Journal of Entomology and Zoology Studies
Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(1): 270-277

Received: 15-11-2018
Accepted: 20-12-2018

Fouzia Bari
Uttar Banga Krishi Vishwavidyalaya, Pundibari, Cooch Behar, West Bengal, India

Malik Mukhtar Ahmad
Sher-e- Kashmir University of agricultural science and technology, Shalimar, Kashmir, Jammu and Kashmir, India

Asma Sherwani
Sher-e- Kashmir University of Agricultural Science and Technology, Shalimar, Kashmir, Jammu and Kashmir, India

Ashraf Alam Wani
Sher-e- Kashmir University of Agricultural Science and Technology, Shalimar, Kashmir, Jammu and Kashmir, India

Correspondence
Fouzia Bari
Uttar Banga Krishi Vishwavidyalaya, Pundibari, Cooch Behar, West Bengal, India

Determining the influence of nozzle on droplet spectrum and pesticide deposition in cabbage against *Pieris brassicae* (Linn.)

Fouzia Bari, Malik Mukhtar Ahmad, Asma Sherwani and Ashraf Alam Wani

Abstract
Droplet size is the diameter of an individual spray droplet. Nozzles are specially designed to make the liquid into fine droplets. The present experiment entitled "Determining the influence of nozzle on droplet spectrum and pesticide deposition in cabbage against *Pieris brassicae* (Linn.)" was undertaken at RCRQA (Research centre for residue and quality analysis) Laboratory of the Division of Entomology, Shalimar during the year 2014-15. In this experiment effectiveness of different sizes of droplets produced by hollow cone nozzle and full cone nozzle in controlling cabbage butterfly was evaluated keeping in view the pesticide deposition and droplet spectrum of insecticides produced by nozzles. 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 were calculated and compared. It was found that Volume Median Diameter produced by hollow cone nozzle was smaller than the full cone nozzle. Hollow cone nozzle produced uniform spectra of droplets as is evident from the relative span and ratio between VMD and NMD of 1.38 and 1.25 as compared to full cone 1.47 and 1.60. Among all the treatment best result was observed in hollow cone nozzle.

Keywords: toxicity, drift, droplet spectrum, cabbage butterfly, residual, pesticide, relative span factor

Introduction

Nozzles determine the amount of spray volume at a given operating pressure, travel speed, and spacing. The proper selection of a nozzle type and size is essential for proper pesticide application. Nozzle is a major factor in determining the amount of spray applied to an area, the uniformity of application, the coverage obtained on the target surface, and the amount of potential drift. Minimizing drift is especially important for pesticides as well as herbicides (Miller, 1999) [14]. Drift can be minimized by selecting nozzles that produce the largest droplet size while providing adequate coverage at the intended application rate and pressure (Klein, 2011) [11]. Nozzles break the liquid into droplets, form the spray pattern, and propel the droplets in the proper direction. The size of the spray particle is important because it affects both efficacy and spray drift of the application of an herbicide, insecticide, or fungicide. If the size of the spray particle (for example, 250–500 microns) is doubled and the application volume stays the same, you have only one-eighth as many spray droplets to gain optimum efficacy in weed control, a 10–20 gallons per acre (GPA) spray volume is typically recommended, with a "medium" droplet size suggested for contact non translocating herbicides, and a "coarse" droplet size suggested for contact translocating herbicides. Concern for drift may cause larger droplet sizes and higher spray volumes. Even though spray nozzles are a physically small component in overall operation, they are vitally important. However, many users perceive spray nozzles as fairly simple components, when in fact it is quite the opposite. There are dozens of nozzle types from various manufacturers that offer very different performance. A nozzle's spray pattern is made up of many droplets of varying sizes. Droplet size is the diameter of an individual spray droplet. Droplet sizes are measured in microns (micrometers). One micron equals 0.001 mm. The most reliable droplet size data will conform to the British Crop Protection Council (BCPC) standard in accordance with the American Society of Agricultural Engineers (ASAE) standard. This standard provides strict conditions for spray droplet measurement and eliminates interpretation differences when comparing statistical data among different types of laser measuring equipment (Greg, 2011) [10].

Cabbage and cauliflower are widely grown as vegetables crops. These crops are attacked by a number of insect pests, the cabbage butterfly, *Pieris brassicae* is one of the limiting factor for the successful cultivation of Cole crops. *Pieris brassicae* (Linn.) (Lepidoptera: Pieridae), is a pest of kale, cabbage, cauliflower and other Cole crops distributed all over the regions of the world (Feltwell, 1978) [7]. In Indian subcontinent, it is distributed along Himalayan region including Pakistan, Nepal and throughout the plains except southern states of India (Lal and Ram, 2004; Younas *et al.*, 2004) [12, 19]. The losses caused by *Pieris brassicae* is more than 50 per cent in Kashmir (Bhat, 2008). Insecticide application against the larval stage is the primary method of control of *Pieris brassicae* (Linn.), but high tolerance to most insecticides and associated environmental problems may jeopardize their continued use (Grisakova *et al*., 2006) [6]. Long-term use of broad-spectrum pesticides may result in outbreaks of insect pests by destruction of their natural enemies. Frequent uses of insecticides have led to the development of resistance in many species of insect pests and also have negative effects on the survival and adaptation of natural enemies (Hossain and Poehling, 2006) [8]. Keeping the above mentioned views in consideration, the present study entitled "Determining the influence of nozzle on droplet spectrum and pesticide deposition in cabbage against *Pieris brassicae* (Linn.)" was planned with the following objectives:

