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PERSISTENT TOXICITY OF SPINOSYN AND DIAMIDE AGAINST *SPODOPTERA LITURA* (F.) ON COWPEA AND SOYBEAN

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ABSTRACT

The persistent toxicity (PT) of three insecticides viz. spinetoram @0.01%, chlorantraniliprole @0.006% and flubendiamide @0.01% has been determined on cowpea (*Vigna unguiculata* L. Walp.) and soybean (*Glycine max* L.) against 4d old larvae of *Spodoptera litura* (F.). The order of persistent toxicity was same for both the crop plants at 72 hours after feeding (HAF) i.e. spinetoram@0.01% > chlorantraniliprole@0.006% > flubendiamide@0.01%. On cowpea plant at 48 HAF, spinetoram showed the highest PT value but chlorantraniliprole and flubendiamide showed the same PT value and at 24 HAF the order of persistent toxicity was spinetoram > flubendiamide > chlorantraniliprole; on the other hand on soybean the order of persistence was as spinetoram > chlorantraniliprole > flubendiamide for all 24, 48 and 72 HAF.On cowpeaspinetoram @0.01% was the most persistent insecticide with a PT value of 759.96 followed by flubendiamide @0.01% (597.24) and chlorantraniliprole @0.006% (575.00) at 24 HAF. After 72 HAF on the treated leaves, spinetoram again showed highest PT value of 1897.2 followed by chlorantraniliprole (1542.72) and flubendiamide (1279.98). On soybean spinetoram @0.01% was the most persistent insecticide with a PT value of 740.16 followed by chlorantraniliprole @0.006% (PT= 491.60) and flubendiamide @0.01% (476.00) at 24 HAF. At 72 HAF, spinetoram showed highest PT value of 1954.32 followed by chlorantraniliprole (1554.24) and flubendiamide (1485.60).

Key words: *Spodoptera litura***,** persistent toxicity, flubendiamide**, s**pinetoram, chlorantraniliprole, cowpea, soybean.

Cowpea (*Vigna unguiculata* L. Walp.) and soybean (*Glycine max* L.) are the most important economic crop plants belonging to family Leguminosae. Both of the crops are attacked by a number of defoliators and among the major lepidopteran defoliators, the tobacco cutworm, *Spodoptera litura* (Lepidoptera: Noctuidae) is one of the major defoliator of cowpea and soybean crop (Ram et al., 1988; Meena and Dudwal, 2017). It has become a major pest of soybean (*Glycine max*) throughout India (Fand et al., 2015).*S. litura* is the most widespread and destructive polyphagous agricultural pest and can feed on more than 389 species of economic plants belonging to 109 families (Lin et al., 2019). Insecticides are considered as the most reliable means to reduce the pest populations when it exceeds economic threshold levels (ETLs) (Jindal et al., 2013). Various chemicals have been recommended by Central Insecticide Board and Registration Committee (CIB&RC, 2018)for the management of this pest on the various crops.

The efficiency of an insecticidemajorly depends on its initial activity (acute toxicity) against the target pest and its residual activity (persistence) on the particular host against the target pest (Brevault et al., 2009). Both of the properties are important to determine adequate doses of insecticides and to determine the time interval of spraying of insecticides in a pest management program (Walgenbach et al., 1991). These properties are influenced by various environmental parameters such as temperature, sunlight and rainfall (Mulrooney and Elmore, 2000) and also the host on which they are applied against a pest (Xue et al., 2010). Several laboratory studies have been done by various workers to test the efficacy of the spinosyn and diamide insecticides against *S. litura*, however there are only few studies on the persistent toxicity of these insecticides on different host plants against *S. liura*, such as the persistent toxicity of these insecticides was studied against *S. litura* on rajmah and moong bean crop by Chand (2016) and Negi and Srivastava (2018) and on tomato by Sharma and Sharma (2018). Keeping in view the importance of the persistence study the present investigation has been done on the persistence toxicity of diamide and spinosyn insecticides against *S. litura* on cowpea and soybean plants.

