2.66
Amravati	0.014	0.008-0.019	0.067	0.046-0.158	1.91±0.42	1.91
Buldhana	0.013	0.005-0.018	0.084	0.051-0.342	1.56±0.41	0.64
Yavatmal	0.014	0.008-0.019	0.070	0.047-0.177	1.85±0.42	1.39
Wardha	0.014	0.007-0.018	0.070	0.046-0.185	1.80±0.42	2.35

homogeneity in the larval population used for bioassay studies.

Toxicity of Profenofos 50% EC

The results of the laboratory bioassay studies on toxicity of **Profenofos 50% EC** to *P. gossypiella* populations from Akola, Washim, Amravati, Buldhana, Yavatmal and Wardha locations are presented in Table 2 The results revealed that **Profenofos 50% EC** at LC_{50} (range of 0.109 % to 0.132%) was more or less equally toxic to *P. gossypiella* populations collected from all these locations. However, at LC_{90} (range of 0.271 to 0.523**)** levels have shown considerable variability in responce to this insecticide. Amongst the *Pectinophora gossypiella* populations tested Buldhana and Amravati populations at LC_{50} and Yavatmal and Buldana populations of *Pectinophora gossypiella at* LC_{90} level were more susceptible to **Profenofos 50% EC**. It was observed that *P. gossypiella* population from Akola at LC_{50} and LC_{90} levels showing less susceptibility to **Profenofos 50% EC** as compared to *Pectinophora gossypiella* populations from rest of the other places. The slope of Probit test for all the six geographical locations was in the range of 2.14 to 3.40 which indicated homogeneity in the larval population used for bioassay studies.

Table 2: Toxicity of Profenofos 50% EC to *Pectinophora gossypiella* populations from different locations

Location	***LC_{50} (%)***	***Fiducial limits at LC_{50}***	***LC_{90} (%)***	***Fiducial limits at LC_{90}***	***Slope ± SE***	***Chi square***
Akola	0.132	0.080-0.167	0.523	0.348-1.836	2.14±0.58	0.52
Washim	0.122	0.078-0.151	0.393	0.291-0.846	2.51±0.61	1.16
Amrawati	0.109	0.069-0.136	0.315	0.246-0.549	2.78±0.64	0.94
Buldhana	0.109	0.073-0.133	0.278	0.225-0.425	3.14±0.67	2.85
Yavatmal	0.114	0.082-0.136	0.271	0.223-0.393	3.40±0.69	3.61
Wardha	0.119	0.080-0.146	0.347	0.268-0.632	2.76±0.63	2.05

Toxicity of Thiodicarb 75% WP

The results of the laboratory bioassay studies on toxicity of **Thiodicarb 75% WP** to *Pectinophora gossypiella* populations from Akola, Washim, Amravati, Buldhana, Yavatmal and Wardha locations are presented in Table 3 The results revealed that **Thiodicarb 75% WP** at LC_{50} (range of 0.149% to 0.192%) was more or less equally toxic to *Pectinophora gossypiella* populations collected from all these locations. However, at LC_{90} (range of 0.461% to 0.914%**)** levels considerable variability is seen in response to

Table 3: Toxicity of Thiodicarb 75% WP to *Pectinophora gossypiella* populations from different locations

Location	*LC_{50} (%)*	***Fiducial limits at LC_{50}***	***LC_{90} (%)***	***Fiducial limits at LC_{90}***	***Slope ± SE***	***Chi square***
Akola	0.182	0.143-0.226	0.624	0.411-1.924	2.40±0.58	0.56
Washim	0.192	0.141-0.262	0.914	0.495-9.266	1.89±0.57	0.83
Amrawati	0.162	0.124-0.197	0.521	0.364-1.294	2.52±0.59	0.61
Buldhana	0.160	0.110-0.203	0.675	0.414-3.377	2.05±0.57	0.39
Yavatmal	0.149	0.106-0.183	0.521	0.357-1.458	2.36±0.59	1.63
Wardha	0.153	0.117-0.184	0.461	0.336-0.978	2.68±0.60	1.91

different insecticides. Amongst the *P. gossypiella* populations tested Yavatmal population at LC_{50} and Yavatmal and Buldana populations of *P. gossypiella* LC_{90} level were more susceptible to **Thiodicarb 75% WP**. It was observed that *P. gossypiella* population from Washim location at LC_{50} and LC_{90} levels showing less susceptibility to **Thiodicarb 75% WP** as compared to *Pectinophora gossypiella* populations from rest of the other places. The slope of Probit test for all the six geographical locations was in the range of 1.89 to 2.68 which indicated homogeneity in the larval population used for bioassay studies.