- Assessments of volume median diameter (VMD) and number median diameter (NMD) of droplets produced by hollow cone and full cone nozzle at constant pressure by slide wave techniques.
- Establishment of volume median diameter (VMD) and number median diameter (NMD) of droplets produced by hollow cone and full cone nozzles at constant pressure.
- Comparative effect of hollow cone nozzle and full cone nozzle on relative efficacy of insecticides based on LT50 and LC50 values.

2. Materials and Methods

The studies were carried out during the year 2014 and 2015 in the RCRQA (Research centre for residue and quality analysis) 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.

The cabbage variety was Golden Acre, which had been raised through standard package of practices. 2nd instar larvae of cabbage butterfly, *Pieris brassicae* (Linn.) was used in present study. Three insecticides namely Dichlorvos 76 EC, Malathion 50EC and Quinalphos 25 EC were used at concentrations of 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. Each concentration of insecticide were sprayed with two different nozzles (hollow cone and full cone nozzle). 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 hour after the treatment till the mortality was observed. Mortality of larvae was recorded after every 24 hour and moribund larvae were treated as dead. The mortality data was corrected by Abbott's (1925) formula:

$$\frac{\text{Percent mortality in treated} - \text{Percent mortality in control}}{100 - \text{Control}} \quad 100$$

2.1 Assessment of VMD & NMD produced by hollow cone and full cone nozzle at constant pressure by slide wave technique.

For the assessment of VMD & NMD glass microscope slides (2.5 x 7.5 cm) were used. This has been done by waving the slide attached to a meter long stick by a clip once through a cloud of droplets produced through both the hollow as well as full cone nozzles by commencing at a distance of 2 meter from the release point.

There were two treatments and in each treatment 10 separate slides were used. HMO was added to the water used for the assessment of droplets at the rate of 2.0% (20 ml/ liter) to increase viscosity as viscosity and surface tension can affect the formation of droplets. Relative Span Factor (RSF) has been also calculated between the two nozzles.

After the samples of droplets were collected on the slide, it was examined under the fluorescence microscope (OLYMPUS-BX43, OLYMPUS Corporation, Tokyo, Japan), with the camera to project the specimen image onto computer (Think Centre Edge 62z, Lenovo Group Ltd., Beijing, China).The software used for the measurement of each droplet diameter was Q-Capture Pro-7 (Q-Imaging, Surrey, Canada) and fluorescence microscope was adjusted with 4x to measure the droplets. This software works after capturing of the objects photograph. It automatically measures the length of the object by fixing the two ends. The diameter of each droplet on the glass slide was measured in horizontal and vertical direction in Pico meter (10^{-12} meter). Then the measurement was converted into micro meter (10^{-6} meter) by the software (Q-capture Pro-7). The average of both diameter in horizontal and vertical direction was taken as the mean diameter of the droplets. Maximum number of droplets was measured from each slide. All the droplets from one edge of the slide to the other is counted and measured as the slide moves across the field of microscope.

2.2 Calculation of VMD & NMD as per Mathews (1975)

The total numbers of droplets on the slides were counted and their radius was measured (dm). The percentage of number of droplets (% N) was determined and their cumulative percentages (Σ% N) were worked out. The volume of the droplets were ascertained by 4/3 πr^3 (dm^3) and multiplied by the number of droplets (N dm^3). These figures were expressed as percentages (%N dm^3) of the total volume of the sample and the cumulative percentages (Σ% N dm^3) plotted on the same graph. The VMD and NMD was read at 50% intercept and DV 0.10 and DV 0.90 were read at 10 and 90% intersect on the same graph respectively.

Volume median diameter (VMD) or DV 0.5

Most sprays have a range of droplet sizes. The most frequently used measurements is the volume median diameter (VMD) expressed in micrometers (μm). This is the number that divides the spray into two equal parts by volume, one half containing droplets, smaller than this diameter the other half containing droplets larger than this diameter.

Number median diameter (NMD) or DN 0.5

Another measurement is the number median diameter NMD, which is the value that divides the spray into two equal parts by number of droplet, so that half the droplets are smaller and half larger. Both are important as optimum NMD improve spray efficiency while as ideal VMD decreased drift of sprays**.**

Dv 0.9 value
This indicates that 90% of the volume of spray is in droplets smaller or equal and 10% larger than this value. If the value of Dv 0.9 is large too much of the volume of spray may be taken up in a few large droplets. Spray coverage and efficiency may be reduced as there would not be enough droplets to cover all treated surfaces.