MATERIALS AND METHODS

The insecticides viz., chlorantraniliprole (Coragen 18.5 SC, Du PontIndia Pvt. Ltd.), flubendiamide (Fame 480 SC, Bayer Crop Science) andspinetoram (Delegate 11.7 SC, Dow Agro Sciences) were purchased from market and stored in a refrigerator. The plants of cowpea (*V. unguiculata*) and soybean (*G. max*) were grown in pots in the Glass house of Department of Entomology as per requirement of the experiment. The doses of the three test insecticides viz., flubendiamide (Fame 480 SC), chlorantraniliprole (Coragen 18.5 SC) and spinetoram (Delegate 11.7 SC) at the respective concentrations of 0.01, 0.006 and 0.01%, as recommended by CIB&RC (2018)were prepared in tap water and sprayed on cowpea and soybean. The plants were sprayed with the freshly prepared concentrations with the help of a small hand atomizer and each plant was sprayed to the point of slight runoff. Plants in control were sprayed with water alone. All the treated plants were tagged and labelled with the name of insecticide, concentration and date of spraying.

The experiment was conducted during 1st to 30thAprilin 2019. The persistent toxicity was assessed at an interval of 3hr, and thereafter at 1, 6, 10, 14, 18, 24 and 30 days after spraying. The leaves were randomly plucked from each treated plant and brought to the laboratory for feeding to the larvae. The petiole of freshly plucked leaves were wrapped with wet cotton swab and placed in plastic boxes (size: 124 x 15 x 8cm). Newly emerged untreated leaves were avoided for feeding. Each treatment was replicated three times and ten larvae (4d old) of *S. litura* (average larval weight = 0.01g) were placed in each replication containing treated leaves. The larval mortality was recorded at 24, 48 and 72 h after the leaves were offered for feeding. PT values were calculated for each exposure period viz. 24, 48 and 72 h according to Pradhan (1967).The observations recorded on mortality were corrected using Abbott's formula (Abbott, 1925).

The data so obtained was subjected to angular transformation (arcs in transformation). With $n<50$, zero and hundred percent proportions were counted as 1/4n and (n-1/4)/n before applying the transformation, respectively, as suggested by Bartlett (1947) (c.f. Snedecor and Cochran, 1967). The corrected percent mortality data obtained at various specific periods was used to calculate average residual toxicity (T). The persistent toxicity of an insecticide to test insect was found out by calculating the index called PT value. The PT value is the product of average % residual toxicity (T) and period (P) for which the toxicity persisted (Sarup et al.,1970; Chand and Srivatava, 2018 and Negi and Srivastava, 2018).

RESULTS AND DISCUSSION

Cowpea

The data in the Table 1 indicated that spinetoram @0.01% was the most persistent insecticide with a PT value of 759.96 followed by flubendiamide @0.01% (597.24) and chlorantraniliprole @0.006% (575.00) when the mortality was observed at 24 hours after feeding (HAF). Average toxicity at 24 HAF was highest (57.50%) for chlorantranilirople followed by flubendiamide (42.66%) and spinetoram (42.22%) but the period for which persistence was observed was least in case of chlorantraniliprole i.e. 10d, which was expressed as the least PT value at 24 HAF. The persistence was observed for 18 days in case of spinetoram (showing highest PT value) and 14 days for flubendiamide.

On increasing the feeding period to 48h on the same leaves, spinetoram showed the highest PT value of 1371.36 followed by chlorantraniliprole and flubendiamide, exhibiting an equal PT value of 900.00. Average toxicity at 48 HAF was highest (57.14%) for spinetoram with period of 24d. Chlorantraniliprole and flubendiamide showed equal average toxicity of 50% for equal period of 18 day at 48 HAF. After 72 hours of feeding on the treated leaves, spinetoram again showed highest PT value of 1897.2 followed by chlorantraniliprole (1542.72) and flubendiamide (1279.98). The average toxicity was highest (79.05%) for spinetoram and minimum for chlorantraniliporle (64.28%) for equal period of 24 days. Flubendiamide on the other hand showed average toxicity of (71.11%) for a period of 18 days only which was expressed as minimum PT value at 72 HAF.

Soybean

The data presented in the Table 2 show that spinetoram @0.01% was the most persistent insecticide with a PT value of 740.16 followed by chlorantraniliprole @0.006% (PT= 491.60) and flubendiamide @0.01% (476.00) when mortality was observed at 24 HAF. Average toxicity was highest (49.16%) for chlorantraniliprole for the period of 10 days followed by spinetoram (41.12%) for a period of 18 days and flubendiamide (34%) for a period of 14 days.