Toxicity of Lambda cyhalothrin 5% EC

The results of the laboratory bioassay studies on toxicity of **Lambda cyhalothrin 5% EC** to *P. gossypiella* populations from Akola, Washim, Amravati, Buldhana, Yavatmal and Wardha locations are presented in Table 4 The results revealed that **Lambda cyhalothrin 5 % EC** at LC_{50} (range of 0.093% to 0.160%) as well as at LC_{90} (2.920% to 6.896%) shown considerable variability in toxicity to *Pectinophora gossypiella* populations collected from all these locations. Amongst the *Pectinophora gossypiella* populations tested Wardha population at LC_{50} and LC_{90} levels were more susceptible to **Lambda cyhalothrin 5 % EC**. It was observed that *Pectinophora gossypiella* population from Akola location at LC_{50} and LC_{90} levels shown less susceptibility to **Lambda cyhalothrin 5% EC** as compared to *Pectinophora gossypiella* populations from rest of the other places. The slope of Probit test for all the six geographical locations was in the range of 0.78 to 0.95 which indicated homogeneity in the larval population used for bioassay studies.

Toxicity of Fifronil 5% SC

The results of the laboratory bioassay studies on toxicity of **Fifronil 5% SC** to *Pectinophora gossypiella* populations from Akola, Washim, Amravati, Buldhana, Yavatmal and Wardha locations are presented in Table 5 The results revealed that **Fifronil 5% SC** at LC_{50} (range of 0.182% to 0.281%) as well as at LC_{90} (0.910% to 2.00%) was quite equal in toxicity to *Pectinophora gossypiella* populations collected from all the six locations. Amongst the *Pectinophora gossypiella* populations tested Wardha population at LC_{50} and LC_{90} levels were more susceptible to **Fifronil 5% SC**. It was observed that *Pectinophora gossypiella* population from Washim location at LC_{50} and LC_{90} levels shown less susceptibility to **Fifronil 5% SC** as compared to *P. gossypiella* populations tested from rest of the places. The slope of Probit test for all the six geographical locations was in the range of 1.50 to 1.90 which indicated homogeneity in the larval population used for bioassay studies.

Table 4: Toxicity of Lambda cyhalothrin 5 % EC to *Pectinophora gossypiella* populations from different locations

Location	*LC_{50} (%)*	*Fiducial limits at LC_{50}*	*LC_{90} (%)*	*Fiducial limits at LC_{90}*	*Slope ± SE*	*Chi square*
Akola	0.160	0.087-0.606	6.896	1.242-4038.841	0.78±0.23	4.29
Washim	0.150	0.090-0.373	3.349	0.908-154.422	0.95±0.24	2.48
Amrawati	0.159	0.087-0.573	6.445	1.207-2816.546	0.79±0.23	2.55
Buldhana	0.131	0.075-0.345	4.171	0.971-467.266	0.85±0.23	1.41
Yavatmal	0.122	0.071-0.284	3.280	0.862-186.587	0.89±0.23	2.11
Wardha	0.093	0.051-0.194	2.920	0.771-179.736	0.85±0.23	2.12

Table 5: Toxicity of Fifronil 5% SC to *Pectinophora gossypiella* populations from different locations

Location	*LC_{50} (%)*	*Fiducial limits at LC_{50}*	*LC_{90} (%)*	*Fiducial limits at LC_{90}*	*Slope ± SE*	*Chi square*
Akola	0.234	0.177-0.431	1.098	0.537-9.317	1.90±0.49	1.71
Washim	0.281	0.193-0.972	2.000	0.702-160.514	1.50±0.47	0.40
Amrawati	0.225	0.168-0.433	1.206	0.554-14.428	1.75±0.47	2.81
Buldhana	0.235	0.167-0.599	1.670	0.635-75.253	1.50±0.46	0.76
Yavatmal	0.223	0.162-0.480	1.421	0.590-33.005	1.59±0.46	1.23
Wardha	0.182	0.140-0.282	0.910	0.470-6.059	1.83±0.46	1.39

Relative Toxicity of insecticides to Pectinophora gossypiella populations from Washim location