Dv 0.1 value
This indicates that 10% of the volume of spray is in droplet smaller or equal and 90% larger than this value. If the value of Dv 0.1 is large then there are droplets in spray that are prone to drift.

Relative span factor (RSF)
The relative span factor (RSF) reduces the distribution of spray spectrum to one number. This parameter indicates the unity of drop size distribution. The closer this number to one, more uniform the spray will be:

$$RSF = \frac{Dv\ 0.9 - Dv\ 0.1}{Dv\ 0.5}$$

2.3 Estimation of relative efficacy of different insecticide based on LT_{50} and LC_{50}values.
Relative efficacy of each insecticide based on LT_{50} and persistent toxicity (PT) values of each insecticide were determined. The data was subjected to Probit analysis (Finney, 1972) 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) [17] by taking the LT_{50} values of least toxic insecticide as unity.

3. Result and Discussion
3.1 Volume median diameter (VMD)
The volume median diameter (Dv 0.5) of droplets produced by spray of different type nozzle at flow rate of 2 lit/min from a distance of 2 meter at constant pressure were recorded larger (59 µm) in full cone nozzle (Table-3) were as smaller (50 µm) in case of hollow cone nozzle (Table-2, Fig.2).The value of Dv 0.1 was recorded higher (21 µm) in case of hollow cone nozzle (Table-2) and lower (10 µm) in full cone nozzle (Table-3). The value of Dv 0.9 was recorded higher (97 µm) in case of full cone nozzle (Table-3) and lower (90 µm) in hollow cone nozzle (Table-2). These results are in accordance with the result obtained by Jonnes (2006) [9] in pesticide application in forest by the use of knapsack sprayer, who reported that small droplets were produced by hollow cone nozzle as compared to full cone nozzle. Hollow cone consists of a swirl plate surrounded by a swirl core with the swirl chamber between the two (Fig.5). Liquid passes through the spiral slots in the swirl core, and into the swirl chamber where it acquires a high rotational velocity and high pressure, discharging from the nozzle in a hollow cone spray pattern. This nozzle is widely used with knapsack sprayers; the fine droplets ensure that it is very suitable for foliar application of insecticides and fungicides. In the full cone the swirl plate has a centrally drilled hole where it acquires comparatively less rotational velocity and less pressure, discharging from the nozzle to create the full cone effect (Fig.6).

3.2 Number median diameter (NMD)
The number median diameter of droplets produced by spray of different type of nozzle at flow rate of 2 lit/min from a distance of 2 meter at constant pressure was recorded larger (40 µm) in hollow cone nozzle (Table-2, Fig. 1) and smaller (37 µm) in full cone nozzle (Table-3, Fig. 4). The value of number median diameter (NMD) of droplets was recorded larger (40 µm) in hollow cone nozzle (Table-2, Fig. 2) and smaller (37µm) in full cone nozzle (Table-3, Fig. 3). These results are in accordance with Ashraf and Safwat (2013) [1] who reported a theoretical model for predicting the mean droplet diameter in Spray based on the linear Stability Model and after analysis it was found that number median diameter of droplets varies from nozzle to nozzle and more was measured in hollow cone nozzle as compare to full cone nozzle. These results are in accordance with the result obtained by Jonnes (2006) [9] in pesticide application in forest by the use of knapsack sprayer, who reported that the number median diameter of droplets produced by hollow cone nozzle were large as compare to full cone nozzle.

3.3 Relative span factor (RSF)
The relative span factor of droplet spectra was recorded (Table-1) higher (1.47) in full cone nozzle as there was much variation among the droplet produced by full cone nozzle and lower (1.38) in hollow cone nozzle, due to less variations among the droplets produced by hollow cone nozzle This result is in accordance with Nissaichareon (2005) [15] who reported that relative span factor (RSF) value provides a direct indication of the range of drop sizes relative to the volume median diameter (VMD). RSF is indicative term of the uniformity of the drop size distribution. The closer this number is to one, the more uniform the spray will be.

3.4 Ratio (R)
The ratio of droplet size between the values of VMD and NMD by various nozzle was recorded (Table-1) higher (1.60) in case of full cone nozzle as there was more variation observed between the sizes of droplets in spray spectrum, were as lower (1.25) value recorded in hollow cone nozzle as there was less variation observed between the sizes of droplets in spray spectrum. The less value shows that there is less variation and more homogeneity is observed among the droplets produced by hollow cone nozzle and more value shows the more variation and less homogeneity among the droplets produced by full cone nozzle. Nuyttens *et al.* (2009) [16] also reported that ratio of VMD and NMD was found more in full cone nozzle and less in hollow cone nozzle. This is due to differences in droplet size characteristics, as the proportion of small droplets diameter is less for high drift nozzle (hollow cone nozzle) as compared with low-drift nozzles (full cone nozzle).
The result are in line with Dobson and King (1996) [4] who reported that ratio of VMD and NMD of droplets among the various nozzles, and found that highest ratio (1.9) was observed in full cone nozzle and lowest ratio (1.5) in hollow cone nozzle, he also reported that ratio gives a measure of the homogeneity of the droplet spectrum, the nearer it is to 1.0, the more uniform the droplet sizes.