An increase in PT value was observed on increasing the feeding hours to 48 hours on the same treated

Table 1. Persistent toxicity of insecticides to *S. litura* (4d old larvae) - Cowpea

Insecticide (Trade name)	Conc. (%)	Abbott's corrected mortality (%)														
		3h after spray			1 DAS			6 DAS			10 DAS			14 DAS		
		HAF														
		24	48	72	24	48	72	24	48	72	24	48	72	24	48	72
Spinetoram (Delegate 11.7 SC)	0.01	83.33 (65.88)	100.00 (84.74)	100.00 (84.74)	76.66 (61.07)	100.00 (84.74)	100.00 (84.74)	70.00 (56.79)	93.33 (75.00)	100.00 (84.74)	10.00 (18.44)	36.66 (37.23)	100.00 (84.74)	6.66 (14.89)	33.33 (35.24)	73.33 (58.89)
chlorantraniliprole (Coragen 18.5 SC)	0.006	76.66 (61.07)	90.00 (71.56)	100.00 (84.74)	63.33 (52.71)	83.33 (65.88)	100.00 (84.74)	63.33 (52.71)	73.33 (58.89)	96.66 (79.37)	26.66 (31.05)	40.00 (39.23)	73.33 (58.89)	0.00 (5.23)	10.00 (18.44)	40.00 (39.23)
flubendiamide (Fame 480 SC)	0.01	70.00 (56.79)	90.00 (71.56)	100.00 (84.74)	63.33 (52.71)	83.33 (65.88)	100.00 (84.74)	56.66 (48.79)	76.66 (61.07)	96.66 (79.37)	20.00 (26.56)	30.00 (33.21)	70.00 (56.79)	3.33 (10.47)	16.66 (24.04)	36.66 (37.23)
Control	-	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)

Abbott's corrected mortality (%)									Toxicity (T)			Period (days) (P)			PT		
18 DAS			24 DAS			30 DAS											
HAF									HAF			HAF					
24	48	72	24	48	72	24	48	72	24	48	72	24	48	72	24 HAF	48 HAF	72 HAF
6.66 (14.89)	33.33 (35.24)	70.00 (56.79)	0.00 (5.23)	3.33 (10.47)	10.00 (18.44)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	42.22	57.14	79.05	18	24	24	759.96	1371.36	1897.2
0.00 (5.23)	3.33 (10.47)	33.33 (35.24)	0.00 (5.23)	0.00 (5.23)	6.66 (14.89)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	57.50	50.00	64.28	10	18	24	575.00	900.00	1542.72
0.00 (5.23)	3.33 (10.47)	23.33 (28.86)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	-	-	-	42.66	50.00	71.11	14	18	18	597.24	900.00	1279.98
0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	-	-	-	-	-	-	-	-	-

Mean larval wt. = 0.01g (4d old); PT= Persistent toxicity value, DAS= Days after spraying, HAF= Hours after feeding; n = 30, Data in parentheses angular transformed (arcsin) values.

Table 2. Persistent toxicity of insecticides to *S. litura* (4d old larvae) - Soybean

Insecticide (Trade name)	Conc. (%)	Abbott's corrected mortality (%)														
		3h after spray			1 DAS			6 DAS			10 DAS			14 DAS		
		HAF														
		24	48	72	24	48	72	24	48	72	24	48	72	24	48	72
spinetoram (Delegate 11.7 SC)	0.01	73.33 (58.89)	100.00 (84.74)	100.00 (84.74)	70.00 (56.79)	100.00 (84.74)	100.00 (84.74)	63.33 (52.71)	80.00 (63.44)	100.00 (84.74)	33.33 (35.24)	50.00 (45.00)	93.33 (75.00)	3.33 (10.47)	26.66 (31.05)	70.00 (56.79)
chlorantraniliprole (Coragen 18.5 SC)	0.006	73.33 (58.89)	100.00 (84.74)	100.00 (84.74)	60.00 (50.77)	86.66 (68.53)	100.00 (84.74)	56.66 (48.79)	83.33 (65.88)	100.00 (84.74)	6.66 (14.89)	20.00 (26.56)	80.00 (63.44)	0.00 (5.23)	6.66 (14.89)	30.00 (33.21)
flubendiamide (Fame 480 SC)	0.01	53.33 (46.89)	83.33 (65.88)	100.00 (84.74)	53.33 (46.89)	73.33 (58.89)	100.00 (84.74)	50.00 (45.00)	66.66 (54.70)	93.33 (75.00)	6.66 (14.89)	36.66 (37.23)	76.66 (61.07)	6.66 (14.89)	10.00 (18.44)	23.33 (28.86)
Control	-	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)