The relative toxicities of insecticides calculated at LC_{50} level (Table 6) revealed that Fifronil 5% SC is least toxic to *P. gossypiella* population from Washim location. It is evident that Chlorantraniliprole 18.5% SC, Profenofos 50% EC, Thiodicarb 75 % WP and Lambda cyhalothrin 5 % EC, respectively at 20.08, 2.30, 1.47 and 1.88 fold were more toxic than Fifronil 5% SC to Washim location of *P. gossypiella*. On the basis of order of relative toxicity (ORT) at LC_{50} these insecticides can be arranged in descending order of their toxicity as [Chlorantraniliprole 18.5% SC] > [Profenofos 50% EC] > [Lambda cyhalothrin 5 % EC] > [Thiodicarb 75 %WP] > [Fifronil 5% SC].

At the LC_{90} level Lambda cyhalothrin 5% EC was recorded as the least toxic compound to *P. gossypiella* population from Washim location. Chlorantraniliprole, Profenofos, Thiodicarb and Fifronil, respectively at 42.40, 8.52, 3.67 and 1.68 fold were more toxic than Lambda cyhalothrin. On the basis of order of relative toxicity (ORT) at LC_{90} these insecticides can be arranged in descending order as [Chlorantraniliprole 18.5% SC] > [Profenofos 50% EC] > [Thiodicarb 75 %WP] > [Fifronil 5% SC] > [Lambda cyhalothrin 5% EC].

Table 6: Relative Toxicity of insecticides to *Pectinophora gossypiella* populations from Washim location

Insecticide	*Relative Toxicity (RT) at LC_{50}*			*Relative Toxicity (RT) at LC_{90}*		
	LC_{50} (%)	*RT*	*ORT*	*LC_{90} (%)*	*RT*	*ORT*
Chlorantraniliprole 18.5% SC	0.014	20.08	1	0.079	42.40	1
Profenofos 50% EC	0.122	2.30	2	0.393	8.52	2
Thiodicarb 75 %WP	0.192	1.47	4	0.914	3.67	3
Lambda cyhalothrin 5 % EC	0.150	1.88	3	3.349	1.00	5
Fifronil 5% SC	0.281	1.00	5	2.000	1.68	4

(ORT- Order of Relative Toxicity)

Relative Toxicity of insecticides to Pectinophora gossypiella populations from Amravati location

The relative toxicities of insecticides calculated at LC_{50} level (Table 7) revealed that Fifronil 5% SC is least toxic to *P. gossypiella* population from Amravati location. It is evident that Chlorantraniliprole 18.5% SC, Profenofos 50% EC, Thiodicarb 75% WP and Lambda cyhalothrin 5% EC, respectively at 16.08, 2.07, 1.39 and 1.41 fold were more toxic than Fifronil 5% SC to *P. gossypiella* of Amravati location. On the basis of order of relative toxicity (ORT) at LC_{50} these insecticides can be arranged in descending order of their toxicity as [Chlorantraniliprole 18.5% SC] > [Profenofos 50% EC] > [Lambda cyhalothrin 5% EC] > [Thiodicarb 75 %WP] > [Fifronil 5% SC].

At the LC_{90} level Lambda cyhalothrin 5% EC was recorded as the least toxic compound to *P. gossypiella* population from Amravati location. Chlorantraniliprole, Profenofos, Thiodicarb and Fifronil, respectively at 96.20, 20.47, 12.38 and 5.34 fold were more toxic than Lambda cyhalothrin. On the basis of order of relative toxicity (ORT) at LC_{90} these insecticides can be arranged in descending order as [Chlorantraniliprole 18.5% SC] > [Profenofos 50% EC] > [Thiodicarb 75 %WP] > [Fifronil 5% SC] > [Lambda cyhalothrin 5 % EC].

