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Effect of different nozzles droplet sizes of insecticides on the persistent toxicity against larvae of cabbage butterfly *Pieris brassicae* (Linn)

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Abstract
The present investigation was undertaken at Division of Entomology, SKUAST-Kashmir, Shalimar during the year 2014. In this experiment effectiveness of hollow cone nozzle and full cone nozzle in controlling cabbage butterfly was evaluated keeping in view the persistent toxicity, relative residual toxicity, LC_{50}, LT_{50} value and order of relative efficacy of three insecticides namely Dichlorvos 76 EC, Malathion 50 EC and Quinalphos 25 EC at three different concentrations. The three concentrations of insecticides were 0.1, 0.05 and 0.025% for Dichlorvos, 0.14, 0.07 and 0.035% for Malathion and 0.07, 0.035 and 0.0175% for Quinalphos.It was found that Malathion proved to be least toxic to the 2nd instar larvae of cabbage butterfly followed by Quinalphos and Malathion. Persistent toxicity of all the three insecticides was more in hollow cone nozzle as compare to full cone nozzle.

Keywords: Cabbage butterfly, persistent toxicity, droplet size, drift, residual toxicity

Introduction
Cole vegetables are the winter season vegetable occupies an important position in meeting the dietary requirements of the people all over the world. Among the all winter vegetables, cabbage *Brassica oleracea* var. *capitata* Linn. is a popular and extensively cultivated crop because of its nutritional and economical values. It is grown for its edible enlarged terminal buds, which is a rich source of Ca, P, Na, K, S, vitamin A, vitamin C and dietary fibre. India is the second largest producer of cabbage in the world after China producing 68.70 lakh tonnes in an area of 3.1 lakh hectares with a productivity of 22.20 MT/ha (Anonymous, 2009) [3]. Cabbage butterfly, *Pieris brassicae* (Linn.) is one of the important pest of cruciferous crops. Damage causes both in quality (100%) and quantity reducing yield (25.6%) considerably. *P. brassicae* (Linn.) is also the serious insect pest of cabbage in the Kashmir valley (Anonymous, 1987) [2]. Among the plethora of insect pests, cabbage white butterfly, *Pieris brassicae* (Linn.), is one of the most destructive pest causing damage at all the growth stages including seedling, vegetative growth and flowering stage (Hasan and Ansari, 2010) [13]. Insecticide application against the larval stage is the primary method of control of *P. brassicae* (Linn.), but high tolerance to most insecticides and associated environmental problems may jeopardize their continued use (Grisakova *et al.*, 2006) [11]. Many insecticides such as Dichlorvos, Malathion and Quinalphos are being used for the management of cabbage butterfly on cruciferous crops in Kashmir (Shah *et al.*, 1999) [21]. No doubt, these insecticides have been giving effective control of the pest, but the farmers are using them repeatedly at higher doses and frequencies than the recommended ones without knowing their persistency and health hazards to consumer and beneficial insects. Pesticides, although play fundamental role in the current agricultural production system, it has been the subject of growing concern because of their potential environmental risk (Barcellos *et al.*, 1998) [6]. In practice, the dose of pesticide used is much higher than required (Fernandes, 1997) [9]. The nozzle is a primary factor in determining the amount of spray applied to an area, the uniformity of application, the coverage achieved on the target surface and the amount of potential drift. Nozzles break the liquid into droplets and form the spray pattern, and propel the droplets in the proper direction. While choosing nozzles droplet sizes for spray applications, applicators must consider uniformity of coverage and drift potential. As a rule, smaller droplets provide better coverage, but larger droplets are less likely to drift. Drift can be minimized by selecting nozzles that produce the largest droplet size while providing adequate coverage at the intended application rate and pressure.

Keeping the above-mentioned views in consideration, the present study was conducted on cabbage variety Golden Acre with the objective Persistence of residual toxicity of Dichlorvos 76 EC, Malathion 50 EC and Quinalphos 25 EC under different droplet sizes against 2nd Instar larvae of cabbage butterfly *Pieris brassicae* Linn. and Estimation of relative efficacy of insecticide based on LT_{50} values.

