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Persistence toxicity of different insecticides against *Helicoverpa armigera*

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Abstract
The present investigation were conducted at Dr. PDKV, Akola Persistence of different treatments against *Helicoverpa armigera*. Twenty laboratory reared, initial third instar larvae per treatment were released in the plastic vials individually, where fresh Pigeonpea flowers/pod from the treated plots were kept. The food material after completion of spraying was offered to the insects. A check was set up by using flowers/pod from untreated control. The treated food was collected at an interval of 0 (one hour after spray), 1, 3, 5, 7, 10 and14 days after application and offered to the larvae subsequently for different seven sets of experiments. Correspondingly, larvae were feed with the same food material continuously for treatment. The mortality data was recorded after every 24 hours of exposure and the PT values were calculated. Amongst the different chemicals tested in laboratory against *H. armigera*, the treatment with flubendiamide 20 WDG proved most effective in recording highest (914.20) persistence toxicity followed by emamectin benzoate 5 SG, spinosad 45 SC, indoxacarb 15.8EC, HaNPV 500 LE+ silver nano particles, profenophos 50 EC, azadiractin 10000 ppm and deltametrin 1%+ trizophos 35% recording 723.10, 695.90, 636.50, 361.05, 332.71, 200.85 and 143.85 PT values, respectively.

Keywords: Persistence toxicity, insecticides against, *Helicoverpa armigera*

Introduction
Pigeonpea, *Cajanus cajan* (L) Mill. vernacularly known as Red gram, *Arhar* or *Tur* is one of the most important pulse crop. Among the biotic and abiotic factors responsible for low yields of pigeonpea, insect pests are the major ones. More than 250 insect pests are reported on pigeonpea and extent of damage caused by insect pests varies from 30 to 80 percent (Sharma *et al.*, 2010) [12]. Out of these *Helicoverpa armigera* (Hubner) and pod fly (*Melanagromyza obtusa* Malloch) are important constraints in attainment of desired production and productivity of pigeonpea (Sharma *et al.*, 2008) [11]. Various methods have been tried for the control of pod borer complex, but agrochemicals are still the first choice of farmers. Management of pod borer complex in pigeonpea relies heavily on insecticides, often to the exclusion of other methods of control, because of their quick action, effectiveness and adaptability to various situations. Considerable numbers of insecticides have been tested and few of them found effective against the pod borers in pigeonpea (Yadav and Dahiya, 2004) [17]. Farmers, use chemical pesticides indiscriminately, which leads to increased cost of plant protection resulting in low profitability. Farmers in southern India had to spray 3-6 times per season without much success and economic benefits (Shanower *et al.*, 1999) [13]. Sole reliance on chemical pesticides led to development of resistance and resurgence of secondary pests. With reports of pesticide resistance in pod borer (Kranthi *et al.*, 2002) [6] and subsequent promotion of IPM, highlighted the need for development of safe, economic and effective pest management strategies.

Materials and Methods
Rearing of test Insect in the Laboratory
The larvae of *H. armigera* ranged from second to third instars were collected from the unsprayed fields of cotton, sunflower etc. and reared on artificial diet for further development. The chickpea based semi synthetic diet was prepared as suggested by Armes *et al.*, (1992) [2] using the following ingredients and methodology.

Composition of semi synthetic diet for rearing *H. armigera* larvae (For 1.0 liter)

Sr. No.	Ingredients	Quantity
1	Chickpea flour	160.0 g
2	Wheat germ	60.0 g
3	Ascorbic acid	5.3 g
4	Methyl-4 hydroxy benzoate	3.5 g
5	Sorbic acid	1.7 g
6	Distilled water	550.0 ml
7	Auriomycin	2.5 g
8	Formaldehyde	15.0 ml
9	Yeast	53.0 g
10	Agar-agar	16.0 g
11	Distilled water	550.0 ml

The required quantity of warm distilled water (550 ml) was taken in each of the separate containers. In one of the above containers 16 g agar-agar was added and the mixture was heated to boil and later on cooled up to 60 °C. The water from another container was boiled and the same was added in the mixer pot containing measured quantity of chickpea flour and rotated for two minutes. To this mixture, agar-water mixture along with measured quantity of Methyl – 4 hydroxy benzoate, sorbic acid and yeast were added and rotated for two minutes. Later on, measured quantity of ascorbic acid, auriomycin and formaldehyde were added in the above mixture and again rotated for one minute. The diet was then filled in multicellular plastic trays one third of their capacity and allowed to cool for 2-3 hours and stored in refrigerator for further use (Armes *et al.*, 1992) [2].