Table 7 : Relative Toxicity of insecticides to *Pectinophora gossypiella* populations from Amravati location

Insecticide	*Relative Toxicity (RT) at LC_{50}*			*Relative Toxicity at LC_{90}*		
	LC_{50} (%)	*RT*	*ORT*	*LC_{90} (%)*	***RT***	***ORT***
Chlorantraniliprole 18.5% SC	0.014	16.08	1	0.067	96.20	1
Profenofos 50% EC	0.109	2.07	2	0.315	20.47	2
Thiodicarb 75 %WP	0.162	1.39	4	0.521	12.38	3
Lambda cyhalothrin 5 % EC	0.159	1.41	3	6.445	1.00	5
Fifronil 5% SC	0.225	1.00	5	1.206	5.34	4

(ORT- Order of Relative Toxicity)

Relative Toxicity of insecticides to Pectinophora gossypiella populations from Buldhana location

The relative toxicities of insecticides calculated at LC_{50} level (Table 8) revealed that Fifronil 5% SC is least toxic to *P. gossypiella* population from Buldhana location. It is evident that Chlorantraniliprole 18.5% SC, Profenofos 50% EC, Thiodicarb 75 % WP and Lambda cyhalothrin 5 % EC, respectively at **18.08**, **2.15**, **1.47** and **1.80** fold were more toxic than Fifronil 5% SC to *P. gossypiella* of Buldhana location. On the basis of order of relative toxicity (ORT) at LC_{50} these insecticides can be arranged in descending order of their toxicity as [Chlorantraniliprole 18.5% SC] > [Profenofos 50% EC] > [Lambda cyhalothrin 5 % EC] > [Thiodicarb 75 %WP] > [Fifronil 5% SC].

At the LC_{90} level Lambda cyhalothrin 5% EC was recorded as the least toxic compound to *P. gossypiella* population from Buldhana location. Chlorantraniliprole, Profenofos, Thiodicarb and Fifronil, respectively at **49.65**, **15.00**, **6.18** and **2.50** fold were more toxic than Lambda cyhalothrin. On the basis of order of relative toxicity (ORT) at LC_{90} these insecticides can be arranged in descending order as [Chlorantraniliprole 18.5% SC] > [Profenofos 50% EC] > [Thiodicarb 75 %WP] > [Fifronil 5% SC] > [Lambda cyhalothrin 5% EC].

Table 8: Relative Toxicity of insecticides to *Pectinophora gossypiella* populations from Buldhana location

Insecticide	*Relative Toxicity (RT) at LC_{50}*			***Relative Toxicity at LC_{90}***		
	LC_{50} (%)	***RT***	***ORT***	***LC_{90} (%)***	***RT***	***ORT***
Chlorantraniliprole 18.5% SC	0.013	**18.08**	**1**	0.084	**49.65**	**1**
Profenofos 50% EC	0.109	**2.15**	**2**	0.278	**15.00**	**2**
Thiodicarb 75 %WP	0.160	**1.47**	**4**	0.675	**6.18**	**3**
Lambda cyhalothrin 5 % EC	0.131	**1.80**	**3**	4.171	**1.00**	**5**
Fifronil 5% SC	0.235	**1.00**	**5**	1.670	**2.50**	4

(ORT- Order of Relative Toxicity)

Relative Toxicity of insecticides to Pectinophora gossypiella population from Yavatmal location

The relative toxicities of insecticides calculated at LC_{50} level (Table 9) revealed that Fifronil 5% SC is least toxic to *P. gossypiella* population from Yavatmal location. It is evident that Chlorantraniliprole 18.5% SC, Profenofos 50% EC, Thiodicarb 75 % WP and Lambda cyhalothrin 5 % EC, respectively at **15.92**, **1.95**, **1.50** and **1.82** fold were more toxic than Fifronil 5% SC to *P. gossypiella* of Yavatmal location. On the basis of order of relative toxicity (ORT) at LC_{50} these insecticides can be arranged in descending order of their toxicity as [Chlorantraniliprole 18.5% SC] > [Profenofos 50% EC] > [Lambda cyhalothrin 5% EC] > [Thiodicarb 75 %WP] > [Fifronil 5% SC].

At the LC_{90} level Lambda cyhalothrin 5% EC was recorded as the least toxic compound to *P. gossypiella* population from Yavatmal location. Chlorantraniliprole, Profenofos, Thiodicarb and Fifronil, respectively at **46.85**, **12.10**, **6.30** and **2.30** fold were more toxic than Lambda cyhalothrin. On the basis of order of relative toxicity (ORT) at LC_{90} these insecticides can be arranged in descending order as [Chlorantraniliprole 18.5% SC] > [Profenofos 50% EC] > [Thiodicarb 75 %WP] > [Fifronil 5% SC] > [Lambda cyhalothrin 5% EC].