Materials and methods

The study was carried out during the summer season of the year 2014 in the Acarology Laboratory of the Division of Entomology, SKUAST-Kashmir, Shalimar campus. The place is situated at an altitude of 1587 meter above from mean sea level between 34°08′ north latitude and 74°83′ East longitude. Three insecticides namely Dichlorvos 76 EC, Malathion 50EC and Quinalphos 25 EC was used in the present study. All the insecticides were used as emulsions. The formulations of insecticides was diluted with water to get the required concentrations and sprayed at three concentrations, one above, recommended and one below the recommended dosages. The three concentrations of insecticides were 0.1, 0.05 and 0.025% for Dichlorvos, 0.14, 0.07 and 0.035% for Malathion and 0.07, 0.035 and 0.0175% for Quinalphos.

These insecticides were sprayed on potted cabbage plants with foot sprayer to provide uniform coverage of the leaves with spray fluid. Each concentration of insecticide was sprayed with two different nozzles (hollow cone and full cone nozzle) with different volume median diameter. There were 20 treatments including control and each treatment replicated thrice. In control only water was sprayed with each nozzle. About 2-3 treated leaves was plucked from the potted plant and kept in petri plates 100 mm. diameter and about 15 larvae of cabbage butterfly were released at an interval of 1, 6 and subsequently every 24 hours after the treatment till the mortality was observed. Leaves from different treatment were collected daily (from 1st day to 15th day after). The insecticides sprayed leaves were then placed in thoroughly cleaned petri plates of diameter 100 mm then 15 number of 2nd Instar larvae of cabbage butterfly of nearly uniform age and size were placed in petri plates. The uncovered petri plate was covered with muslin cloth held in the position by rubber bands and kept in B.O.D. Incubator at 28±1 °C and 70% RH, for assessment of residual toxic effect.

For evaluating the performance of these insecticides in the laboratory different concentration of various insecticides were used in the experimental study. Persistent residual toxicity was determined by the method of Sarup *et al.*, (1970) [20]. The average persistent toxicity (T) were determined by adding the values of corrected percentage mortalities of each observation and dividing the total by the total number of observations. The persistent toxicity (PT) were calculated by multiplying the average toxicity (T) by the period for which the toxicity persisted. On the basis of persistent toxicity (PT) values, the order of relative efficacy of each treatment were determined. For comparing the residual toxicity of different insecticides (RRT) were worked out by taking the persistent toxicity (PT) value of least toxic insecticide as unity.

Relative efficacy of each insecticides based on LT_{50} and persistent toxicity (PT) values of each insecticide were determined. The data was subjected to probit analysis (Finney, 1972) [10] for determining the LT_{50} values. LT_{50} values were determined by transforming percentage larval mortalities to probits and plotting these against log transformed time values. Relative persistent and residual toxicity of each insecticide were determined as per Pradhan and Venkatraman (1962) [18] by taking the LT_{50} values of least toxic insecticide as unity.

Results and Discussion

Median Lethal Concentration (LC_{50})

The present studies revealed that LC_{50} value was significantly affected by spray with different types of nozzle. The observation was recorded by the spray of same insecticide with same concentration under various nozzles (Table-2) on cabbage plants and fed to 2nd instar larvae of *P. brassicae* (Linn.) and mortality was recorded after 24 hours. Data was subjected to probit analysis (Finney, 1972) [10] for calculation of LC_{50} values of different insecticides. Significantly maximum LC_{50} value (0.0862%) was recorded by the application of Malathion sprayed with full cone nozzle followed by the application of Malathion sprayed by hollow cone nozzle (0.0810%), and the lowest value (0.0372%) was recorded by application of Dichlorvos sprayed with hollow cone nozzle against 2nd Instar larvae of *P. brassicae* (Linn.).

Correlation analysis was applied to each insecticide with the provided amount of dose as below recommended, recommended and above recommended concentrations sprayed under different nozzles. In all the insecticides at different concentration the relationship between mortality and concentration was found positive (Table-1) and significant according to 95 percent confidence interval (p=0.05). It is clear that dose and mortality are correlated and significantly affected by nozzle type (Table-1).

