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Effect of different pesticide application techniques on distribution, spray drift and lost on soil

Elsanusi, O.G [a,*], Zaalouk, A.K. [b], Werpy, R.A.A. [b], Ammar, A.E. [c]

[a] Graduate Student of Agricultural Machinery and Power Engineering Department, Faculty of Agricultural Engineering, Al-Azhar University, Cairo, Egypt.

[b] Agricultural Machinery and Power Engineering Department, Faculty of Agricultural Engineering, Al-Azhar University, Cairo, Egypt.

[c] Plant Protection Research Institute, Agricultural Research Center (ARC), Doki, Giza, Egypt.

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ABSTRACT

This research aims to evaluate the effect of different pesticide application techniques on vertical distribution of the droplets on the plant leaves eggplant plants, drift outside treatment and Lost spray on soil during spraying. The following are the techniques for applying the pesticides were used: Centrifugal Atomization Technique "CAT" (17.3 L/fed); Pressure or Hydraulic Atomization Technique "PHAT" (129.8 L/fed); Air Atomization Technique "AAT" (46.7 L/fed) and integrating Hydraulic with Air Atomization Technique "HAAT" (43.3 L/fed) with variable spraying rates, and with the use of two pesticides (Buprofezin and Fenpyroximate) for control pest spider mite *Tetranychus urticatae* koch on Eggplant leaves. The results showed that the highest spray spectrum deposit value on the lower surface of plant leaves ranged between 26 to 44 and 30 to 44 droplets/cm² and 63 to 95 and 72 to 95 µm for HAAT while, the lowest spray spectrum deposit value was on the lower surface of plant leaves ranged between 19 to 24 and 14 to 35 droplets/cm² and 100 to 103 and 93 to 103 µm for PHAT for each Buprofezin and Fenpyroximate respectively. Also, the spraying with CAT gave less drift spray value outside treatment and lost spray on soil if compared with techniques used.

1. Introduction

Different types of sprayers can be used according to the growth of different types of crops as follows: Hand operated sprayer, Engine operated sprayer and Electric motor pump sprayer using electricity for charging battery (Narete and Waghmare, 2016). The Pesticide sprays aimed to maximize Pesticide efficacy and minimize their adverse effects. also, factors such as optimum droplet size for killing, number of droplets per unit area might be optimized (Sundaram et al., 1985). Droplet size is one of the greatest factors that affects spray drift of pesticides (Bird et al., 1996). Spray drift affects not only water pollution and the environment but also adjacent sensitive areas, such as schools and natural parks, and bystanders (Ellis et al., 2014). May be negative impact if spray consisting of large droplet fall on the soil in the target area or small droplet drifting on to neighboring crops (Ali et al., 2011). The air-assisted spraying improved the penetration of the spray solution into the plants and led to better distribution on the upper and lower surface of the leaves. Air assistance could be added to the electrostatic spraying to further improve spray deposition (Cerqueira et al., 2017).

The insecticide effect of droplets sprayed is dependent on spectrum droplets (Palti and Ausher, 1986). They found that deposition on plant surfaces was also found to be more than 13.4% with release height at 40 cm to 60 cm and wind speed less than 4 m/s. For controlling flying pests, airborne deposit can increase chemical's spread on its body, so smaller volume medium diameter (VMD) was more effective (Zhang et al., 2017). Bigger droplets have higher kinetic energy than smaller ones, they penetrate more through the internal portions of cotton plant. The author noticed that a greater

* Corresponding authors.
E-mail addresses: omargad365@gmail.com (Elsanusi, O.G)

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number of small droplets were affected by air currents (Shazly, 1985).

Drift occurs by two methods: vapor drift and particle drift. Particle drift is the actual movement of spray particles away from the target area at or near the time of application . Many factors affect this type of drift, but the most important is initial droplet size. Small droplets decelerate quicker than large droplets and fall through the air slowly, making them more likely to be carried farther by air movement (Greg et al., 2019). The performance of pest control depends on the proper choice of suitable technique to use for spraying.