The field collected larvae were reared individually in each cell containing artificial diet to avoid cannibalism till pupation. The pupae were collected and transferred in petri dishes containing soil which was sterilized previously at 100 °C for one hour in hot air oven. These petri dishes along with pupae were kept in adult emergence chamber. The adults emerged out were then transferred to adult mating and oviposition chamber. The eggs laid on the cloth were collected daily and were sterilized in formaldehyde for 45 minutes with subsequent washing for one hour under tap water as described by Smith and Rivers, (1966) [15].

These eggs were kept for incubation in BOD incubator for egg hatching at 27 ± 2 °C temperature and 78 ± 2 percent relative humidity. The larvae were emerged after 3-4 days and the newly hatched larvae were transferred with the help of camel brush moistened with 0.02 percent sodium hypochloride solution to separate cells containing artificial diet. These vials were kept in a incubation chamber until the larvae attained the third instar stage (30-40 mg) and such larvae were further used to study the persistent toxicity.

Persistence of different treatments against *H. armigera*

Twenty laboratory reared, initial third instar larvae per treatment were released in the plastic vials individually, where fresh Pigeonpea flowers/pod from the treated plots were kept. The food material after completion of spraying was offered to the insects. A check was set up by using flowers/pod from untreated control. The treated food was collected at an interval of 0 (one hour after spray), 1, 3, 5, 7, 10 and14 days after application and offered to the larvae subsequently for different seven sets of experiments. Correspondingly, larvae were feed with the same food material continuously for treatment.

The mortality data was recorded after every 24 hours of exposure and the PT values were calculated as per the procedure given by Pradhan (1967) [7]. The corrected mortality was worked out as per Abbott (1925) [1].

Calculation of PT values

For comparison of persistence toxicity of different treatments, PT values were calculated. PT values refer to the product of average percentage residual toxicity (T) and the period (P) for which toxicity is observed (Pradhan, 1967 and Sarup *et al.*, 1970) [7, 10]. The average residual toxicity was calculated by adding the values of corrected percentage mortality of 0, 1, 3, 5, 7, 10 and 14 days interval and then dividing the total by number of observations.

Statistical analysis

The data collected from each year of experimentation were averaged out for respective parameter and subjected for analysis of variance. Similarly, the result of both the years were pooled and averages were worked out. The data thus obtained were transformed appropriately to arc sine and square root transformation wherever necessary as per Gomez and Gomez (1984) [5] and further statistical analysis was done for testing of the level of significance. Daily larval mortality of *H. armigera* on 0, 1, 3, 5, 7, 10 and14 days sets were recorded to study the persistence toxicity under laboratory condition.

Experimental Details:

The field persistence of pesticides used in different modules during field testing in laboratory was studied.

1. Design - Non Replicated
2. No of larvae/ treatment of pesticide - 20
3. Sets of larvae - Seven i.e. at 0, 1, 3, 5, 7, 10, 14 days after treatment.
4. Observations - Daily on mortality of larvae.