Relative toxicity of various insecticides based on median lethal (LC_{50}) value was ordered as Dichlorvos > Quinalphos > Malathion. Malathion was proved to be least toxic followed by Quinalphos and Dichlorvos was highly toxic against 2nd Instar larvae of cabbage butterfly *P. brassicae* (Linn). The observations on the LC_{50} value of different insecticides was significantly affected by spray with different insecticides on cabbage plant and fed to 2nd instar larvae of *Pieris brassicae* (Linn). Significantly maximum LC_{50} value of 0.0862 percent was recorded in Malathion sprayed with full cone nozzle and lowest 0.0372 percent was recorded in Dichlorvos sprayed with hollow cone nozzle. This may be due to highest percent of mortality was observed in Dichlorvos under hollow cone nozzle as it produces less droplet sizes making the more surface area of the toxicant and hence more mortality. And it is clear from the data (Table-1, 2) Dichlorvos proved more toxic against 2nd instar larvae of cabbage butterfly, *Pieris brassicae* (Linn) than Quinalphos and Malathion. This result is in line with the result obtained from Saler and Saglam (2005) who reported lower LC_{50} value of Dichlorvos (DDVP) in water flea *Daphinia magna* (Stratus) verses time.

Median Lethal time (LT_{50})

LT_{50} was found significantly affected by spray with different types of insecticides at different concentration under different nozzles (Table-3). The observation was recorded on the basis of temporal response of 2nd instar larvae of *P. brassicae* (Linn.) exposed to different insecticide at different concentrations and mortality was recorded after every 24 hours and the data was subjected to probit analysis (Finney, 1972) [10] for calculation of LT_{50} values of each insecticides at each concentration under different nozzles. Significantly maximum LT_{50} (110.86 hours) was recorded by the treatment of Dichlorvos 76 EC @ 0.10% sprayed with hollow cone nozzle, followed by Dichlorvos 76 EC @ 0.10% sprayed with full cone nozzle (100.12 hours) and minimum (38.82 hours) was recorded after the treatment of Malathion 50EC @

0.035% sprayed with full cone nozzle.The reason for significantly maximum and minimum value of Dichlorvos and Malathion may be due to the droplet size produced by hollow cone nozzle which are high penetrating, more persistent and quality of spray was more uniform, and proved to be more effective as compared to full cone nozzle. This result is in accordance with who reported that for the application of insecticide in field crops hollow cone nozzle provide better foliage penetration and complete coverage of the leaf surface. The same observation gets support from the finding of Nair *et al* (2010) [16] who reported the LT_{50} value of quinalphos 25 EC was 2.437 days where as endosulfan 35% EC LT_{50} value was 5.313 days and and for cypermethrin 10% EC the LT_{50} value was 2.659 days against looper, *Hyposidra infixaria* (Walk.).

Persistent Toxicity (P.T)