Table 9: Relative Toxicity of insecticides to *Pectinophora gossypiella* populations from Yavatmal location

Insecticide	***Relative Toxicity (RT) at LC_{50}***			***Relative Toxicity at LC_{90}***		
	LC_{50} (%)	***RT***	***ORT***	***LC_{90} (%)***	***RT***	***ORT***
Chlorantraniliprole 18.5% SC	0.014	**15.92**	**1**	0.070	**46.85**	**1**
Profenofos 50% EC	0.114	**1.95**	**2**	0.271	**12.10**	**2**
Thiodicarb 75 %WP	0.149	**1.50**	**4**	0.521	**6.30**	**3**
Lambda cyhalothrin 5 % EC	0.122	**1.82**	**3**	3.280	**1.00**	**5**
Fifronil 5% SC	0.223	**1.00**	**5**	1.421	**2.30**	4

(ORT- Order of Relative Toxicity)

Relative Toxicity of insecticides to Pectinophora gossypiella populations from Wardha location

The relative toxicities of insecticides calculated at LC_{50} level (Table 10) revealed that Fifronil 5% SC is least toxic to *P. gossypiella* population from Wardha location. It is evident that Chlorantraniliprole 18.5% SC, Profenofos 50% EC, Thiodicarb 75 % WP and Lambda cyhalothrin 5 % EC, respectively at **13.00**, **1.52**, **1.19** and **1.95** fold were more toxic than Fifronil 5% SC to *P. gossypiella* of Wardha location. On the basis of order of relative toxicity (ORT) at LC_{50} these insecticides can be arranged in descending order of their toxicity as [Chlorantraniliprole 18.5% SC] > [Profenofos 50% EC] > [Lambda cyhalothrin 5 % EC] > [Thiodicarb 75 %WP] > [Fifronil 5% SC].

At the LC_{90} level Lambda cyhalothrin 5% EC was recorded as the least toxic compound to *P. gossypiella* population from Wardha location. Chlorantraniliprole, Profenofos, Thiodicarb and Fifronil, respectively at **41.71**, **8.41**, **6.33** and **3.20** fold were more toxic than Lambda cyhalothrin. On the basis of order of relative toxicity (ORT) at LC_{90} these insecticides can be arranged in descending order as [Chlorantraniliprole 18.5% SC] > [Profenofos 50% EC] > [Thiodicarb 75 %WP] > [Fifronil 5% SC] > [Lambda cyhalothrin 5% EC].

Table 10: RelativeToxicity of insecticides to *Pectinophora gossypiella* populations from Wardha location

Insecticide	*Relative Toxicity (RT) at LC_{50}*			*Relative Toxicity at LC_{90}*		
	LC_{50} (%)	*RT*	*ORT*	*LC_{90} (%)*	*RT*	*ORT*
Chlorantraniliprole 18.5% SC	0.014	**13.00**	**1**	0.070	**41.71**	**1**
Profenofos 50% EC	0.119	**1.52**	**3**	0.347	**8.41**	**2**
Thiodicarb 75 %WP	0.153	**1.19**	**4**	0.461	**6.33**	**3**
Lambda cyhalothrin 5 % EC	0.093	**1.95**	**2**	2.920	**1.00**	**5**
Fifronil 5% SC	0.182	**1.00**	**5**	0.910	**3.20**	4

Security Indices of Insecticides for *Pectinophora gossypiella Populations at* Different Locations

Insecticides with > 1 Security Index values were considered as effective while those < 1 was considered as high risk insecticides. The Security Indices of insecticides calculated for respective *P. gossypiella* populations from different locations are presented in the following subheads

Security indices for Akola location

For Akola population of *P. gossypiella* the five newer insecticides recorded security indices (S.I.) in the range of 1.45 to 38.24 (Table 11). None of the insecticide tested was found as high risk insecticide (i.e. S.I. = < 1). Profenofos 50% EC with highest S.I. emerged as most safe insecticide for Akola population of *Pectinophora gossypiella*. Based on the security index rating (S.I.R.) all the insecticides tested against Akola population of *P. gossypiella* can be arranged in descending order as [Profenofos 50% EC] > [Thiodicarb 75 % WP] > [Chlorantraniliprole 18.5 % SC] > [Fifronil 5% SC] > [Lambda cyhalothrin 5 % EC]

Security indices for Washim location

For Washim population of *P. gossypiella* the five newer insecticides recorded security indices (S.I.) in the range of 2.99 to 50.90 (Table 12). None of the insecticides tested was found as high risk insecticide (i.e. S.I. = < 1). Profenofos 50% EC with highest S.I. emerged as most safe insecticide

