Toxicity and the latent effect of certain pyrethroids on pink bollworm

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ABSTRACT

Vail residue assay technique was used in laboratory trails to study the toxicity of certain pyrethroids (deltamethrin, cypermethrin, cyfluthrin, α-cypermethrin and fenpropathrin) against both males and females of the laboratory population of pink bollworm. Regarding the toxicity results against the male moths, deltamethrin was the most toxic followed by cyfluthrin, α- cypermethrin, cypermethrin and the lowest toxic insecticide was fenpropathrin. Also against the female moths deltamethrin proved to be the most toxic followed by cyfluthrin, fenpropathrin, α- cypermethrin where cypermethrin was the least toxic one. The toxicity data mean that female moth is tolerant than male moth. The survival males and females were transferred to the matting cages (one pair / cage) to study the latent effects of these pyrethroids. The fecundity study indicated that there was a significant difference between treated and untreated females; this difference is a response to the treatment with pyrethroids. The most effective insecticide on the fecundity of females was α-cypermethrin followed by deltamethrin, cyfluthrin, cypermethrin and the least effective one was fenpropathrin. The viability of the laid eggs showed high reduction percentages of the hatched eggs. General observations indicated that all the treatments produced few viable eggs, the greatest effect was for cypermethrin and cyfluthrin followed by deltamethrin, α-cypermethrin and then fenpropathrin. Regarding the larval stage it was obvious that cyfluthrin showed superiority over the other used insecticides, while the least effective one was deltamethrin. On the other hand, not all the developed offspring succeed to be pupae there were some of them malformed and dead in all the treatments and the untreated except the treatment of cypermethrin. The effect on the pupal stage revealed that both deltamethrin and cyfluthrin hadn't reduced the developed pupae to adults, while the rest treatments gave slight reduction.

Key words: Pyrethroids, toxicity, Pink bollworm, latent effect, fecundity, viability.

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INTRODUCTION

The pink bollworm (PBW) *Pectinophora gossypiella* (Saunders) is a worldwide pest of cotton and in some regions of the world is the key cotton pest. It has been recorded to cause loss in the yield and increase the costs of insect control with substantial indirect losses occur as a result of the destruction of beneficial insects and the development of insecticides resistance in cotton (El-Bassiony 2001).

Synthetic pyrethroids have high contact activity and are particularly effective against lepidopterous larvae. They were introduced to replace the resistance-prone and environmentally unsuitable organochlorines, cyclodienes and organophosphates; they possessed an inherently high activity and could be applied at extremely low doses (McCaffery 1999). Most but not all of pyrethroids have a very low mammalian toxicity (Elliott 1989).

They are used to control a wide range of insect pests of agriculture and horticultural crops and for use in control of insect vectors of disease. Pyrethroids have also made substantial inroads into public health, industrial, amenity and household outlets, as well as grain and food stores. Pyrethroids have become the first choice for an insecticide in these different situations because dosages can be kept extremely low. Since their introduction in the mid-1970s the pyrethroids have proved a powerful insecticide control tool which has in some cases threatened their longer term viability through rapid development of pest resistance (Dent 2000).

The biological parameters are considered a powerful tool to clarify and understand the impact of any external factor on the growth, survival, reproduction and population increase rate (Wittmeyer and Coudron 2001, El-Gemeiy 2002 and El-Metwally *et al* 2007).

The latent effects on the biological parameters (total number of the laid eggs, hatching %, survival ratio of the immature stages, rate of development and the sex ratio), of any insecticides are considered as the basic parameter which should be established before any recommended use of an insecticide.

The present investigation aimed to study the toxicity of some pyrethroid insecticides against the male and female moths of pink bollworm and there latent effect on some biological parameters.

MATERIALS AND METHODS

I) Vial Residue Assay Technique (VRAT): An alternative method for resistance monitoring was perfected by Plapp 1971for larvae and Plapp *et al* 1990 for adults. This technique was adapted by Shekeban 2000 to use for the adults of bollworms as follow:

1- Coated vials were prepared in this way:
   - a- Insecticides were diluted with acetone into many appropriate concentrations.
   - b- One ml of each concentration was pipetted into the vials to design the desired series.
   - c- The uncapped vials were placed in the coating tray and the coating devise was moved until dryness.