Persistent toxicity was significantly affected by treatment of different insecticides with different concentration sprayed by various types of nozzle. The value of persistent toxicity was recorded highest (540.36) after the treatment of Dichlorvos 76 EC @ 0.10% sprayed by hollow cone nozzle (Table-4b) and 5.6% mortality was observed on 12th day after the treatment, followed by the treatment of Dichlorvos 76 EC @ 0.10% (517.00) and 5.1% mortality was seen on 12th day after the treatment sprayed by full cone nozzle (Table-4a), whereas the lowest value (154.00) was recorded by treatment of Malathion 50 EC @ 0.035% sprayed by full cone nozzle (Table-4a) and 6.1% mortality was seen on 5th day after the treatment. Since in the present study the value of persistent toxicity was recorded highest (540.36) in Dichlorvos 76 EC @ 0.10% sprayed by hollow cone nozzle (Table-4b) as 5.6 percent mortality was seen on 12th day after the treatment, followed by the treatment of Dichlorvos 76 EC @ 0.10% with persistent toxicity of 517.00 as 5.1 percent mortality was recorded on 12th day after the treatment sprayed by full cone nozzle (Table-4a), lowest value of persistent toxicity of 154.00 was recorded in Malathion 50% EC @ 0.035% sprayed by full cone nozzle (Table-4a) and 6.1 percent mortality was recorded on 5th day after the treatment. The persistent toxicity value was recorded highest in hollow cone nozzle treatment than full cone nozzle might be due to effective droplet size of insecticide and uniform coverage after the spray by hollow cone nozzle, were as due to larger droplet size produced by full cone nozzle there might be less amount of deposition and more run off and less uniformity in coverage proved less persistent. These results are in accordance with the result of Bandral (2007) [7] who reported that among the four insecticides namely Cypermethrin, Dimethoate, Malathion and Methyl demeton, significantly maximum persistent toxicity value was recorded in Dimethoate (821.25) and minimum persistent toxicity value was recorded in Malathion (140.42), due to higher concentration of insecticide, chemical nature and sensitivity against the neonate larvae of *P. brassicae*. Nishi *et al*. (2009) [17] also reported that among the three insecticides Endosulfan 0.07%, Dichlorvos 0.05% and Malathion 0.05% the value of persistent toxicity was recorded highest in Dichlorvos (297.60), followed by endosulfan (288.90) and lowest (184.29) in Malathion.

Relative residual toxicity (R.R.T)

The relative residual toxicity in case of hollow cone nozzle was recorded to be highest (3.31) in case of Dichlorvos 76 EC @ 0.10% by treatment with hollow cone nozzle (Table-4b), followed by Quinalphos 25 EC @ 0.07% (2.73) sprayed by hollow cone nozzle (Table-4b) and lowest (1) was recorded by treatment of Malathion 50 EC @ 0.035% sprayed by hollow cone nozzle (Table-4b).

This may be due to the relatively high toxic nature of dichlorvos, more mortality has been observed as compared to quinalphos and Malathion. The death rate of the larvae was more during initial days due to more concentration of insecticides during the early days, high mortality of early instars (Ahmad *et al.* 2007) [1].

Estimation of relative efficacy of insecticides based on LT_{50} values

In the present findings, the order of relative efficacy of each insecticide at three different doses against 2nd instar larvae of cabbage butterfly (*P. brassicae*) was recorded highest (1) in Dichlorvos 76 EC @ 0.10% sprayed by hollow cone nozzle (Table-4b), followed by Quinalphos 25 EC @ 0.07% and lowest (9) was recorded in Malathion 50 EC @ 0.035% sprayed by full cone nozzle (Table-4a). This may be due to the reason that the order of relative efficacy was based on RRT value and it was arranged in descending order. The highest RRT value (3.34) was ordered as 1 in Dichlorvos and lowest RRT (1.00) was ordered as 9 in Malathion. These results are in accordance with the result of Bandral (2007) [7] who reported that among the four different insecticides viz. cypermethrin (0.01%), dimethoate (0.03%), malathion (0.05%) and methyl demeton (0.025%), the order of relative efficacy of malathion was found least (1.00). Comparison between the tested insecticides on the basis of relative efficacy against *P. brassicae* (Linn) shows that the most toxic insecticide by unit weight of active ingredient was dichlorvos, followed by pirimicarb, thiamethoxam, pirimiphos-methyl and least toxic was malathion (Tawfiq *et al*., 2010) [22].

Balakrishnan *et al.* (2003) [5] also reported the order of relative efficacy of insecticides, Dichlorovos 0.05% caused maximum larval mortality (99.2%) and was statistically on par with endosulfan 0.07%, quinalphos 0.035% and Malathion 0.05%.