Table 1: Comparison of droplet size spectra between hollow cone and full cone nozzle

Nozzle	VMD (µm) Dv0.5	NMD (µm)	Droplet volume 0.90 (µm) Dv 0.9	Droplet volume 0.10 (µm) Dv 0.1	Relative span =	Dv 0.9-Dv 0.1	Ratio =	VMD
						Dv 0.5		NMD
Hollow cone	50	40	90	21	1.38 =	90-21	1.25 =	50
						50		40
Full cone	59	37	97	10	1.47 =	97-10	1.60 =	59
						59		37

3.5 Comparative effect of hollow cone and full cone nozzle on the relative efficacy of insecticides by based on LT50 and LC50 values

The relative efficacy of insecticides was found to be significantly affected by RRT values and LT_{50}. In the present findings the order of relative efficacy of each insecticides 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-4), followed by Quinalphos 25 EC @ 0.07% and lowest (9) was recorded in Malathion 50 EC @ 0.035% sprayed by full cone nozzle (Table-5). 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 Bandran (2007) [3] 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) [18].
Balakrishnan *et al.* (2003) [2] 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%. The order of relative efficacy of Dichlorovos 0.05% was found to be maximum (1.00) followed by Endosulfan 0.07% was 2.00 and lowest was recorded in Malathion (4.00).

Table 2: Droplet size spectrum for calculation of volume median diameter (VMD) and number median diameter (NMD) of hollow cone nozzle at flow rate of 2 lit/min from a distance of 2 meter (As per Matthews, 1975)

No. of droplets (N)	Mean radius of droplets in (µm) (dm)	% N	∑ %N	Volume of droplets (4/3л r^3) (dm^3)	N dm^3	% N dm^3	∑ % N dm^3	VMD Dv0.5	NMD	Dv0.9	Dv0.1
35	112	4.6	4.6	5884948	205973180	0.50	0.5				
37	124	4.9	9.5	7986447	295498539	0.72	1.22				
41	133	5.4	14.9	9854702	404042782	0.98	2.2				
54	154	7.2	22.1	15298567	826122618	2.0	4.2				
58	175	7.7	29.8	22449297	1302059226	3.1	7.3	50 µm	40 µm	90 µm	21 µm
65	198	8.6	38.4	32515031	2113477015	5.1	12.4				
70	221	9.3	47.7	45213219	3164925330	7.7	20.1				
98	243	13.1	60.8	60104561	5890246978	14.4	34.5				
140	267	18.7	79.5	79730115	11162216100	27.3	61.8				
150	291	20.0	99.5	103220884	15483132600	37.90	99.7				
Total =748					Total = 40847694368						

Table 3: Droplet size spectrum for calculation of volume median diameter (VMD) and number median diameter (NMD) of full cone nozzle at flow rate of 2 lit/min from a distance of 2 meter (As per Matthews, 1975)

No. of droplets (N)	Mean radius of droplets in (µm) (dm)	% N	∑ %N	Volume of droplets (4/3л r^3)(dm^3)	N dm^3	% N dm^3	∑ % N dm^3	VMD Dv0.5	NMD	Dv0.9	Dv0.1
15	166	2.5	2.5	19160766	287411490	0.32	0.32				
21	183	3.5	6.0	25670946	539089866	0.60	0.92				
24	204	4.0	10.0	35561421	853474104	0.95	1.87				
37	237	6.2	16.2	55761397	2063171689	2.3	4.1				
48	263	8.1	24.3	76200155	3657607440	4.1	8.2	59 µm	37 µm	97 µm	10 µm
62	285	10.5	34.8	96966828	6011943336	6.75	15.0				
68	317	11.5	46.3	133433966	9073509688	10.1	25.1				
81	344	13.7	60.0	170515529	13811757849	15.5	40.6				
112	365	18.9	78.9	203688824	22813148288	25.6	66.2				
122	388	20.6	99.5	244671726	29849950572	33.5	99.72				
Total = 590					Total = 88961064322						

Table 4: 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 5: 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