Table 11: Security indices of insecticides for *Pectinophora gossypiella* population at Akola location

Insecticide	*LC_{90} (%) computed*	*Field dose* (%)*	*Security Index*	*S. I. R.*
Chlorantraniliprole 18.5 % SC	0.095	0.03	31.58	3
Profenofos 50% EC	0.523	0.20	38.24	1
Thiodicarb 75 %WP	0.624	0.20	32.05	2
Lambda cyhalothrin 5 % EC	6.896	0.10	1.45	5
Fifronil 5% SC	1.098	0.15	13.66	4

* As per CIBRC (www.cibrc.gov.in) S. I. R. = Security Index rating

Table 12: Security indices of insecticides for *Pectinophora gossypiella* populations at Washim location

Insecticide	LC_{90} *(%) computed*	*Field dose* (%)*	*Security Index*	*S. I. R.*
Chlorantraniliprole 18.5 % SC	0.079	0.03	37.98	2
Profenofos 50% EC	0.393	0.2	50.90	1
Thiodicarb 75 %WP	0.914	0.2	21.89	3
Lambda cyhalothrin 5 % EC	3.349	0.1	2.99	5
Fifronil 5% SC	2.000	0.15	7.5	4

* As per CIBRC (www.cibrc.gov.in) S. I. R. = Security Index rating

for Washim population of *P. gossypiella*. Based on the security index rating (S.I.R.) all the insecticides tested against Washim population of *P. gossypiella* can be arranged in descending order as [Profenofos 50% EC] > [Chlorantraniliprole 18.5 % SC] > [Thiodicarb 75 % WP] > [Lambda cyhalothrin 5 % EC] > [Fifronil 5% SC]

Security indices for Amravati location

For Amravati population of *P. gossypiella* the five newer insecticides recorded security indices (S.I.) in the range of 1.55 to 63.50 (Table 13). None of the insecticides tested was found as high risk insecticide (i.e. S.I. = < 1). Profenofos 50% EC with highest S.I. emerged as most safe insecticide for Amravati population of *P. gossypiella*. Based on the security index rating (S.I.R.) all the insecticides tested against Amravati population of *P. gossypiella* can be arranged in descending order as [Profenofos 50% EC] > [Chlorantraniliprole 18.5 % SC] > [Thiodicarb 75 % WP] > [Fifronil 5% SC] > [Lambda cyhalothrin 5 % EC]

Security indices for Buldhana location

For Buldhana population of *P. gossypiella* the five newer insecticides recorded security indices (S.I.) in the range of 2.40 to 71.94. (Table 14). None of the insecticides tested was found as high risk insecticide (i.e. S.I. = < 1). Profenofos 50% EC with highest S.I. emerged as most safe insecticide for Buldhana population of *P. gossypiella*. Based on the security index rating (S.I.R.) all the insecticides tested against Buldhana population of *P. gossypiella* can be arranged in descending order as [Profenofos 50% EC] > [Chlorantraniliprole 18.5 % SC] > [Thiodicarb 75 % WP] > [Fifronil 5% SC] > [Lambda cyhalothrin 5 % EC]

Security indices for Yavatmal location

For Yavatmal population of *P. gossypiella* the five newer insecticides recorded security indices (S.I.) in the range of 3.04 to 73.80. (Table 15). None of the insecticides tested was found as high risk insecticide (i.e. S.I. = < 1). Profenofos

Table 13: Security indices of insecticides for *Pectinophora gossypiella* populations at Amravati location

Insecticide	LC_{90} *(%) computed*	*Field dose* (%)*	*Security Index*	*S. I. R.*
Chlorantraniliprole 18.5 % SC	0.067	0.03	44.78	2
Profenofos 50% EC	0.315	0.2	63.50	1
Thiodicarb 75 %WP	0.521	0.2	38.39	3
Lambda cyhalothrin 5 % EC	6.445	0.1	1.55	5
Fifronil 5% SC	1.206	0.15	12.43	4

* As per CIBRC (www.cibrc.gov.in) S. I. R. = Security Index rating

Table 14: Security indices of insecticides against *Pectinophora gossypiella* populations for Buldhana location