Details of Insecticides used

Sr. No.	Common name	Chemical name	Trade name	Supply source
1	Emamectin Benzoate 5 SG	4"-epimethylamino-4"-deoxyavermectin B1a Natural fermentation product of soil bacterium- *Streptomyces avermitilis*	Proclaim	Syngenta India Limited, Mumbai.
2	Indoxacarb 15.8 EC	(3)-methyl 7 chloro-2, 5-dihydro 2 [(methoxy carbonyl)-4 trifluromethoxy phenyl amino carbonylindenol] 1, 2-e-1,3,4 oxadiazine 4 (a) (3II) carboxylate	Avaunt	Dupont pesticides India Ltd. Mumbai
3	Spinosad 45 SC	*Saccharopolyspora spinosa*	Spintar 45 SC	De-Nocil crop protection Pvt.Ltd., Gujarat
4	Flubendiamide 20 WDG	N2-[1,1-dimethyl-2-(methylsulfonyl)ethyl]-3-iodo-N1-[2-methyl-4-[1,2,2,2-tetrafluoro-1-(triflouromethyl)ethyl]phenyl]-1,2-benzenedicarboxamide	Takumi	Rallis India Ltd Mumbai, India
5	*Helicoverpa armigera* nuclear polyhedrosis virus	*Helicoverpa armigera* nuclear polyhedrosis virus	HaNPV	Deptt. of Entomology, Dr.P.D.K.V., Akola.
6	Azadirachtin 10000 ppm	Azadirachtin 10000 ppm	Margo Econeem Plus	Margo Biocontrols Pvt. Ltd. Bangalore
7	Deltametrin1%+ Triazophos 35% EC	1, R-(a(-s)3a)-cyano (3 phenoxy-phenyl) methyl 3-(2,2, dibromoethenyl)-2,2, diethyl-0-7- phenyl-14-1,2,4+ triazol-3-71) phosphorothioate.	Spark	Bayer India Ltd., Mumbai.
8	Profenophos 50 EC	O-4-bromo-2-chloro phyenyl-0-ethylspropyl phosphorothioate	Curacron	Syngenta India Ltd., Mumbai.

Result and Discussion

Toxicity and Persistence of Different Treatments against *H. armigera* 2012-13

The data generated in the laboratory on toxicity and persistence of different treatments against *H. armigera* (Table 1.) revealed that the significantly higher mortalities were noticed during the first few days after application of the treatments, which further declined as the days advanced. The treatments of Indoxacarb 15.8 EC, *Ha*NPV + Silver nano particle, Emamectin benzoate 5 SG, Spinosad 45 SC and Flubendiamide 20 WDG resulted in causing 100 percent mortality of *H. armigera* when the treated food of zero day i.e. just one hour after the treatments i.e. zero day was offered to the insects. It was followed by the treatments Profenophos 50 EC, Deltametrin 1% + Trizophos 35% EC and Azadirachtin 10,000 ppm which recorded 75.00, 66.66 and 44.44 percent mortality, respectively.

The similar trend of results with decreasing larval mortality was recorded in the experiment conducted with the treated food offered to *H. armigera* after one day of the treatments. The maximum mortality of 100 percent was recorded in the treatments of *Ha*NPV + Silver nano particle, Emamectin benzoate 5 SG, Spinosad 45 SC and Flubendiamide 20 WDG. These treatments were followed by the treatments of Indoxacarb 15.8 EC, Profenophos 50 EC, Deltametrin 1% + Trizophos 35% EC and Azadirachtin 10,000 ppm recording 88.88, 62.50, 50.00 and 44.44 percent larval mortality, respectively.

In the case of larvae fed with the treated food of 3 days old after application of treatments revealed that the larval mortality of 87.50 percent was obtained due to the treatment of Flubendiamide 20 WDG followed by the treatments of Emamectin benzoate 5 SG, Indoxacarb 15.8 EC, Spinosad 45 SC, *Ha*NPV + Silver nano particle, Profenophos 50 EC, Deltametrin 1% + Trizophos 35% EC and Azadirachtin 10,000 ppm, recording 75.00, 75.00, 66.66, 62.25, 44.44, 22.22 and 14.29 percent larval mortality of *H. armigera*, respectively.

The treatment of Emamectin benzoate 5 SG recorded the highest larval mortality of *H. armigera* (75.00%) when the larvae were fed with the treated food after 5th day of applications, followed by the treatments of Flubendiamide 20 WDG, Spinosad 45 SC, Indoxacarb 15.8 EC, *Ha*NPV + Silver nano particle, Profenophos 50 EC, Deltametrin 1% + Triazophos 35% EC and Azadirachtin 10,000 ppm, recording 71.43, 62.50, 62.50, 33.33, 33.33, 11.11 and 10.00 percent mortality, respectively.