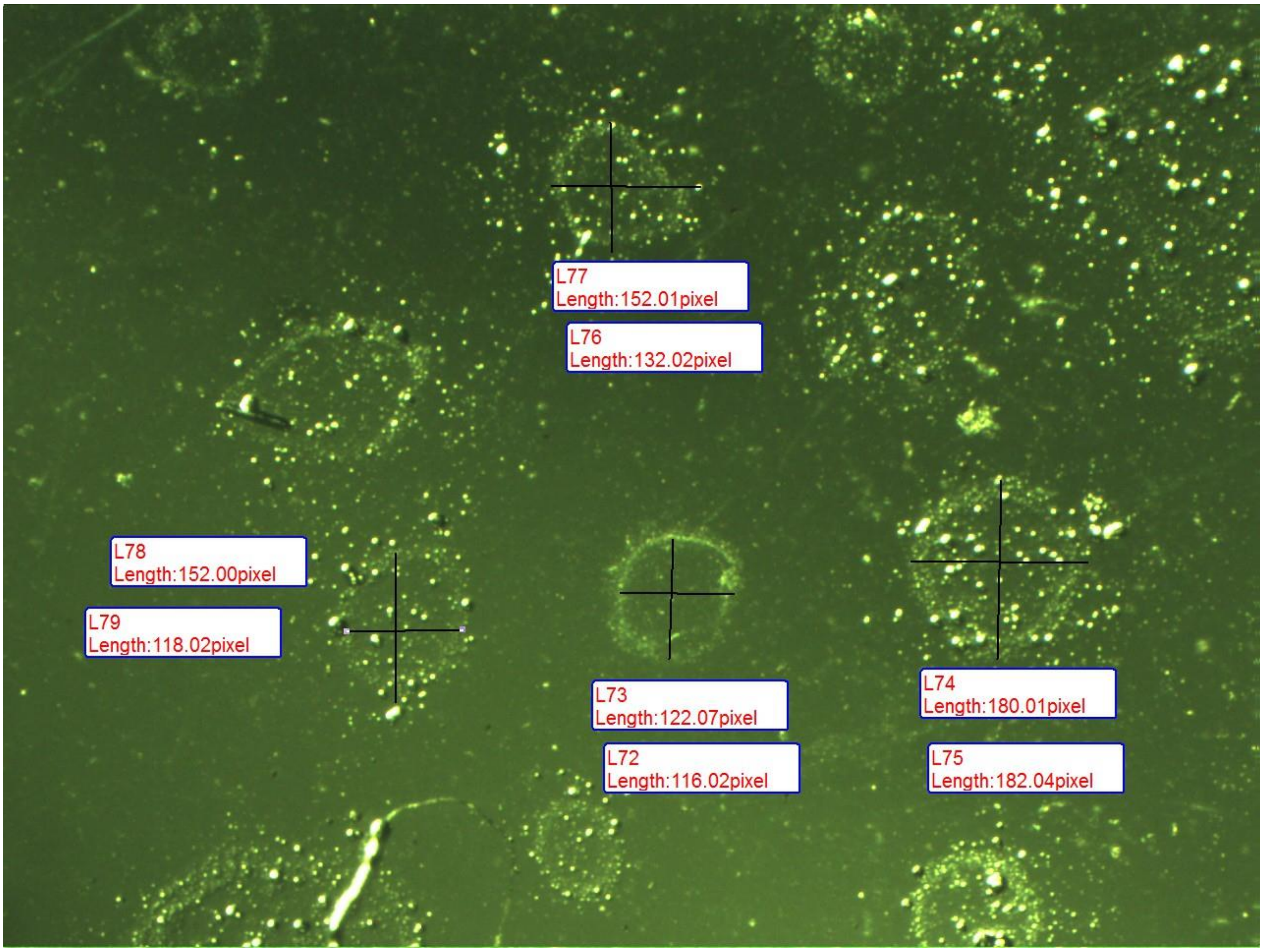

Fig 1

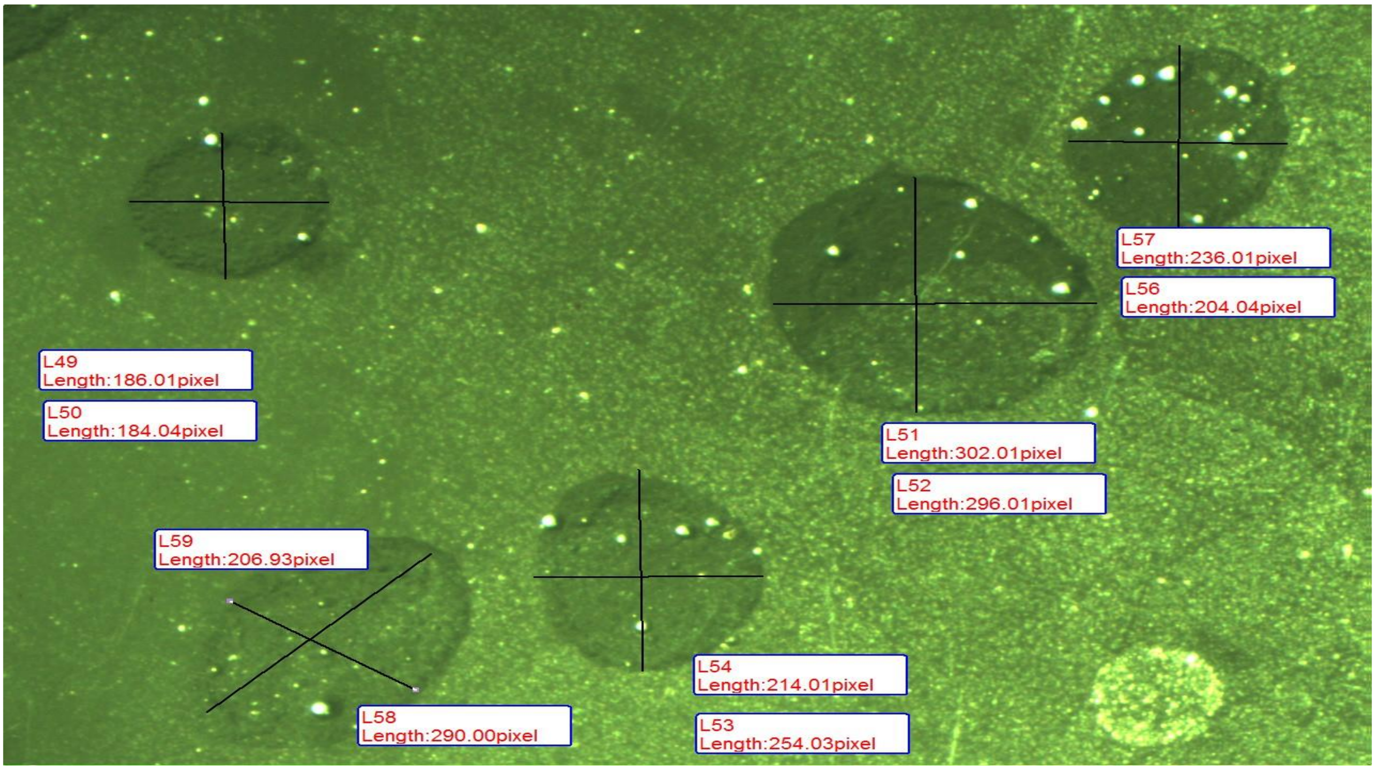

Fig 2

Fig 1, 2: Droplet pattern of hollow cone nozzle at a flow rate of 2lit/min

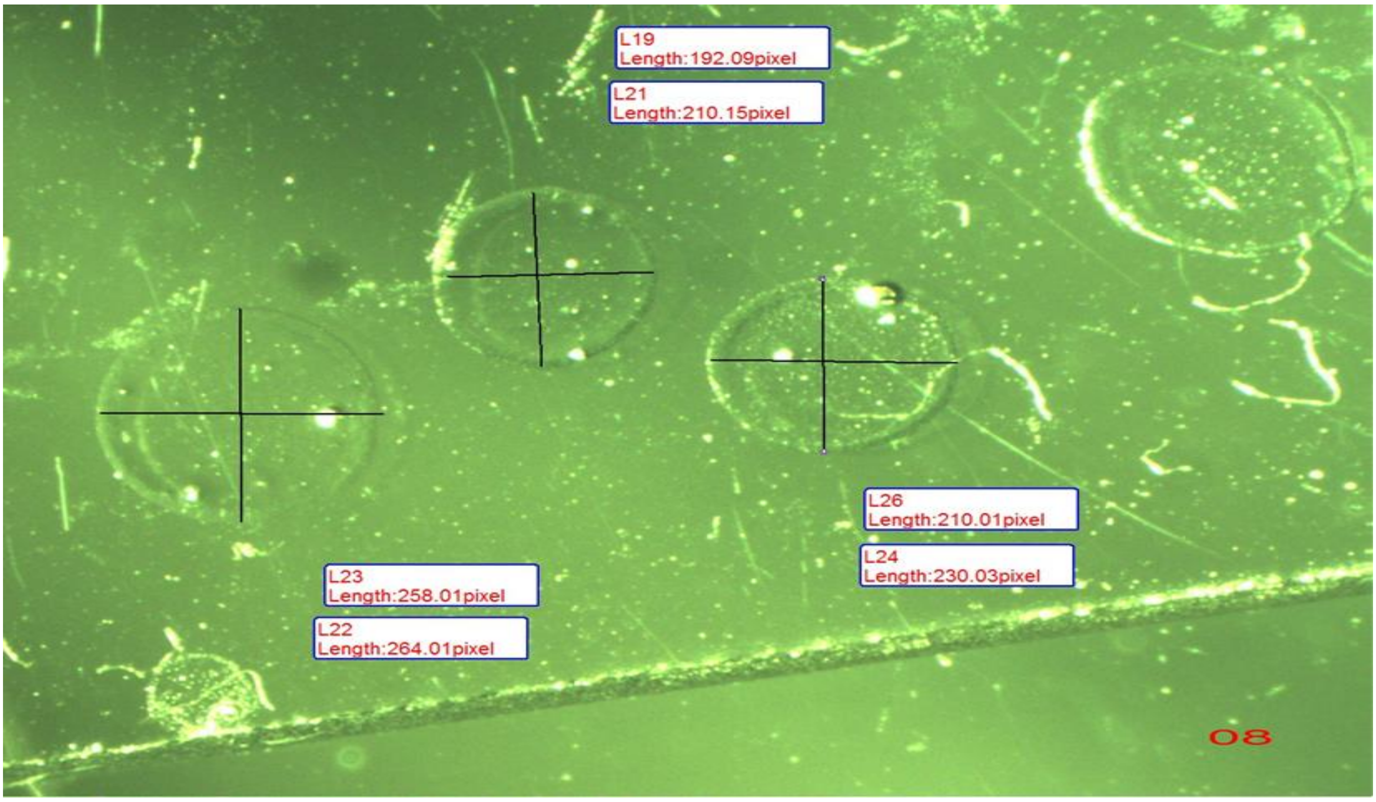

Fig 3

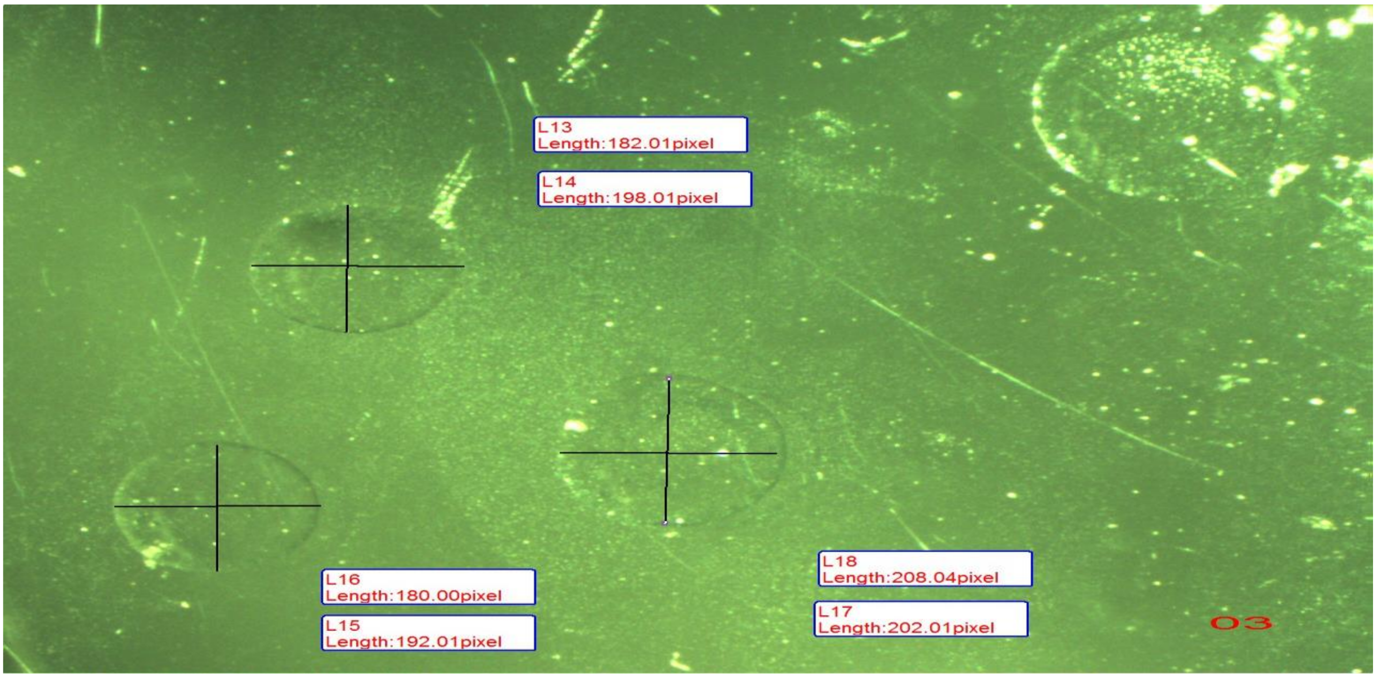

Fig 4

Fig 3, 4: Droplet pattern of full cone nozzle at a flow rate of 2lit/min

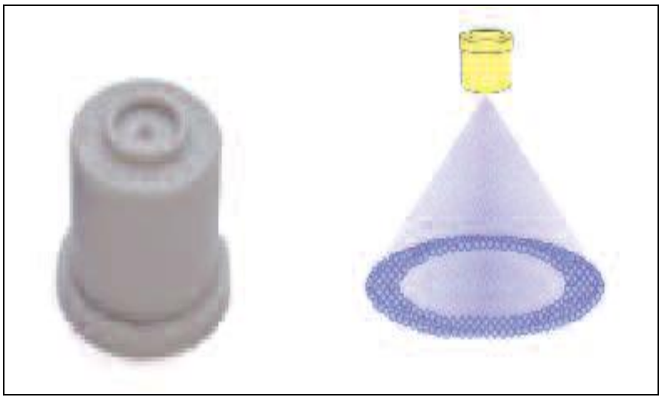

Fig 5: Hollow cone nozzle

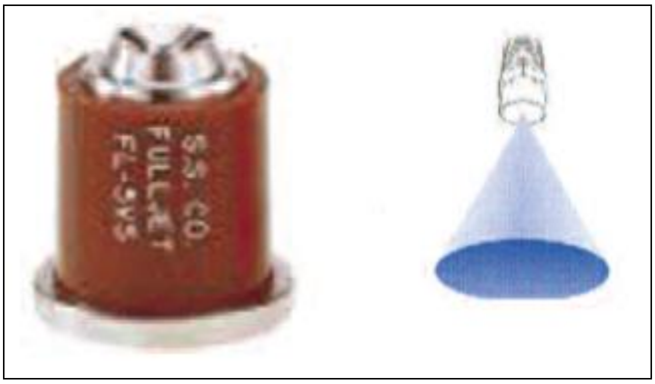

Fig 6: Full cone nozzle

Conclusion

Based on the experimental result it may be concluded that hollow cone nozzle performed better for the spray of insecticides as it provides uniform coverage with minimum losses due to drift and effective deposits to control cabbage butterfly *Pieris brassicae* (Linn.). Improper application of plant protection products can be extremely costly if re-spraying is required, performance is reduced or legal issues arise as a result of chemical drift. Hollow cone nozzle is better for spraying of insecticides as well as for full coverage and optimium flow rate is maintained in vegetable garden. 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.