The aim of this study was to determine the effect of different pesticide application techniques on distribution, spray drift and loss on soil.

2. Materials and methods

The main experiments were carried out during the agricultural seasons of 2020/2021, 2021/2022 at the New Salheia, ElSharkia Governorate**.**

2.1. Materials

2.1.1. Eggplant crop

The variety (*Tamara*) was used in this study for manual planting, planted in ridges. The distance between ridges was 100 cm and the distance between the plants in row was 40cm. The plant is upright, branching, and the plant height ranges between 70 – 80 cm.

2.1.2. Field layout

The experiments were carried out in a square shape area about 1.2 feddan. The experiment area divided into eight plots area of plot 350 m² (10m in width and 35m in length), and five meters were left between each plot (treatment) for measure the drift spray. Also, left area between each pesticide and the other (6m in width and 75m in length).

2.1.3. Pesticide used

a) Buprofezin: Buprolord 25% SC (Suspension Concentrate) with recommended rate 400cm³/fed.
b) Fenpyroximate: Ortus Super 5% EC (Emulsifiable Concentrate) with recommended rate 50 cm³ /100 L (200cm³/fed) of water, **(APC, 2021).**

2.1.4. Sprayers techniques used

The difference of spraying techniques. In addition to integrating hydraulic with air atomization techniques. Following are the techniques for application of spray:

a) Centrifugal Atomization Technique (CAT),
b) Pressure or Hydraulic Atomization Technique (PHAT),
c) Air Atomization Technique (AAT),
d) Hydraulic with Air Atomization Technique (HAAT).

2.1.5. Weather conditions

Weather conditions (temperature, relative humidity and wind speed) during spray on the basis that wind speed, relative humidity and air temperature were ranged between (2 to 3 m/sec), (61 to 68%) and (17 to 22°C) respectively during the agricultural seasons of 2021, 2022.

2.1.6. Technical data

Table 1 show data of spraying volume at different pesticide application techniques.

Table 1.

Spraying volume at different pesticide application techniques

Item	CAT	PHAT	AAT	HAAT
Swath width, (m)	1.00	1.00	5.00	3.00
Working speed, (km/h)	2.4	2.4	2.4	2.4
Flow rate, (l/min.)	0.165	1.236	2.226	1.236
Height of nozzle respect to the plant, (m)	0.50			
Rate of application, (l/fed.)	17.3	129.8	46.7	43.3

2.2. Methods

2.2.1. Distribution of the spray on Eggplant plants

The distribution and homogeneity of Buprofezin and Fenpyroximate deposits on Eggplant leaves were investigated using water-sensitive papers (Ciba- Geigy, Switzerland). Water-sensitive paper was stuck to the upper and lower side of leaves on three vertical levels of Eggplant leaves for each plant. The sampling line consisted of five plants at a distance of one meter, in diagonal line inside each treatment to collected sprayer chemicals. Then the sensitive papers were collected carefully after allowing 1 h for spray to dry and scanned using Canon LiDE 400 scanner. Scanned images were subjected to deposit Scan free analytical software according to (Zhu *et al.,* 2011). The average volume median diameter (VMD or $D_{v0.5}$), and both $D_{v0.1}$ and $D_{v0.9}$ were estimated, also coverage of droplet deposits expressed as number of droplets (N) per cm^2, (Bateman, 1993).

Comparing differences, mean the main effect and independent factors interaction were analyzed throughout SPSS software version 19.

2.2.1.1. Homogeneity factor (HF)

Homogeneity factor is an indication of the droplet size range. As the HF tends to be 1, spray droplets tend to have the same size, which can only be generated from a uniform droplet generator (Matthews, 1975). This is not the case in real spraying machines. The smaller this ratio, the more uniform in size and the narrower in spectrum are the droplets (Kathirve et al., 2000)

The homogeneity factor, symmetric distribution, and spray bulk were calculated (Hanafi et al., 2016) according to as follows:

$$\mathrm{HF} = \mathrm{VMD}/\mathrm{NMD} \quad \text{... [1]}$$

where:

VMD: volume medium diameter, and
NMD: number medium diameter.