Table 1: Relative toxicity of various insecticides based on LC_{50} values sprays under two different nozzles

Insecticide	Nozzle type	LC_{50} Value	Order of relative toxicity (ORE)
Malathion	Full cone	0.0862	1
Quinalphos	Full cone	0.0598	3
Dichlorvos	Full cone	0.0399	5
Malathion	Hollow cone	0.0810	2
Quinalphos	Hollow cone	0.0561	4
Dichlorvos	Hollow cone	0.0372	6

Table 2: Comparison of LC_{50} values of different insecticides under various nozzles

Insecticides	LC_{50} values of hollow cone nozzle					LC_{50} values of full cone nozzle				
	Lethal Conc.	C.I		r	$*_{\chi^2}$	Lethal Conc.	C.I		r	$*_{\chi^2}$
		Upper limit	Lower limit				Upper limit	Lower limit		
Dichlorvos	0.0372	0.0721	0.0252	0.962	6.52	0.0399	0.0821	0.0226	0.982	6.85
Quinalphos	0.0561	0.0626	0.0261	0.925	6.81	0.0598	0.0621	0.0126	0.921	6.93
Malathion	0.0810	0.1215	0.0625	0.972	6.81	0.0862	0.0921	0.0626	0.992	6.03

* = $_{\chi^2}$ (Data significantly homogenous at P = 0.05) C.I = Confidence interval at 95%

Table 3: Comparison of LT_{50} values of various insecticides at different concentrations under various nozzles

Insecticides	Conc. %	LT_{50} values of hollow cone nozzle						LT_{50} values of full cone nozzle					
		Hours	Days	C.I		r	$*_{\chi^2}$	Hours	Days	C.I		r	$*_{\chi^2}$
				Upper limit	Lower limit					Upper limit	Lower limit		

Insecticides	Dose (g a.i/ha)	Days after treatment													(P)	(T)	(PT)	(ORE)
		1	2	3	4	5	6	7	8	9	10	11	12	13				
Dichlorvos	250	90.6	78.8	52.6	30.5	20.6	10.5	5.0	-	-	-	-	-	-	7	41.22	288.54	6
	500	96.5	90.9	68.5	36.6	32.5	22.6	15.6	13.5	10.6	-	-	-	-	9	43.03	387.27	3
	1000	100	95.6	73.6	67.6	60.9	42.5	32.6	22.6	17.3	13.5	8.6	5.6	-	12	45.03	540.36	1
Quinalphos	175	82.5	50.3	31.5	19.4	8.6	5.1	-	-	-	-	-	-	-	6	32.90	197.40	8
	350	85.2	72.7	60.5	40.2	34.2	23.5	17.5	12.2	10.5	7.2	-	-	-	10	36.37	363.70	4
	700	100	80.5	61.3	53.3	40.2	32.5	24.5	20.1	15.6	11.5	6.5	-	-	11	40.54	445.94	2
Malathion	350	70.1	43.6	25.5	18.6	5.2	-	-	-	-	-	-	-	-	5	32.60	163.00	9
	700	88.3	67.6	41.5	30.6	24.5	14.6	10.5	7.5	-	-	-	-	-	8	35.63	285.04	7
	1400	87.6	69.4	58.1	49.5	38.6	20.1	18.3	9.1	5.6	-	-	-	-	9	39.58	356.22	5

Table 4a: Persistent toxicity of some insecticides at three different doses against 2nd instar larvae of cabbage butterfly *Pieris brassicae* (Linn.) at various intervals sprayed with full cone nozzle.

Insecticides	Dose (g a.i/ha)	Days after treatment													(P)	(T)	(PT)	(ORE)
		1	2	3	4	5	6	7	8	9	10	11	12	13				
Dichlorvos	250	83.6	69.5	52.1	31.6	25.2	14.5	8.6	-	-	-	-	-	-	7	40.72	285.04	6
	500	90.6	80.2	69.6	46.5	30.1	25.2	16.5	10.1	8.2	-	-	-	-	9	41.88	376.92	3
	1000	100	90.6	80.9	66.2	52.6	38.1	30.3	20.6	14.5	11.3	7.5	5.1	-	12	43.14	517.68	1
Quinalphos	175	81.5	50.1	30.2	18.4	6.5	5.2	-	-	-	-	-	-	-	6	31.98	191.88	8
	350	87.6	70.5	52.5	32.3	24.5	16.4	10.5	7.6	5.0	-	-	-	-	9	34.10	306.90	5
	700	100	78.6	59.5	50.1	39.1	31.5	22.2	19.5	14.3	10.1	5.2	-	-	11	39.10	430.10	2
Malathion	350	69.4	41.5	22.2	15.7	6.1	-	-	-	-	-	-	-	-	5	30.98	154.90	9
	700	86.6	64.2	39.6	28.8	22.5	12.5	9.6	6.1	-	-	-	-	-	8	33.75	270.00	7
	1400	86.6	66.2	56.1	48.2	36.5	19.1	16.5	8.2	5.5	-	-	-	-	9	38.10	342.90	4