The observations recorded on the set of experiment wherein the larvae were exposed to 7 day old treated food material indicated that five treatments *viz*. Flubendiamide 20 WDG, Spinosad 45 SC, Emamectin benzoate 5 SG, Indoxacarb 15.8 EC and Profenophos 50 EC recorded 62.25, 62.25, 55.55, 37.50 and 10.00 percent respective larval mortality. However, the remaining treatments, i.e. *Ha*NPV + Silver nano particle, Deltametrin 1% + Triazophos 35% EC and Azadirachtin 10,000 ppm recorded zero percent larval mortality of *H. armigera.* However, when the larvae were fed on 10 day old treated food have shown less influence in causing the mortality of *H. armigera.* The treatments of Flubendiamide 20 WDG, Spinosad 45 SC, Emamectin benzoate 5 SG and Indoxacarb 15.8 EC, have resulted in recording the mortality to the extent of 33.33, 30.00, 25.00 and11.11 percent, respectively.

Whereas, the larvae fed on 14 days old treated food, no mortality was recorded in any treatments except Flubendiamide 20 WDG, recording 11.11 percent larval mortality.

Based on the PT values, the descending order of persistence of different treatments was worked out as: Flubendiamide 20 WG (924.56) > Emamectin benzoate 5 SG (731.50) > Spinosad 45 SC (694.00) > Indoxacarb 15.8 EC (625.00) > *Ha*NPV + Silver nano particle (369.50) > Profenophos 50 EC (315.35) > Deltametrin 1% + Trizophos 35% EC (187.50) > Azadirachtin 10,000 ppm (141.46).

Table 1: Toxicity and persistence of different treatments against *H. armigera*- 2012-13

Tr. No.	Treatments	Percent corrected mortality days after treatment							P	T	PT	ORE
		0	1	3	5	7	10	14				
1	Azadiractin 10000 ppm	44.44	44.44	14.29	10.00	0.00	0.00	0.00	5	28.29	141.46	8
2	Deltametrin 1%+ Trizophos 35% EC	66.66	50.00	22.22	11.11	0.00	0.00	0.00	5	37.50	187.50	7
3	Profenophos 50 EC	75.00	62.50	44.44	33.33	10.00	0.00	0.00	7	45.05	315.35	6
4	Indoxacarb 15.8 EC	100.00	88.88	75.00	62.50	37.50	11.11	0.00	10	62.50	625.00	4
5	HaNPV 500 LE+ silver nano particles	100.00	100.00	62.25	33.33	0.00	0.00	0.00	5	73.90	369.50	5
6	Emamectin benzoate 5 SG	100.00	100.00	75.00	75.00	55.55	33.33	0.00	10	73.15	731.50	2
7	Spinosad 45 SC	100.00	100.00	66.66	62.50	62.25	25.00	0.00	10	69.40	694.00	3
8	Flubendiamide 20 WDG	100.00	100.00	87.50	71.43	62.25	30.00	11.11	14	66.04	924.56	1

P: Period for which toxicity persisted.
T: Average residual toxicity
PT: Persistence toxicity
ORE: Order of relative efficacy

Toxicity and Persistence of Different Treatments against *H. armigera* 2013-14

The data generated in the laboratory on toxicity and persistence of different treatments against *H. armigera* (Table 2.) revealed that the significantly higher mortalities were noticed during the first few days after application of the treatments, which further declined as the days advanced.

The treatments of Indoxacarb 15.8 EC, *Ha*NPV + Silver nano particle, Emamectin benzoate 5 SG, Spinosad 45 SC and Flubendiamide 20 WDG resulted in causing 100 percent mortality of *H. armigera* when the treated food of zero day i.e. just one hour after the treatments was offered to the insects. It was followed by the treatments of Profenophos 50 EC, Deltametrin 1% + Trizophos 35% EC and Azadirachtin 10,000 ppm which recorded 77.77, 62.50 and 44.44 percent mortality respectively.

The similar trend of results with decreasing larval mortality was recorded in the experiment conducted with the treated food offered to *H. armigera* after one day of the treatments. The maximum mortality of (100 percent) was recorded in the treatments of *Ha*NPV + Silver nano particle, Emamectin benzoate 5 SG, Spinosad 45 SC and Flubendiamide 20 WDG. These treatments were followed by the treatments of Indoxacarb 15.8 EC, Profenophos 50 EC, Deltametrin 1% + Trizophos 35% EC and Azadirachtin 10,000 ppm recording 88.88, 77.77, 55.55 and 37.50 percent larval mortality, respectively.