Abbott's corrected mortality (%)									Toxicity (T)			Period (days) (P)			PT		
18 DAS			24 DAS			30 DAS											
HAF									HAF			HAF					
24	48	72	24	48	72	24	48	72	24	48	72	24	48	72	24 HAF	48 HAF	72 HAF
3.33 (10.47)	23.33 (28.86)	66.66 (54.70)	0.00 (5.23)	16.66 (24.04)	40.00 (39.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	41.12	56.66	81.43	18	24	24	740.16	1359.84	1954.32
0.00 (5.23)	3.33 (10.47)	23.33 (28.86)	0.00 (5.23)	3.33 (10.47)	20.00 (26.56)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	49.16	43.33	64.76	10	24	24	491.60	1039.92	1554.24
0.00 (5.23)	6.66 (14.89)	23.33 (28.86)	0.00 (5.23)	0.00 (5.23)	16.66 (24.04)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	34.00	46.11	61.90	14	18	24	476.00	829.98	1485.60
0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	0.00 (5.23)	-	-	-	-	-	-	-	-	-

Mean larval wt. = 0.01g (4d old); PT= Persistent toxicity value, DAS= Days after spraying, HAF= Hours after feeding; n = 30, Data in parentheses angular transformed (arcsin) values.

leaves. Spinetoram showed the highest PT value of 1359.84 followed by chlorantraniliprole (1039.92) and flubendiamide (829.98) at 48 HAF. The average toxicity at 48 HAF was highest (56.66%) for spinetoram for a period of 24 days, followed by flubendiamide (46.11%) for a period of 18 days and chlorantraniliprole (43.33%) for a period of 24 days. The order of persistence at 72 HAF was found to be same as that of 24 and 48 HAF. Spinetoram showed highest PT value of 1954.32 followed by chlorantraniliprole (1554.24) and flubendiamide (1485.60) at 72 HAF. Average toxicity was highest for spinetoram (81.43%) followed by chlorantraniliporle (64.76%) and flubendiamide (61.90%). The period for toxicity persisted was same for all the insecticides i.e., 24 days at 72 HAF.

The order of persistent toxicity was same for both the crop plants at 72 HAF i.e. spinetoram@0.01% > chlorantraniliprole@0.006% > flubendiamide@0.01%. On cowpea plant at 48 HAF, spinetoram showed the highest PT value but chlorantraniliprole and flubendiamide showed the same PT value and at 24 HAF the order of persistent toxicity was spinetoram > flubendiamide > chlorantraniliprole; on the other hand on soybean the order of persistence was as spinetoram > chlorantraniliprole > flubendiamide for all 24,48 and 72 HAF. A fast degradation of chlorantraniliprole and flubendiamide was observed on cowpea plant. Chlorantraniliprole persisted for 18 days on cowpea when mortality was observed at 48 HAF however on soybean it persisted for 24 days for the same 48 HAF. On the other hand flubendiamide persisted for only 18 days on cowpea plant; however it persisted for 24 days on soybean plant when mortality was observed at 72 HAF. All the insecticides showed a higher PT value on cowpea plant at 24 HAF than soybean plant. Spinetoram and flubendiamide showed higher PT value on cowpea whereas chlorantraniliprole showed higher PT values on soybean plant at 48 HAF. Higher PT values of all the insecticides were observed on soybean plant than on cowpea plant at 72 HAF.