Insecticide	LC_{90} ***(%) computed***	***Field dose* (%)***	***Security Index***	***S.I.R.***
Chlorantraniliprole 18.5 % SC	0.084	0.03	35.71	2
Profenofos 50% EC	0.278	0.2	71.94	1
Thiodicarb 75 %WP	0.675	0.2	29.62	3
Lambda cyhalothrin 5 % EC	4.171	0.1	2.40	5
Fifronil 5% SC	1.670	0.15	8.99	4

* As per CIBRC (www.cibrc.gov.in) S. I. R. = Security Index rating

50% EC with highest S.I. emerged as most safe insecticide for Yavatmal population of *P. gossypiella*. Based on the security index rating (S.I.R.) all the insecticides tested against Yavatmal population of *P. gossypiella* can be arranged in descending order as [Profenofos 50% EC] > [Chlorantraniliprole 18.5 % SC] > [Thiodicarb 75 % WP] > [Fifronil 5% SC] > [Lambda cyhalothrin 5 % EC]

Security indices for Wardha location

For Wardha population of *P. gossypiella* the five newer insecticides recorded security indices (S.I.) in the range of 3.42 to 57.63. (Table 16). None of the insecticides tested was found as high risk insecticide (i.e. S.I. = < 1). Profenofos 50% EC with highest S.I. emerged as most safe insecticide for Wardha population of *P. gossypiella*. Based on the security index rating (S.I.R.) all the insecticides tested against Wardha population of *P. gossypiella* can be arranged in descending order as [Profenofos 50% EC] > [Thiodicarb 75 % WP] > [Chlorantraniliprole 18.5 % SC] > [Fifronil 5% SC] > [Lambda cyhalothrin 5 % EC]

DISCUSSION

No considerable variations in log dose probit assay values in bioassay studies were recorded for respective insecticide against *P. gossypiella* populations from different locations. However, it appears from the bioassay studies that sensitivity to Chlorantraniliprole 18.5 % SC, Profenofos 50% EC, Thiodicarb 75 %WP, Lambda cyhalothrin 5 % EC and Fifronil 5% SC in *P. gossypiella* populations, respectively, from Buldhana, Amravati & Buldhana, Yavatmal and Wardha and Wardha was found higher. Sabry *et al.*, (2014) also reported that chlorantraniliprole with LC_{50} value of 19.0 PPM was highly toxic to *P. gossypiella* in laboratory bioassay studies. Kodandaram *et al.* (2015) reported that chlorantraniliprole is more toxic to brinjal shoot and fruit borer *Leucnodes orbonalis* than insecticides like flubendiamide and cypermethrin. Madeha *et al.* (2017) noticed that Chloranitraniliprole at sublethal dose of LC_{25} was quite effective against the 4th instar larvae of *Spodoptera litura in* laboratory. Gayi *et al.* (2016) reported that Agrolambacin a mixture of lambda Cyhalothrin + Profenofos showed maximum mortality (100%) after 96 hours against cotton bollworm (*Helicoverpa armigera).* Sanghi et al., (2018) in field experiment, studies, however, observed that Chlorantraniliprole 20 SC is less effective (51.6%) against *P. gossypiella*. Insecticides like chlorantraniliprole and lambda-cyhalothrin were also reported as effective against pink bollworm in field trials (Sabry, 2013 and Sabry et al., 2014). In view of long term indiscriminate use of some new label claim insecticide formulations it is critical to evaluate their effectiveness (relative toxicity) before being they are used extensively in major cotton growing areas. In the present

Table 15: Security indices of insecticides for *Pectinophora gossypiella* populations at Yavatmal location

Insecticide	*LC_{90} (%) computed*	*Field dose* (%)*	*Security Index*	*S.I.R.*
Chlorantraniliprole 18.5 % SC	0.070	0.03	42.85	2
Profenofos 50% EC	0.271	0.2	73.80	1
Thiodicarb 75 %WP	0.521	0.2	38.39	3
Lambda cyhalothrin 5 % EC	3.280	0.1	3.04	5
Fifronil 5% SC	1.421	0.15	10.55	4

* As per CIBRC (www.cibrc.gov.in) S. I. R. = Security Index rating

Table 16: Security indices of insecticides for *Pectinophora gossypiella* populations at Wardha location