In the case of larvae fed with the treated food of 3 days old after application of treatments revealed that the larval mortality of 77.77 percent was obtained due to the treatment of Flubendiamide 20 WDG, Emamectin benzoate 5 SG, Indoxacarb 15.8 EC, followed by the treatments of Spinosad 45 SC, *Ha*NPV + Silver nano particle, Profenophos 50 EC, Deltametrin 1% + Trizophos 35% EC and Azadirachtin 10,000 ppm, recording 71.43, 57.14, 50.00, 33.33 and 25.00 percent, larval mortality of *H. armigera* respectively.

The treatment of Flubendiamide 20 WDG recorded the highest larval mortality of *H. armigera* (71.43%) when the larvae were fed with the treated food after 5th day of applications, followed by the treatments of Emamectin benzoate 5 SG, Spinosad 45 SC, Indoxacarb 15.8 EC, Profenophos 50 EC, *Ha*NPV + Silver nano particle, Deltametrin 1% + Trizophos 35% EC and Azadirachtin 10,000 ppm, recording 66.66, 66.66, 66.66, 33.33, 25.00, 20.00 and 10.00 percent mortality, respectively.

The observations recorded on the set of experiment wherein the larvae were exposed to 7 day old treated food material indicated that five treatments *viz.* Flubendiamide 20 WDG, Emamectin benzoate 5 SG, Spinosad 45 SC, Indoxacarb 15.8 EC and Profenophos 50 EC recorded, 66.66, 62.25, 55.55, 44.44 and 11.11 percent, respective, larval mortality. However, the remaining treatments, i.e. *Ha*NPV + Silver nano particle, Deltametrin 1% + Trizophos 35% EC and Azadirachtin 10,000 ppm recorded no larval mortality of *H. armigera.*

However, when the larvae were fed on 10 days old treated food have shown negligible influence in causing the mortality of *H. armigera* The treatments of Flubendiamide 20 WDG, Spinosad 45 SC, Emamectin benzoate 5 SG and Indoxacarb 15.8 EC, have resulted in recording the mortality to the extent of 25.00, 25.00, 22.22 and11.11 percent, respectively.

Whereas, the larvae fed on 14 days old treated food, no mortality was recorded in any treatments except Flubendiamide 20 WG, which recorded 11.11 percent larval mortality.

Based on the PT values, the descending order of persistence of different treatments was worked out as: Flubendiamide 20 WDG (903.98) > Emamectin benzoate 5 SG (714.80) > Spinosad 45 SC (697.70) > Indoxacarb 15.8 EC (648.10) > *Ha*NPV + Silver nano particle (352.70) > Profenophos 50 EC (350.00) > Deltametrin 1% + Trizophos 35% EC (214.25) > Azadirachtin 10,000 ppm (146.20).

Table 2: Toxicity and persistence of different treatments against *H. armigera* 2013-14

Tr. No.	Treatments	Percent corrected mortality days after treatment							P	T	PT	ORE
		0	1	3	5	7	10	14				
1	Azadiractin 10000 ppm	44.44	37.50	25.00	10.00	0.00	0.00	0.00	5	29.24	146.20	8
2	Deltametrin 1%+ Trizophos 35% EC	62.50	55.55	33.33	20.00	0.00	0.00	0.00	5	42.85	214.25	7
3	Profenophos 50 EC	77.77	77.77	50.00	33.33	11.11	0.00	0.00	7	50.00	350.00	6
4	Indoxacarb 15.8 EC	100.00	88.88	77.77	66.66	44.44	11.11	0.00	10	64.81	648.10	4
5	HaNPV 500 LE+ silver nano particles	100.00	100.00	57.14	25.00	0.00	0.00	0.00	5	70.54	352.70	5
6	Emamectin benzoate 5 SG	100.00	100.00	77.77	66.66	62.25	22.22	0.00	10	71.48	714.80	2
7	Spinosad 45 SC	100.00	100.00	71.43	66.66	55.55	25.00	0.00	10	69.77	697.70	3
8	Flubendiamide 20 WDG	100.00	100.00	77.77	71.43	66.66	25.00	11.11	14	64.57	903.98	1

P: Period for which toxicity persisted.
T: Average residual toxicity
PT: Persistence toxicity
ORE: Order of relative efficacy

Toxicity and Persistence of Different Treatments against *H. armigera* (Pooled)

The pooled data generated in the laboratory on toxicity and persistence of different treatments against *H. armigera* are presented in Table 3. The results revealed that the significantly higher mortalities were noticed during the first few days after application of the treatments, which further declined as the days advanced. It was also observed that the maximum cumulative mortalities were occurred on the 10th day of observations in most of the treatments and hence the same values were taken for interpretation of the results.