2- The pheromone live traps were placed at chosen locations in the field and were left overnight. Moths were collected before sunrise and moved to the laboratory quickly.

3- Small pieces of cotton (approximately 0.5 cm in size) were dipped in 10% sugar solution and squeezed to remove all excess liquid and placed one wick into each vial.

4- Five live moths were inserted in each coated vial including the control vial, then the vials were plugged with cotton and incubated at fixed temperature of 25 ^{0}C.

5- Mortalities were recorded and subjected to probit analysis computer program (Finney 1971).

II) Insect used: Laboratory male and female moths population of pink bollworm (PBW) *Pectinophora gossypiella* (Saunders) (Lepidoptera : Gelechiidae) was supplied by the Bollworm Research Department, Plant Protection Research Institute, Agricultural Research Center, Dokki, Egypt, where it has been reared for several years in conditioned laboratory without exposure to insecticides. The rearing procedure was adopted as that recorded by Abd El-Hafez *et al* (1982) .

III) Insecticides used:

1- Deltamethrin (Decis 2.5 % E.C). Produced by Roussel Uclaf, France.

Chemical name: (S)- α-cyano-3-phenoxy-benzyl- (1R)-cis-3-(2,2-dibromovinyl)- 2,2-dimethyl cyclopropane carboxylate.

2- Cypermethrin (Polytrin 20% E.C). Dow. Agro Sciences. USA.
Chemical name: (R,S)- α-cyano-3-phenoxy-benzyl- (1R,1S)-cis,trans-3-(2,2-dichlorovinyl)- 2,2-dimethyl cyclopropane carboxylate.

3- Cyfluthrin (Baythroid 5 % EC). Produced by Bayer AG, Germany.
Chemical name: α-cyano-4-fluoro-3-phenoxy-benzyl-3-(2,2-dichlorovinyl)- 2,2-dimethyl cyclopropane carboxylate.

4- α- Cypermethrin (Fastac 10 % E.C). Produced by Shell International, British.
Chemical name: (1R cis) S and (1S cis) R enantiomer isomer pair of α-cyano-3-phenoxy-benzyl-3-(2,2-dichlorovinyl)- 2,2-dimethyl cyclopropane carboxylate.

5- Fenpropathrin (Meothrin 20 % E.C). Produced by Sumitomo, Japan.
Chemical name: (R,S)- α-cyano-3-phenoxy-benzyl- 2,2,3,3-tetramethyl cyclopropane carboxylate.

IV) Latent effects study: Five pears of the survival adults from each insecticide treatment were confined in glass oviposition cage of one liter size and were used to determine the latent effect on the biological parameters of the pink bollworm in comparison with that of the control. Five replicates with one pear were implemented for each treatment. The oviposited and the hatched eggs were counted daily for nine days and the hatchability percentages were calculated. Also, the reduction percentages in oviposition, hatchability were calculated. the untreated semi- artificial diet were offered to the 1st instar larvae and they were incubated in the same conditions of the mass rearing. The survived insects along the developed stages were inspected till the adult emergence and the percentages of stage development success or failure were calculated.

V) Statistical Analysis:

a- Regression equation LC_{50}, LC_{95} and confidence limits were calculated according to (Finney 1971) probit analysis computer program.

b- Toxicity Index (T. I) and Relative Toxicity (R.T.) were calculated as follow:

$$T.I = \frac{LC_{50} \text{ of the most toxic insecticide}}{LC_{50} \text{ of the tested insecticide}} \times 100 \quad \text{(Sun 1950)}$$

$$R.T = \frac{LC_{50} \text{ of the lowest toxic insecticide}}{LC_{50} \text{ of the tested insecticide}} \text{ fold} \quad \text{(Metcalf 1967)}$$

c- The hatchability percentages were calculated according to Shekeban *et al.* 2010.