There is no direct reference on persistent toxicity of spinetoram, chlorantraniliprole and flubendiamide on cowpea and soybean plant against 4d old larvae of *S. litura*. However, Chand (2016) found that on rajmah bean against 6d old larvae of *S. litura* at 24 HAF, flubendiamide + thiacloprid @0.019% showed the PT value of 493.3 followed by spinetoram @0.005% (PT= 486.6) and flubendiamide @0.004% (PT= 345.6). At 48 HAF flubendiamide reflected the highest PT value of 632.4 while flubendiamide + thiacloprid reflected the lowest PT value of 519.9. At 72 HAF flubendiamide showed PT = 713.3, however the least persistent toxicity was found in spinetoram (673.3). The order of persistent toxicity at 24 HAF was flubendiamide+thiacloprid (493.3) > spinetoram (486.6) > flubendiamide (345.6); however, at 48 HAF it was flubendiamide (632.4) > spinetoram (539.9) > flubendiamide + thiacloprid (519.9) and at 72 HAF, flubendiamide (713.3) >flubendiamide + thiacloprid (686.6) > spinetoram (673.3). The persistent toxicity of insecticides on rajmah bean and mulberry plants was evaluated by Negi and Srivastava (2018) against the 5d old larvae of *S. litura*. Chlorantraniliprole + lambda-cyhalothrin @0.027% was found to be the most persistent (PT value = 1841.60 and 2119.98) followed by cypermethrin + indoxacarb @0.02% (PT value = 812.68 and 1764.26) on mulberry and rajmah bean plants, respectively.

In another experiment, the persistent toxicity of some insecticide was examined on rajmah bean and mung bean plants against 6d old larvae of *S. litura*. Chlorantraniliprole @0.0055% showed highest persistence (PT value = 916.52, 1072.50) and residual toxicity on rajmah (11 days after spray (DAS)) and mung bean (15 DAS) plants, respectively. The persistent toxicity of flubendiamide (0.008%), indoxacarb (0.015%), lambda-cyhalothrin (0.004%), malathion (0.050%), novaluron (0.010%) by spray and imidacloprid (0.018%) drenching as well as spray was tested by Sharma and Sharma (2018)on tomato leaves against 2nd instar larvae of *S. litura* . Flubendiamide was found to reflect the maximum PT value during winter as well as summer seasons.

The persistent toxicity of spinetoram was tested byAbdu-Allah (2010) against *S. littoralis* in cotton and castor. The mortality caused by spinetoram, in cotton and castor was 96.67, 3.33 and 3.33% and 0.00, 2.86 and 0.00%, respectively after 0, 3 and 6 days; however, Abdu-Allah(2011)observed that under field conditions, spinetoram did not show any persistence in castor bean, while emamectin benzoate retained its persistence against *S. littoralis.* Hardke et al. (2011)reported that chlorantraniliprole and cyantraniliprole resulted in 53.1% mortality when observed at 72 HAF at 28 days after treatment (DAT) against fall armyworm in grain sorghum *Spodoptera frugiperda* (JE Smith). Depalo et al. (2016) reported that spinetoram provided control for approximately 10 DAT against Oriental fruit moth *Grapholita molesta* (Busck) and codling moth *Cydia pomonella* (L.).

Thus the present study on the persistent toxity of spinosyn and diamide insecticides revealed that at recommended doses they persisted longer on soybean than on cowpea e.g. flubendiamide persisted for 18 days on cowpea and 24 days on soybean. None of the insecticides showed phytotoxicity. Since the study was conducted under glasshouse conditions, the standadisation of spray schedule if needed, must be based on field trials conducted under different agroclimatic conditions.

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REFERENCES

Abbott W S. 1925. A method of computing the effectiveness of an insecticide. Journal of Economic Entomology 18(2): 265-267.

Abdu-Allah G. 2010. Laboratory and field evaluation of emamectin benzoate and spinetoram on cotton leafworm larvae. Resistant Pest Management Newsletter 20(1):12-16.

Abdu-Allah G. 2011. Potency and residual activity of emamectin benzoate and spinetoram on *Spodoptera littoralis* (Boisduval). African Entomology 19(3): 733-737.

Bartlett M S. 1947. The use of transformations. Biometrics 3(1): 39-52.