The treatments of Indoxacarb 15.8 EC, *Ha*NPV + Silver nano particle, Emamectin benzoate 5 SG, Spinosad 45 SC and Flubendiamide 20 WDG resulted in causing 100 percent mortality of *H. armigera* when the treated food of zero day i.e. just one hour after the treatments was offered to the insects. It was followed by the treatments of Profenophos 50 EC, Deltametrin 1% + Trizophos 35% EC and Azadirachtin 10,000 ppm which recorded 76.39, 64.58 and 44.44 percent mortality, respectively.

The similar trend of results with decreasing larval mortality was recorded in the experiment conducted with the treated food offered to *H. armigera* after one day of the treatments. The maximum mortality of 100 percent was recorded in the treatments of *Ha*NPV + Silver nano particle, Emamectin benzoate 5 SG, Spinosad 45 SC and Flubendiamide 20 WDG. These treatments were followed by the treatments of Indoxacarb 15.8 EC, Profenophos 50 EC, Deltametrin 1% + Trizophos 35% EC and Azadirachtin 10,000 ppm recording, 88.88, 70.14, 52.78 and 40.97 percent larval mortality, respectively.

In the case of larvae fed with the treated food of 3 days old after application of treatments revealed that the larval mortality of 82.64 percent was obtained due to the treatment of Flubendiamide 20 WG, followed by the treatments of Emamectin benzoate 5 SG, Indoxacarb 15.8 EC, Spinosad 45 SC, *Ha*NPV + Silver nano particle, Profenophos 50 EC, Deltametrin 1% + Trizophos 35% EC and Azadirachtin 10,000 ppm, recording 76.38, 76.38, 69.05, 59.69, 47.22, 27.78 and 19.65 percent respectively larval mortality of *H. armigera*, respectively.

The treatment of Flubendiamide 20 WDG recorded the highest larval mortality of *H. armigera* (71.43%) when the larvae were fed with the treated food after 5th day of applications, followed by the treatments of Emamectin benzoate 5SG, Spinosad 45 SC, Indoxacarb 15.8 EC, Profenophos 50 EC, *Ha*NPV + Silver nano particle, Deltametrin 1% + Trizophos 35% EC and Azadirachtin 10,000 ppm, recording 70.83, 64.58, 64.58, 33.33, 29.16, 15.55 and 10.00 percent mortality, respectively.

The observations recorded on the set of experiment wherein the larvae were exposed to 7 day old treated food material indicated that five treatments *viz*. Flubendiamide 20 WDG, Emamectin benzoate 5 SG, Spinosad 45 SC, Indoxacarb 15.8 EC and Profenophos 50 EC recorded, 64.45, 58.90, 58.90, 40.97 and 10.55 percent, respective, larval mortality. While, the remaining treatments, i.e. *Ha*NPV + Silver nano particle, Deltametrin 1% + Triazophos 35% EC and Azadirachtin 10,000 ppm recorded no larval mortality of *H. armigera.*

However, when the larvae were fed on 10 day old treated food have shown negligible influence in causing the mortality of *H. armigera* The treatments of Flubendiamide 20 WDG, Emamectin benzoate 5 SG, Spinosad 45 SC, and Indoxacarb 15.8 EC, have resulted in recording the mortality to the extent of 27.50, 27.50 25.00, and 11.11 percent, respectively.

Whereas, the larvae fed on 14 days old treated food, no mortality was recorded in any treatments except Flubendiamide 20 WDG, which recorded 11.11 percent larval mortality.