$$\text{Hatchability \%} = \frac{\text{Number of hatched eggs}}{\text{Total laid eggs}} \times 100$$

d- The reduction percentages were calculated according to Abbott 1925.

$$\text{Reduction \%} = \frac{N_1 \text{ control} - N_2 \text{ treated}}{N_1 \text{ control}} \times 100$$

Where:

N_1 control = the total number of oviposited or the total number of hatched
N_2 treated = the total number of oviposited or the total number of hatched

RESULTS AND DISCUSSION

I) The toxicity study: Results in Table (1) show the toxicity parameters of five conventional pyrethroids (deltamethrin, cypermethrin, cyfluthrin, α- cypermethrin and fenpropathrin) against the male moths of the laboratory reference strain of pink bollworm . These results indicated that deltamethrin was the most toxic (LC_{50} = 0.029 ppm) followed by cyfluthrin (LC_{50} = 0.09 ppm), α- cypermethrin (LC_{50} = 0.1 ppm), cypermethrin, (LC_{50} = 0.14 ppm) and the lowest toxic insecticide was fenpropathrin (LC_{50} = 0.16 ppm). The calculated values of the LC_{95} were 0.98, 1.67, 2.5, 1.91 and 2.71 ppm for deltamethrin, cypermethrin, cyfluthrin, α- cypermethrin and fenpropathrin, respectively. These data were in agreement with those obtained by Shekeban *et al.* 2003 when tested pyrethroids against the male moths of pink bollworm and indicated that deltamethrin was the most toxic against the laboratory strain followed by the alpha-cypermethrin, cypermethrin and the least toxic one was fenpropathrin. Also, deltamethrin was the most toxic against the field strain followed by cypermethrin and alpha-cypermethrin while fenpropathrin was the least toxic one. El-Bassiony 2001 obtained the same trend of results when tested these compounds against the laboratory strain of pink bollworm using the attracticide resistance monitoring technique.

Table (1): Toxicity of certain pyrethroids against the male moths of PBW using VRAT.

Insecticides	Reg. Equation Y= a + bx	LC_{50} (ppm) (95% C L)	LC_{95} (ppm) (95% C L)	R.T. Fold	T.I.
Deltamethrin	Y=1.66 +1.08 x	0.029 (0.058-.0.015)	0.98 (5.93 - 0.20)	5.52	100
Cypermethrin	Y=1.30 +1.55 x	0.14 (0.24 - 0.085)	1.67 (5.7 - .63)	1.14	20.7
Cyfluthrin	Y=1.19 +1.14 x	0.09 (0.17 - 0.046)	2.5 (14.48 - 0.63)	1.78	32.2
α- Cypermethrin	Y=1.28 +1.29 x	0.1 (0.18 - 0.055)	1.91 (8.4 - 0.59)	1.6	29
Fenpropathrin	Y=1.07 +1.33 x	0.16 (0.28 - 0.087)	2.71 (12.75 - 0.82)	1	18.1

The toxicity parameters data for the tested pyrethroids against the female moths were collected and tabulated in Table (2). These data showed that, the LC_{50} values of the five used pyrethroids can arranged in the following descending order : deltamethrin > cyfluthrin > fenpropathrin > α- cypermethrin > cypermethrin. The calculated LC_{95} values were 2.88, 4.56, 7.6, 2.99 and 4.52 ppm for deltamethrin, cypermethrin, cyfluthrin, α- cypermethrin and fenpropathrin, respectively.

Reviewing the previous results from Table (1) and Table (2), it can show, the increase in both LC_{50} values and LC_{95} values of the tested compounds against the females than that of the males, this means that the female moth is tolerant than the male moth. These findings are in agreement with the finding of Stadelbacher *et al.* (1990) when reported that survival 2.9% of the tested males and 5.6% of the tested females of bollworm (*Heliothis zea*) when treated at the rate of 10 μg/vial of cypermethrin, also, survival of tobacco budworm females was significantly higher than males (41.5 versus 26%).