Insecticide	***LC_{90} (%) computed***	***Field dose* (%)***	***Security Index***	***S.I.R.***
Chlorantraniliprole 18.5 % SC	0.070	0.03	42.82	3
Profenofos 50% EC	0.347	0.2	57.63	1
Thiodicarb 75 %WP	0.461	0.2	43.39	2
Lambda cyhalothrin 5 % EC	2.920	0.1	3.42	5
Fifronil 5% SC	0.910	0.15	16.49	4

* As per CIBRC (www.cibrc.gov.in) S. I. R. = Security Index rating

experiments the five insecticides tested have not shown difference in the trend of effectivity at LC_{50} or LC_{90} levels. For Akola, Washim, Amravati, Buldhana, Yavatmal and Wardha populations of *P. gossypiella* the relative toxicity trend (at LC_{90}) was [Chlorantraniliprole 18.5% SC] > [Profenofos 50% EC] > [Thiodicarb 75 %WP] > [Fifronil 5% SC] > [Lambda cyhalothrin 5 % EC]. This may be due to specific mode of action of these insecticides sabotaging wild insect pest population spread accross a wider geographic range. The effectiveness of Chlorantraniliprole (Kushwaha and Painkra,2016; Sarnabati and Ray, 2017), Profenofos (Gayi *et al.*, 2016; Sarnabati and Ray, 2017), Thiodicarb (Shah *et al*., 2012; Dhamdhere and Sharma, 1991; Gayi *et al.,* 2016; Sahu *et al*. 2018), and Lambda cyhalothrin (Anil and Sharma, 2010; Roy *et al*., 2016; Gayi *et al.,* 2016) against cryptic pests like *P. gossypiella* and *L. orbonalis* have been reported earlier. Kulkarni *et. al*. (2018[a]) reported that Chlorantraniliprole 18.5% SC was 1.11, 1.11 and 1.01 times less toxic than Spinosad 45% SC, respectively to Akola, Buldhana and Yavatmal populations of *H. armigera* elaborating differential response of same insecticide against two types of pests and response pattern of geographically different populations to same insecticide. *The* superiority of insecticides in terms of safety and effectiveness can be precisely determined by estimating security index (Sauphanor et al. 1998). In the present investigations all the insecticides found to be safer and none is considered as high risk However, high Security Index values of Profenofos 50% EC, followed by Thiodicarb 75 % WP and Chlorantraniliprole 18.5% SC at almost all places rated them as most safer and effective insecticides for use against *P. gossypiella.* Although Chlorantraniliprole 18.5% SC was found highly toxic in bioassay studies it was trailing in S.I. rating. Similar observations reported by Karuppaiah *et al*. (2017) for *Spodoptera litura*. It may be due to more use of this insecticide by cotton growers in the area. Kulkarni et. al (2018[b]) concluded that the Security Index > 1 for Cypermethrin 10 EC correspond to resistance development in *P. gossypiella* populations from Akola, Buldana, Washim and Yavatmal districts. Amongsts the tested insecticides Profenofos 50% EC, Thiodicarb 75 % WP and Chlorantraniliprole 18.5% SC would be better chemical to manage *P. gossypiella* irrespective of their geographical locations. At recommended field dose, however, all the five insecticides scored the security index (SI) threshold value ≥1 for all populations and they could be considered effective insecticides for the management of *P. gossypiella* amidst sequential preference.

CONCLUSIONS

- In conclusion, the present study revealed local variation in their sensitivity to some insecticides has been observed among the *P. gossypiella* strains collected from six different locations
- Chlorantraniliprole 18.5%SC and Profenofos 50% EC showed better toxicity irrespective of *P. gossypiella* population from different locations.
- All insecticides studied found effective recording > 1 security index which means that *P. gossypiella* population is sensitive to the field doses of these insecticides.
- However, although effective, Lambda cyhalothrin 5 % EC and Fifronil 5% SC be given last options.
- These studies will prove as a hand in tool for selection and application of insecticide for effective management of ever damaging *P. gossypiella.*
- In the context of effectiveness and safety, newer chemistry insecticides were better in terms of toxicity and their threshold of security index value.
- The LC_{50} value obtained from this study would serve ready reckoner for the selection of insecticides for field strain.
- The base line data could be useful for the comparisons of relative toxicity and monitoring resistance in *P. gossypiella.*
- The information on local variation in sensitivity of *P. gossypiella* could be helpful in devising local management strategies.
- The findings emerged with a following preferential selection of tested insecticides for location specific application in better management of P. gossypiella

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