2.2.1.2. Spraying bulk and vertical distribution

The spraying bulk (SB) was calculated from Equation (Hanafi et al., 2016) as follows:

$$\mathrm{SB} = \mathrm{VMD} \times \mathrm{NMD} \quad \text{... [2]}$$

The percent of vertical distribution (VD) was calculated from Equation **(Hanafi et al., 2016)** as follows:

$$\mathrm{VD}\ \% = \mathrm{SB_i}/\mathrm{SB_t} \times 100 \quad \text{... [3]}$$

where:

SB_i: is the spray bulk at certain, and
SB_t: is the total spray bulk at all levels.

2.2.2. Drift spraying

Three sensitive cards were placed on a wire holder were fixed in (L) shape on the top wire holders in the distances 1, 2, and 3m outside the limits of each treatment to measure the drift spray lost by air of each Spraying techniques.

2.2.3. Lost spray on soil

Water sensitive paper was placed on the ground under five plants in order to estimate the spray deposited on the soil. illustrated the spray coverage on Plants and loses on land.

3. Results and discussions

3.1. Distribution of the spray on Eggplant leaves

Table 2 shows a comparative study of qualitative distribution of Buprofezin and Fenpyroximate of spray droplets on water sensitive paper, distribution throughout the treated field at different plant directs. The droplet density as number of droplets per square centimeter (N/cm^2) deposited on water sensitive paper (WSP) distributed at all treatments using different spraying techniques.

Results showed that in spray deposition (volume medium diameter VMD and number medium diameter NMD) was found between the top and the two lower levels (middle and bottom) and between upper and lower leaf surface within the plant for the tested spraying techniques.

Moreover, an uneven deposition could be detected throughout the different levels of the plants. The top level has apparently received the highest amount of deposits, while the middle level showed an apparent decrease in the spray deposits and the bottom level showed the lowest values.

Results showed that the spray was deposited on the upper surfaces of the leaves, while the lower surfaces received low levels of the spray deposits.

Moreover, an uneven detected throughout the different levels on the plant.

Data also, the register highest value of average volume medium diameter (VMD) was the upper surface of the leaves, while the lower surface of the leaves, register lowest value of average volume medium diameter (VMD) with all levels.

3.1.1. Droplets VMD and NMD

Droplet comparison between different spraying techniques. Table 2 represent the summary statistics of VMD and NMD as determined for the tested spraying techniques and conditions. All results are the average of all replicates and all specimens for each technique. The volume medium diameter (VMD) and number medium diameter (NMD) ranged from (41 to 192µm), (28 to 189µm) and (19 to 78 N/cm^2), (14 to 69 N/cm^2) for each Bubrofezin and Fenpyroximate respectively.

The uniformity of drop spectra is an important factor that affects the efficacy and the extent of losses due to drift from various spraying techniques. Therefore, terms that may be useful to study the droplets size-spectra from various spraying techniques are VMD and NMD.

Data also, showed that the highest value spray spectrum deposit on lower surfaces of the leaves plants ranged number droplet between (26 to 44 N/cm^2), (30 to 44 N/cm^2) and ranged volume droplet between (63 to 95 µm), (72 to 95 µm) at Hydraulic with Air Atomization Technique (HAAT) (43.3 L/fed), for each Bubrofezin and Fenpyroximate respectively, while that the lowest value spray spectrum deposit on lower surfaces on the leaves for plants ranged number droplet between (19 to

Table 2.