Table 4b: Persistent toxicity of some insecticides at three different doses against 2nd instar larvae of cabbage butterfly *Pieris brassicae* (Linn.) at various intervals sprayed with hollow cone nozzle.

Insecticides	Dose (g a.i/ha)	Days after treatment													(P)	(T)	(PT)	(ORE)
		1	2	3	4	5	6	7	8	9	10	11	12	13				
Dichlorvos	250	90.6	78.8	52.6	30.5	20.6	10.5	5.0	-	-	-	-	-	-	7	41.22	288.54	6
	500	96.5	90.9	68.5	36.6	32.5	22.6	15.6	13.5	10.6	-	-	-	-	9	43.03	387.27	3
	1000	100	95.6	73.6	67.6	60.9	42.5	32.6	22.6	17.3	13.5	8.6	5.6	-	12	45.03	540.36	1
Quinalphos	175	82.5	50.3	31.5	19.4	8.6	5.1	-	-	-	-	-	-	-	6	32.90	197.40	8
	350	85.2	72.7	60.5	40.2	34.2	23.5	17.5	12.2	10.5	7.2	-	-	-	10	36.37	363.70	4
	700	100	80.5	61.3	53.3	40.2	32.5	24.5	20.1	15.6	11.5	6.5	-	-	11	40.54	445.94	2
Malathion	350	70.1	43.6	25.5	18.6	5.2	-	-	-	-	-	-	-	-	5	32.60	163.00	9
	700	88.3	67.6	41.5	30.6	24.5	14.6	10.5	7.5	-	-	-	-	-	8	35.63	285.04	7
	1400	87.6	69.4	58.1	49.5	38.6	20.1	18.3	9.1	5.6	-	-	-	-	9	39.58	356.22	5

P = Period for which toxicity was observed
T = Average residual toxicity
PT = Index of persistent toxicity
ORE = Order of relative efficacy based on PT values

Table 5: Relative efficacy of various insecticides at three different doses against 2nd instar larvae of cabbage butterfly *Pieris brassicae* (Linn.) at various intervals sprayed with hollow cone nozzle

Insecticides	Dose (g a.i/ha)	Persistent toxicity (PT)	RRT	Order of relative residual toxicity in descending order
Dichlorvos	250	288.54	1.77	6
	500	387.27	2.37	3
	1000	540.36	3.31	1
Quinalphos	175	197.40	1.21	8
	350	363.70	2.23	4
	700	445.94	2.73	2
Malathion	350	163.00	1.00	9
	700	285.04	1.74	7
	1400	356.22	2.18	5

RRT = Relative residual toxicity

Table 6: Relative efficacy of various Insecticides at three different doses against 2nd instar larvae of *Pieris brassicae* (Linn.) sprayed with full cone nozzles

Insecticides	Dose (g a.i/ha)	Persistent toxicity	RRT based on (PT)	Order of relative residual toxicity in descending order
Dichlorvos	250	285.04	1.84	6
	500	376.92	2.43	3
	1000	517.68	3.34	1
Quinalphos	175	191.88	1.23	8
	350	306.90	1.98	5
	700	430.10	2.77	2
Malathion	350	154.90	1.00	9
	700	270.00	1.74	7
	1400	342.90	2.21	4

RRT= Relative residual toxicity

Conclusion

It was concluded that among the three insecticides at different concentrations the best performance is observed in Dichlorvos 76 EC at the concentration of 0.10% for the effective control of 2nd instar larvae of *Pieris brassicae* (Linn.). Malathion proved to be safe for consumption due to lowest waiting period than Quinalphos and Dichlorovos.

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