Table (2): Toxicity of certain pyrethroids against the female moths of PBW using VRAT.

Insecticides	Reg. Equation Y=a + bx	LC_{50} (ppm) (95%C L)	LC_{95} (ppm) (95%C L)	R.T. Fold	T.I.
Deltamethrin	Y=1.2 +0.97 x	0.058 (0.082 – 0.028)	2.88 (31.7 - 0.38)	4.13	100
Cypermethrin	Y=0.80 +1.28 x	0.24 (0.46 - 0.13)	4.56 (28.64 - 1.19)	1	24.2
Cyfluthrin	Y=0.74 +1.03 x	0.19 (0.41 - 0.092)	7.6 (91.55 - 1.28)	1.26	30.5
α-Cypermethrin	Y=0.96 +1.44 x	0.21 (0.38 - 0.12)	2.99 (13.36 - 0.96)	1.14	27.6
Fenpropathrin	Y=0.84 +1.22 x	0.20 (0.39 - 0.11)	4.52 (28.89 - 1.11)	1.2	29

2) The latent effects study: The latent effects on the life parameters of pink bollworm were studied and the obtained results were tabulated in tables 3, 4, and 5. Data in tables 3 and 4 represented the fecundity of the treated females and the effect of the tested pyrethroids on the viability of the deposited eggs with the reduction percentages of the laid eggs number, the hatched eggs number and the hatchability%.

The fecundity study indicated a significant difference between treated and untreated females; this difference is a response to the treatment with pyrethroids. The total number of the laid eggs by 5 females previously treated with deltamethrin during 9 days was 474 eggs, while it was 546 eggs for cypermethrin, 491 eggs for cyfluthrin, 366 eggs for α-cypermethrin,813 eggs for fenpropathrin and then 950 eggs for the untreated females.

The most effective insecticide on the fecundity of pink bollworm females was α-cypermethrin (main laid eggs/one female/ 5 days = 73.2 eggs and the main laid eggs/one female/ one day= 8.13eggs) followed by deltamethrin (main laid eggs/one female/ 5 days = 94.8 eggs and the main laid eggs/one female/ one day= 10.53 eggs), cyfluthrin (main laid eggs/one female/ 5 days = 98.2 eggs and the main laid eggs/one female/ one day= 10.91eggs), cypermethrin (main laid eggs/one female/ 5 days = 109.2 eggs and the main laid eggs/one female/ one day= 12.13 eggs) and the least effective one was fenpropathrin (main laid eggs/one female/ 5 days = 162.6 eggs and the main laid eggs/one female/ one day= 18.07 eggs).

Table (3): The latent effect of the tested pyrethroids on the number of deposited and hatched eggs and hatchability % from treated females compared with untreated females.

Insecticides	Total No. of eggs/ 9 days	Total Hat. eggs/ 9 days	Avr. No. of eggs/ female/ 9 days	Avr. No. of eggs/ female/ 9 days	Avr. No. of eggs/ female /day	Avr. Hat. eggs/ female /day	Hatchability %
Deltamethrin	474	200	94.8	40	10.53	4.44	42.2
Cypermethrin	546	209	109.2	41.8	12.13	4.64	38.3
Cyfluthrin	491	188	98.2	37.6	10.91	4.18	38.3
α-Cypermethrin	366	183	73.2	36.6	8.13	4.07	50.0
Fenpropathrin	813	478	162.6	95.6	18.07	10.62	58.8
Untreated	950	684	190	136.8	21.11	15.2	72.0

Regarding to the reduction % of the laid eggs (Table 4), the highest recorded reduction percentage was for α-cypermethrin, and it was 61.47% and the lowest one was for fenpropathrin, it was 14.42%. The other reduction % of the laid eggs, were 42.53% for cypermethrin, 50.11% for deltamethrin and 48.32% for cyfluthrin.

The viability of the laid eggs (Table 4) showed high reduction percentages of the hatched eggs, it was 70.76% for deltamethrin, 69.44% for cypermethrin, 72.51% for cyfluthrin, 73.25% for α-cypermethrin and 30.125 for fenpropathrin.