Droplets –size and number spectra from tested spraying technique

Plant level		Top				Middle				Bottom				Lost spray on ground	
		Upper		Lower		Upper		Lower		Upper		Lower			
Sprayer		VMD [(5)] (µm)	No/cm² [(6)]	VMD (µm)	No/cm²	VMD (µm)	No/cm²	VMD (µm)	No/cm²	VMD (µm)	No/cm²	VMD (µm)	No/cm²	VMD (µm)	No/cm²
Bubrofezin	HAAT [(1)]	100 ± 19	69 ± 8	95 ± 8	44 ± 6	104 ± 13	51 ± 11	91 ±6	39 ± 12	119 ± 17	50 ± 14	63 ± 14	26 ± 6	137	24
	AAT [(2)]	118 ± 28	58 ± 17	105 ± 38	39 ± 13	134 ± 26	47 ± 16	99 ±15	28 ± 10	157 ± 28	40 ± 14	89 ± 33	22 ± 15	154	21
	PHAT [(3)]	165 ± 23	39 ± 13	103 ± 12	24 ± 6	192 ± 19	30 ± 13	100 ±16	19 ± 5	191 ± 20	24 ± 4	99 ± 13	20 ± 7	218	23
	CAT [(4)]	88 ± 8	78 ± 14	76 ± 10	41 ± 12	93 ± 13	61 ± 17	77 ± 12	35 ± 5	99 ± 13	63 ± 9	41 ± 26	23 ± 3	105	13
Fenpyroximate	HAAT	105 ± 39	69 ± 12	84 ± 12	43 ± 14	111 ± 31	49 ± 10	95 ± 6	44 ± 16	112 ± 10	42 ± 13	72 ± 13	30 ± 7	122	25
	AAT	123 ± 29	67 ± 13	116 ± 41	40 ± 12	134 ± 26	47 ± 16	101 ± 22	35 ± 11	145 ± 32	39 ± 15	98 ± 19	25 ± 16	154	24
	PHAT	179 ± 32	41 ± 17	109 ± 26	32 ± 9	173 ± 23	30 ± 14	103 ± 30	35 ± 12	189 ± 20	24 ± 11	93 ± 44	14 ± 8	196	19
	CAT	85 ± 15	61 ± 15	79 ± 9	42 ±14	91 ± 8	58 ± 10	75 ± 13	39 ± 6	94 ± 16	55 ± 3	28 ± 10	20 ± 4	109	18

(1) HAAT: Hydraulic with Air Atomization Technique,
(2) AAT: Air Atomization Technique,
(3) PHAT: Pressure or Hydraulic Atomization Technique,
(4) CAT: Centrifugal Atomization Technique,
(5) VMD: volume mean diameter, and
(6) No/cm²: Number of droplets/cm².

24 N/cm²), (14 to 35 N/cm²) and ranged volume droplet between (100 to 103 µm), (93 to 103 µm) at Hydraulic or Pressure Atomization Technique (PHAT) (129.8 L/fed), for each Bubrofezin and Fenpyroximate respectively. The obtained results confirmed the positive relationship between spraying volume and droplet size.

These results agree with (Mathews 1992) indicated that most use of controlling droplet application has been for insecticide application with droplet size in range of 50 -150 µm. According to Gabir (1975) the optimum spectrum of droplet for controlling piercing-sucking insects of field crop be sized between 25-100µm (VMD) with number not less than 20 droplets/cm² distributed homogenously on the treated target.

General recommendations include smaller droplet size for increased coverage and performance, with agree Knoche (1994).

In this study, the airstreams enhanced spray deposition on the underside of leaves. Also, Air Atomization Technique (AAT) and HAAT improved the average deposit of lower leaf surfaces at two pesticides with agree Gan-Mor et al. (1996); Cerqueira et al. (2017). The air-assisted sprayers offered better coverage than the other sprayers on the undersides of leaves and good coverage on the topsides (Sumner and Herzog 2000).

3.1.2. Spray coverage on Eggplant plants

3.1.2.1. Homogeneity factor (HF)

Results in Table 3 reveal that CAT, HAAT, AAT, and PHAT showed satisfactory average homogeneity factors of (1.6 and 1.6), (2.1 and 1.7), (3.1 and 3) and (5.5 and 5.1) with Buprofezin and Fenpyroximate respectively.