References

1. Ashraf B, Safwat W. A theoretical model for predicting the mean droplet diameter in spray based on the linear stability analysis. International Journal of Control, Automation and Systems. 2013; 2(3):41-46.
2. Balakrishnan N, Subharatanam GV, Madhumathi T, Krishnayya PV. Relative toxicity of insecticides to cotton whitefly. Annals of Plant Protection Science. 2003; 11:377-378.
3. Bandran RS. Field-weathered toxicity of some insecticides to larvae of *Pieris brassicae* (L.). Journal of Research, SKUAST-J. 2007; 6(2):281-284.
4. Dobson HM, King W. Pesticide application mastering and monitoring. Natural resources Institute, University of Greenwich at Medway, Central Avenue, 1996.
5. Finney DJ. Probit Analysis. London, Cambridge University Press. 1972, 324.
6. Grisakova M, Metspaler L, Jogar, Hiie K, Kausik A, Poldma P. Effects of biopesticide Neem EC on the Large White Butterfly, *Pieris brassicae* L. (Lepidoptera. Pieridae). Agronomy Research. 2006; 4:181-186.
7. Feltwell J. The depredations of the large white butterfly (*Pieris brassicae*) (Pieridae). The journal of Research on the Lepidoptera. 1978; 17:218-225.
8. Hossain MB, Poehling HM. Non target effects of three bio rationale Insecticides on two endo larval parasitoid of *Lariomyza sativa* (Diptera: Agromyzidae). Journal of Applied Entomology. 2006; 130:360-370.
9. Jonnes BJ. Selecting nozzle for hand held applicators. Technical notes. Journal of Forest Research. 2006; 8(1):1-12.
10. Greg RK, Permin LNO, Persson K. Deposition

characteristics and biological effectiveness of fungicides applied to winter wheat and the hazards of drift when using different types of hydraulic nozzles. State University Extension. Crop Protection. 2011; 11(6):541-546.
11. Klein R. Fine timing of spray with the "ounce" Callibration method. University of Nebraska-Lincoln Extension Neb Guide G, 2011.
12. Lal MN, Ram B. Cabbage butterfly (*Pieris brassicae* L.) an upcoming menace for Brassica oilseed crop in Northen India. Cruciferae News letter. 2004; 25:83-86.
13. Matthews GA. Determination of droplet size. Proceeding of National Academy of Science. 1975; 21(2):213-225.
14. Miller PCH. Factors influencing the risk of drift into field boundaries. In: Proceedings of British Crop Protection Conference on Weeds. Alton, U.K., British Crop Protection Council. 1999, 439-446.
15. Nissaichareon P. Drop size distributions of spray through nozzle at various working pressure. Master mechanical engineering. Thesis submitted to Graduate School Kasetsart University. ISBN 974-9833414, 2005.
16. Nuyttens D, De Schampheleire M, Baetens K, Sonck B. The influence of operator-controlled variables on spray drift from field crop sprayers. Trans. ASABE. 2009; 50(4):1129-1140.
17. Pradhan S, Venkatraman TV. Integration of chemical and biological control of *Chilo zonellus* (swinhoe) the stalk borer of maize and Jower. Bulletin of the National Institute of Science in India 1962; 19:119-125.
18. Tawfiq M, Al-Antary, Ateyyat MA, Abussamin BM, Toxicity of Certain Insecticides to the Parasitoid *Diaeretiella rapae* (Mcintosh) (Hymenoptera: Aphidiidae) and its host, the cabbage Aphid *Brevicoryne brassicae* L. (Homoptera: Aphididae). Australian Journal of Basic and Applied Sciences. 2010; 4(6):994-1000.
19. Younas M, Naeem M, Rquib A, Masud S. Population dynamics of *Pieris brassicae* on five cauliflowers at Peshawar. Asian Journal of Plant Science. 2004; 3:391-393.