General observations (Table 4) indicated that all the treatments produced few viable eggs, the greatest effect was for cypermethrin and cyfluthrin (hatchability % = 38.3) followed by deltamethrin (hatchability % = 42.2), α-cypermethrin (hatchability % = 50) and then fenpropathrin (hatchability % = 58.8). Comparing the hatchability % of the treated pink bollworm adults and the untreated adults showed hatchability reduction percentages of 41.39%, 46.81%, 46.81%, 30.56% and 18.33% for deltamethrin, cypermethrin, cyfluthrin, α- cypermethrin and fenpropathrin, respectively. The previously discussed data were in good agreement with Louis 1984 results when reported that pink bollworm *P. gossypiella* moths which treated with the synthetic pyrethroids cyfluthrin, fenpropathrin, fenvalerate, flucythrinate, and permethrin reduced the number of eggs laid and hatching of eggs was also reduced.

Table 4: The latent effect of the tested pyrethroids on the number of deposited and hatched eggs and hatchability % from treated 5 females compared with the untreated 5 females through 9 days.

Insecticides	No. of eggs	Eggs red. (%)	No. of hat. eggs	Hat. eggs red. (%)	No. of non hat. eggs	Hatchability (%)	Hatchability reduction (%)
Deltamethrin	474	50.11	200	70.76	274	42.2	41.39
Cypermethrin	546	42.53	209	69.44	337	38.3	46.81
Cyfluthrin	491	48.32	188	72.51	303	38.3	46.81
α-Cypermethrin	366	61.47	183	73.25	183	50.0	30.56
Fenpropathrin	813	14.42	478	30.12	335	58.8	18.33
Untreated	950	-	684	-	266	72.0	-

The latent effects of the tested pyrethroid insecticides on the developmental stages of pink bollworm were studied and the results were tabulated in Table 5. The results showed that all the tested pyrethroids decreased the offspring survival larvae number compared with that of the untreated and α-cypermethrin was the most effective one in reducing this number to 183 followed by cyfluthrin (188 larvae), deltamethrin (200 larvae), cypermethrin (209 larvae) and then the least effective one was fenpropathrin (478 larvae). Regarding the larval stage, the number of the developed larvae to the full-grown larvae (4^{th} instar larvae) was differed among insecticide treatments and also between pyrethroids and the untreated. Pyrethroid treatments reduced the full-grown survival % to 20.2, 26.3, 27, 36.1 and 48% for cyfluthrin, cypermethrin, fenpropathrin, α-cypermethrin and deltamethrin, respectively.

On the other hand, not all the developed offspring succeed to be pupae there were some of them malformed and dead in all the treatments and the untreated except the treatment of cypermethrin. Fenpropathrin showed superiority in this case where 19 of the full-grown larvae were misshapen and the rest became pupae where only 4 of them were dead and the other succeeded to develop to adults.

Table 5: The latent effects of the tested pyrethroids on the development of the larvae.

Insecticide	No. of survival larvae	Larval stage			Pupal stage		Adult stage	
		Full-grown larvae	Dead larvae	Survival full-grown larvae %	Malformed larvae	Pupae	Dead pupae	No. Moth
Deltamethrin	200	96	104	48	10	86	0	86
Cypermethrin	209	55	154	26.3	0	55	3	52
Cyfluthrin	188	38	150	20.2	13	25	0	25
α - Cypermethrin	183	66	117	36.1	7	59	3	56
Fenpropathrin	478	129	349	27	19	110	4	106
Untreated	684	538	146	78.7	8	530	0	530

Cyfluthrin treatment have 13 of the full-grown larvae misshapen and 25 could developed to pupae and then to adults, also and in the same manner 10 of the full-grown larvae in deltamethrin treatment were misshapen and the other transferred to pupal stage and then to adult. For cypermethrin treatment all the full-grown larvae became pupae while three of them deceased and the rest developed to adults. Ending with α-cypermethrin treatment where 7 of the full-grown larvae were malformed and 59 of them succeeded to be pupae then three of them were lifeless and 56 developed to adults.