Table 3.
Spray coverage on Eggplant plants, as produced by the tested spraying techniques

Plant levels		Place the spray card	HAAT			AAT			PHAT			CAT		
			SB	HF	VD%	SB	HF	VD%	SB	HF	VD%	SB	HF	VD%
Bubrofezin	Top	Upper	6900	1.4	22.36	6844	2.0	21.74	6435	4.2	22.86	6864	1.1	25.52
		Lower	4180	2.2	13.56	4095	2.7	13.01	2472	4.3	8.78	3116	1.8	11.59
	Middle	Upper	5304	2.0	17.19	8298	2.9	20.00	5760	6.4	20.47	5673	1.5	21.10
		Lower	3594	2.3	11.65	2772	3.5	8.84	1900	5.3	6.75	2895	2.2	10.02
	Lower	Upper	5950	2.4	19.28	6280	3.9	19.95	4584	8.0	16.29	6237	1.6	23.20
		Lower	1638	2.4	5.31	1958	4.0	6.62	1980	5.0	7.03	943	1.8	3.50
Lost spray on ground			3288	-	10.66	3234	-	10.27	5014	-	17.81	1365	-	5.07
Fenpyroximate	Top	Upper	7245	1.5	27.83	8241	1.8	23.88	7339	4.4	25.15	5185	1.4	21.25
		Lower	3612	1.9	12.22	4640	2.9	13.44	3488	3.4	11.95	3318	1.8	13.60
	Middle	Upper	5439	2.2	20.89	6026	2.8	18.35	5190	5.8	17.78	5278	1.6	21.63
		Lower	4180	2.2	5.58	3535	2.9	10.24	3605	3.0	12.35	2925	1.9	11.99
	Lower	Upper	4704	2.7	18.07	5655	3.7	16.38	4536	7.9	15.54	5170	1.7	21.19
		Lower	2160	2.4	3.69	2450	3.9	7.9	1302	6.6	4.46	560	1.4	2.30
Lost spray on ground			3050	-	11.72	3696	-	10.71	3724	-	12.76	1962	-	8.04

3.1.2.2. The percent of vertical distribution (VD%)

After careful examination of the results of homogeneity factor and symmetric distribution pattern the suggest that the most efficient techniques tested was Centrifugal Atomization Technique "CAT" (37.11, 31.12, 26.70%) (34.85, 33.62, 23.49%), followed by the Hydraulic with Air Atomization Technique "HAAT"(35.92, 28.84, 24.59%) (40.05, 26.47, 21.76%) for Buprofezin and ***Fenpyroximate*** respectively.

3.2. Spraying drift

The drift into adjacent land during application of Buprofezin and Fenpyroximate pesticides using different techniques on Eggplant field was studied. Drift deposits of pesticides determined by volume median diameter (µm) and number of droplets No/cm²). The determination was assayed on the sensitive cards within adjacent land positioned at various distances from treated Eggplant field (1,2 and 3m).

Pesticide spraying techniques drift outside the treatment are shown in Table 4.

The results showed that the Centrifugal Atomization Techniques (CAT) gave the lowest drift rate outside the spraying area, followed by the Pressure or Hydraulic Atomization technique (PHAT), the spray drift occurring during the normal application of sprays. Also, note that the drift tends to be greater with smaller droplets than with large droplets. It is observed that, the first distance (1m) within adjacent land has received the highest amount of number of droplets, while the second distance (2m) showed an apparent decrease in the number of droplets and the third distance (3m) showed the lowest values.

It is obvious that the distance travelled by the droplets as drift increases with decreasing their sizes.

Droplets of smaller size can remain suspended in the air for long periods and drift long distances.

Table 4.
Effect of different spraying techniques on drift

Item		Drift								
		1m			2m			3m		
		VMD (μm)	No/cm²	% No	VMD (μm)	No/cm²	% No	VMD (μm)	No/cm²	% No
Buprofezin	CAT	29	8	72.72	29	3	27.28	Nd	Nd	Nd
	HAAT	55	24	66.76	42	11	30.55	29	1	2.78
	AAT	84	22	66.77	77	9	27.27	29	2	6.06
	PHAT	85	20	74.07	72	7	25.93	Nd	Nd	Nd
Fenpyroximate	CAT	103	8	100	Nd [(1)]	Nd	Nd	Nd	Nd	Nd
	HAAT	91	25	52.08	61	14	29.17	44	9	18.75
	AAT	72	26	52.00	76	19	38.00	29	5	10.00
	PHAT	55	12	70.59	59	5	29.41	Nd	Nd	Nd

[(1)] Nd= not detected

3.3. Lost spraying on soil

Table 5 shows the effect of different spraying techniques on lost on soil, the percentages of the spray lost on the soil were 5.07%and 8.04% and 10.66 and 11.72% and 10.27 and 10.71% and 17.81 and 12.76% for Buprofezin and Fewnpyroximate pesticide at CAT, HAAT, AAT and HPAT respectively.