Based on the PT values, the descending order of persistence of different treatments was worked out as: Flubendiamide 20 WDG (914.20) > Emamectin benzoate 5 SG (723.10) > Spinosad 45 SC (695.90) > Indoxacarb 15.8 EC (636.50) > *Ha*NPV + Silver nano particle (361.05) > Profenophos 50 EC (332.71) >Deltametrin 1% + Trizophos 35% EC (200.85) > Azadirachtin 10,000 ppm (143.85).

The better treatments *viz*., Flubendiamide 20 WDG, Emamectin benzoate 5 SG could not be discussed for want of literature. However, Thakre and Sarode (2003b) [16], Boomathi *et al.*, (2006) [3], Prasad *et al.*, (2009) [8-9], Shinde *et al.*, (2010) [14] and Borkar *et al.*, 2013 [4] have worked on persistent toxicity.

The microbial *Ha*NPV 250 LE performed best registering 79.63 to 100 percent larval mortality and recording the maximum average residual toxicity (T) and persistent toxicity index (PT) i.e. 70.67 and 706.76 percent, (Thakre and Sarode (2003b) [16]. Boomathi *et al.*, (2006) [3] stated that Spinosad alone (75 g a.i./ha) recorded 100 percent mortality of 2nd instar larvae at 24 hours after treatment. Spinosad recorded 50.0, 83.3 and 100 percent mortality of 5th instar larvae at 24, 48 and 72 hours after treatment, respectively.

Prasad *et al.*, (2009) [8-9] reported that, indoxacarb @ 131 g a.i./ha showed quick knock-down effect up to 3rd days after spray resulting into 66.67 to 77.67 percent mortality of the larvae, whereas, profenophos @ 750 a.i./ha recorded the larval mortality of 6.67 to 13.33 percent, 12 days after spray.

Shinde *et al.*, (2010) [14] stated that the LT_{50} and PT values were in the order of spinosad 0.005 percent (12.44 days and 1146.46) followed by indoxacarb 0.01 percent (12.22 days and 1138.2), profenofos 0.08 percent (11.42 days and 1082.2). Borkar *et al.*, 2013 [4], stated that spinosad 45 SC, NSE 5 percent and *Ha*NPV 250 LE/ha showed best performance by registering 76.38 to 100 percent larval mortality up to 5th days which supports the present findings.

Considering the above facts, it can be concluded that for the management of pod borer complex of pigeonpea, the Chemical module-II, which includes first spray of Profenophos 50 EC at bud initiation stage, second spray of Flubendiamide 20 WDG at 50 percent flowering, third spray of Indoxacarb 15.8 EC at 15 days after 50 percent flowering, has proved as the most effective and economical module by recording minimum larval population of *H. armigera* and *E. atomosa* and also reducing the pod and grain damage caused by pod borer complex, lepidopteran pests and *M. obtusa.* The Chemical module-II emerged as the best alternative for the management of pod borers.

Table 3: Toxicity and persistence of different treatments against *H. armigera* (Pooled)

Tr. No.	Treatments	Percent corrected mortality days after treatment							P	T	PT	ORE
		0	1	3	5	7	10	14				
1	Azadiractin 10000 ppm	44.44	40.97	19.65	10.00	0.00	0.00	0.00	5	28.77	143.85	8
2	Deltametrin 1%+ Trizophos 35% EC	64.58	52.78	27.78	15.55	0.00	0.00	0.00	5	40.17	200.85	7
3	Profenophos 50 EC	76.39	70.14	47.22	33.33	10.55	0.00	0.00	7	47.53	332.71	6
4	Indoxacarb 15.8 EC	100.00	88.88	76.38	64.58	40.97	11.11	0.00	10	63.65	636.50	4
5	HaNPV 500 LE+ silver nano particles	100.00	100.00	59.69	29.16	0.00	0.00	0.00	5	72.21	361.05	5
6	Emamectin benzoate 5 SG	100.00	100.00	76.38	70.83	58.90	27.77	0.00	10	72.31	723.10	2
7	Spinosad 45 SC	100.00	100.00	69.05	64.58	58.90	25.00	0.00	10	69.59	695.90	3
8	Flubendiamide 20 WDG	100.00	100.00	82.64	71.43	64.45	27.50	11.11	14	65.30	914.20	1

P : Period for which toxicity persisted.
T : Average residual toxicity
PT : Persistence toxicity
ORE : Order of relative efficacy

Conclusion

Amongst the different chemicals tested in laboratory against *H. armigera*, the treatment with flubendiamide 20 WDG proved most effective in recording highest (914.20) persistence toxicity followed by emamectin benzoate 5 SG, spinosad 45 SC, indoxacarb 15.8EC, HaNPV 500 LE+ silver nano particles, profenophos 50 EC, azadiractin 10000 ppm and deltametrin 1%+ trizophos 35% recording 723.10, 695.90, 636.50, 361.05, 332.71, 200.85 and 143.85 PT values, respectively.