The obtained data were in harmony with that reported by Michaelides and Wright 1997 when treated larvae of the southern corn rootworm with tefluthrin and found significant reduction in survival to adulthood compared with untreated larvae. Tefluthrin treatment of larvae also resulted in significantly lower emergent adult. Eissa *et al.* (2005) evaluated the biological effects of the LC_{50}'s of two different groups of chemical insecticides, Deltamethrin (Decis 2.5% Tablets), Chlorpyrifos (Dursban 48%) on the newly hatched larvae of susceptible strains of *P.* gossypiella and *E. insulana* and reported that each treatment affected some biological characters such as percentage of pupation, the hatchability and fecundity percentage per female. In general, mathematically speaking, there is a high and significant difference in the adult emergence percentages of *P. gossypiella* among the treatments and between the insecticides and the control.

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السمية والتأثير المتأخر لبعض البيرثرويدات على دودة اللوز القرنفلية

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استخدمت طريقة المتبقى على الأسطح الداخلية للزجاجات في المعمل وذلك لدراسة سمية خمسة من المبيدات البيرثرويدية (دلتامثرين , سيبرميثرين , سيفلوثرين , الفا-سيبرميثرين و فنبروباثرين) ضد كلاً من ذكور و إناث العشيرة المعملية لدودة اللوز القرنفلية و قد أظهرت النتائج الخاصة بالسمية ضد الذكور أن أكثر المبيدات سمية كان الدلتامثرين تبعه في السمية السيفلوثرين تلاه الالفا-سيبرميثرين ثم السيبرميثرين في حين كان الفنبروباثرين هو الأقل سمية, أما بالنسبة للسمية ضد الإناث فقد اثبت مبيد الدلتامثرين انه الأقوى سمية تبعه السيفلوثرين ثم الفنبروباثرين وبعده الالفا-سيبرميثرين في حين كان السيبرميثرين الأقل سمية ضد إناث دودة اللوز القرنفلية. إن النتائج المتحصل عليها من دراسة السمية توضح أن الإناث أكثر تحملا من الذكور.

لقد تم استخدام خمسة أزواج من الفراشات الناجية من كل معاملة على حده في صورة خمسة مكررات بكل منها زوج من الفراشات وذلك لدراسة التأثيرات المتأخرة لهذه البيرثرويدات.

لقد أظهرت دراسات الخصوبة اختلافاً ما بين معاملات المبيدات وبعضها وكذلك بين معاملات المبيدات و الفراشات الغير معاملة (المقارنة) وهذا الاختلاف راجع إلى المعاملة بالبيرثرويدات. لقد كان أكثر المبيدات تأثيراً على الخصوبة هو مبيد الالفا-سيبرميثرين تبعه الدلتامثرين فالسيفلوثرين ثم السيبرميثرين وكان الفنبروباثرين هو الأقل تأثيراً.

لقد أظهرت نتائج دراسة حيوية البيض الموضوع بواسطة الإناث أن هناك نقص كبير في نسب فقس البيض حيث كان اكبر تأثير لمبيدي السيبرميثرين و السيفلوثرين تبعهما الدلتامثرين وأعقبه الالفا-سيبرميثرين وكان الأقل تأثيراً مبيد الفنبروباثرين.

بخصوص الطور اليرقي فقد أوضحت النتائج أن مبيد السيفلوثرين اظهر قوة اكبر من المبيدات الأخرى في التأثير على اكتمال التطور اليرقي بينما كان الدلتامثرين هو الأقل تأثيراً وفي الوقت نفسه فلم تفلح كل اليرقات كاملة التطور في التحول إلى عذارى حيث تشوه بعضها ولم يتحول ماعدا معاملة مبيد السيبرميثرين. أما التطور إلى حشرة كاملة فقد تطورات جميع عذارى معاملتي الدلتامثرين و السيفلوثرين بينما أظهرت المعاملات الأخرى تأثيراً خفيفا.