Brevault T, Oumarou Y, Achaleke J, Vaissayre M, Nibouche S. 2009. Initial activity and persistence of insecticides for the control of bollworms (Lepidoptera: Noctuidae) in cotton crops. Crop Protection 28(5): 401-406.

Chand A. 2016. Bioefficacy, persistent toxicity and sublethal effects of some insecticides against major insect pests. Thesis, Ph.D. Department of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, India, pp. 387.

Chand A, Srivastava R P. 2018. Persistent toxicity of some insecticides against *Spilosoma obliqua* (Walker) on rajmah and mulberry plants. Journal of Entomological Research 42(1): 81-86.

CIB&RC. 2018. Insecticides/Pesticides Registered under section 9(3) of the Insecticides Act, 1968 for use in the country as on 31.05.2018. http://ppqs.gov.in/divisions/cib-rc/major-uses-of-pesticides. (Last access: September 2018).

Depalo L, Masetti A, Avilla J, Bosch D, Pasqualini E. 2016. Toxicity and residual activity of spinetoram to neonate larvae of *Grapholita molesta* (Busck) and *Cydia pomonella* (L.)(Lepidoptera: Tortricidae): Semi-field and laboratory trials. Crop Protection 89:32-37.

Fand B B, Sul N T, Bal S K, Minhas P S. 2015. Temperature impacts the development and survival of common cutworm (*Spodoptera litura*): simulation and visualization of potential population growth in India under warmer temperatures through life cycle modelling and spatial mapping. PLoS One 10(4) e0124682.

Hardke J T, Temple J H, Leonard B R, Jackson R E. 2011. Laboratory toxicity and field efficacy of selected insecticides against fall armyworm (Lepidoptera: Noctuidae). Florida Entomologist 94(2): 272-278.

Jindal V, Dhaliwal G S, Koul O. 2013. Pest management in 21st century: Roadmap for future. Biopesticides International 9(1): 1-22.

Lin T, Chen X, Li B, Chen P, Guo M, Zhou X, Zhong S and Cheng X. 2019. Geographical origin identification of *Spodoptera litura* (Lepidoptera: Noctuidae) based on trace element profiles using tobacco as intermedium planted on soils from five different regions. Microchemical Journal 146: 49-55.

Meena P K, Dudwal R. 2017. Population dynamics of major defoliators (semiloopers and tobacco caterpillar) in soybean crop. Legume Research: An International Journal 40(1):183-186.

Mulrooney J E, Elmore C D. 2000. Rainfastening of bifenthrin to cotton leaves with selected adjuvants. Journal of Environmental Quality 29(6): 1863-1866.

Negi K, Srivastava R P. 2018. Persistent toxicity of certain newer insecticides on mulberry, rajmah bean and mung bean plants against *Spodoptera litura* (Fabricius). Journal of Entomological Research 42(3): 361-368.

Pradhan S. 1967. Strategy of integrated pest control. Indian Journal of Entomology 29:105-122.

Ram S, Gupta M P, Maurya R P. 1988. Efficacy of three insecticides applied in three regimes against insect-pests of cowpea. Indian Journal of Plant Protection 16(1): 17-20.

Sarup P, Singh D S, Amarpuri S, Rattan Lal. 1970. Persistent and relative residual toxicity of some important pesticides to the adults of sugarcane leaf-hopper, *Pyrilla perpusilla* Walker (Lophopidae : Homoptera). Indian Journal of Entomology 32(3): 256-267.

Sharma P C, Sharma S. 2018. Residual toxicity of different insecticides against tobacco caterpillar. Journal of Hill Agriculture 9(2): 193-197.

Snedecor G W and Cochran W G. 1967. Statistical methods (6th Edn.), Oxford and IBH Publishing Co. New Delhi, pp. 593.

Walgenbach J F, Leidy R B, Sheets T J. 1991. Persistence of insecticides on tomato foliage and implications for control of tomato fruitworm (Lepidoptera: Noctuidae). Journal of Economic Entomology 84(3): 978-986.

Xue M, Pang Y H, Li Q L, Liu T X. 2010. Effects of four host plants on susceptibility of *Spodoptera litura* (Lepidoptera: Noctuidae) larvae to five insecticides and activities of detoxification esterases. Pest Management Science 66(12):1273-1279.

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