References

1. Abbott WS. A method of computing the effectiveness of an insecticide. Journal of Economic Entomology. 1925;18:265-267.
2. Armes NJ, Jadhao DR, Bond GS, King ABS. Insecticide resistance in *Helicoverpa armigera* in India. Pesticide Science. 1992;34:355-364.
3. Boomathi N, Sivasubramanian P, Raguraman S. Toxic effects of spinosad and its combination with other microbial insecticides against *Helicoverpa armigera* (Hubner). Annals of Plant Protection Sciences. 2006;14(1):228-229.
4. Borkar SL, Sarode SV, Bisane KD. Persistent toxicity of botanicals and biopesticides against *Helicoverpa armigera* (Hubner) in cotton. Indian Journal of Entomology. 2013;75(2):154-156.
5. Gomez KA, Gomez AA. Statistical procedures for agricultural research. In: International Rice Research Institute. John Wiley and Sons; c1984. p. 307-308.
6. Kranthi KR, Jadhav DR, Kranthi S, Wanjari R, Ali SS, Russell DA. Insecticide resistance in five major insect pests of cotton in India. Crop Protection. 2002;21(6):449-460.
7. Pradhan S. Strategy of Integrated pest control. Indian Journal of Entomology. 1967;1(1):105-122.
8. Prasad R, Yadav GS, Rohilla HR. Residual toxicity of some newer insecticides against *Helicoverpa armigera* (Hubner) on pigeonpea. Journal of Insect Science (Ludhiana). 2009;22(3):292-295.
9. Prasad NVVSD, Sirisha K, Rosaiah B. Field evaluation of NPV along with adjuvants against *Helicoverpa armigera* on pigeonpea. Journal of Applied Zoological Researches. 2009;20(1):1-4.
10. Sarup P, Singh DS, Amarapuri S, Lal R. Persistent and relative residual toxicity of some important pesticides to the adults of sugarcane leaf-hopper *Pyrilla perpusilla* Walkar (Hemiptera: Homoptera). Indian Journal of Entomology. 1970;32(3):256-267.
11. Sharma HC, Varshney R, Gaur PM, Gowda CLL. Potential for using morphological, biochemical and molecular markers for resistance to insect pests in grain legumes. Journal of Food Legumes. 2008;21:211-217.
12. Sharma OP, Gopali JB, Yelshetty S, Bambawale OM, Garg DK, Bhosle BB. Pests of pigeonpea and their Management. NCIPM, LBS Building, IARI Campus, New Delhi - 110012, India; c2010.
13. Shanower TG, Romeis J, Minja EM. Insect pests of pigeonpea and their management. Annual Review of Entomology. 1999;44:77-96.
14. Shinde ST, Shetgar SS, Pathan NM. Persistence and residual toxicity of different insecticides against first instar larvae of *Helicoverpa armigera*. Journal of Maharashtra Agricultural Universities. 2010;35(3):415-418.
15. Smith KM, Rivers CF. Some viruses affecting insects of economic importance. Pestology. 1966;46:235-242.
16. Thakre SM, Sarode SV. Persistence of some botanicals and microbials against *Helicoverpa armigera* (Hub.) on pigeonpea. State level seminar on pest management for sustainable agriculture. Feb 6-7, at MAU, Parbhani (M.S.); c2003.
17. Yadav GS, Dahiya B. Evaluation of new insecticides/ chemicals against pod borer and pod fly on pigeonpea. Annals of Biology. 2004;20(1):55-56.
18. Yadav JL, Chauhan R, Yadav PR. Persistence and residual toxicity of some insecticides against *Helicoverpa armigera* in field pea. Indian Journal of Plant Protection. 2006;34(1):124-125.