Table 5.
Effect of different spraying techniques on lost on soil

Pesticide	Spraying techniques	VMD (μm)	NMD (No/cm²)	Percentage of the spray lost on ground
Buprofezin	CAT	105	13	5.07
	HAAT	137	24	10.66
	AAT	154	21	10.27
	HPAT	218	23	17.81
Fenpyroximate	CAT	109	18	8.04
	HAAT	122	25	11.72
	AAT	154	24	10.71
	HPAT	196	19	12.76

4. Conclusions

1) The deposition was an uneven throughout the different levels of the plant. The top level has received the highest amount of deposits, while the middle level showed apparent decrease in the spray deposits and the bottom level showed the lowest values.

2) Average pesticide deposits on upper leaf surfaces were found to be higher than average pesticide deposits on lower leaf surface of Eggplant in all pesticide application techniques.

3) The highest spray drift was obtained from HAAT, while lowest spray drift was obtained from CAT followed PHAT.

4) The pest HF occurred with the CAT followed HAAT.

5) The highest lost spraying on ground was obtained from HPAT, while lowest lost spraying on ground was obtained CAT.

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تأثير تقنيات تطبيق مبيدات الآفات المختلفة على توزيع وانجراف الرش والفاقد على التربة

عمر جاد الكريم سقاو السنوسي [١]، أشرف كامل قطب زعلوك [٢]، رأفت علي أحمد وربي [٢]، عبد المجيد السيد عمار [٣]

[١] قسم هندسة االآلات والقوى الزراعية، كلية الهندسة الزراعية، جامعة الأزهر، القاهرة، مصر.
[٢] قسم هندسة االآلات والقوى الزراعية، كلية الهندسة الزراعية، جامعة الأزهر، القاهرة، مصر.
[٣] معهد بحوث وقاية النباتات، مركز البحوث الزراعية، الدقي، الجيزة، مصر.

الملخص العربي

يهدف هذا البحث إلى تقييم تأثير اختلاف تقنيات تطبيق المبيدات المختلفة على التوزيع الرأسي لقطرات الرش على أوراق نباتات الباذنجان والانجراف خارج حدود المعاملة والفاقد على التربة أثناء عملية الرش. وتم استخدام تقنيات تطبيق المبيدات التالية: تقنية التذيذ بالطرد المركزي "CAT" (١٧,٣لتر/فدان)، تقنية التذيذ بالضغط

الهيـدروليكى "PHAT" (١٢٩,٨لتر/فـدان)، تقنيـة الترذيـذ بـالهواء "AAT" (٤٦,٧لتر/فـدان)، دمـج تقنيـة الترذيـذ بالضـغط الهيـدروليكى مـع الهـواء "HAAT" (٤٣,٣لتر/فـدان)، بحجـوم رش متغـيرة، مـع اسـتخدام نـوعين مـن المبيـدات (بـوبروفيزين وفينبيروكسيمات) وذلك لمكافحة آفة العنكبوت الأحمر *Tetranychus urticatae* Koch على نباتات الباذنجان.

أظهـرت النتـائج المتحصـل عليهـا أن أعـلى قيمـة لترسـيب قطـرات الـرش عـلى السـطح السـفلى لأوراق النبـات بـين ٢٦ إلى ٤٤ و ٣٠ إلى ٤٤ قطـرة /سـم^{٢} بأحجـام قطـرات تراوحـت بـين ٦٣ إلى ٩٥ و ٧٢ إلى ٩٥ ميكـرون وذلـك مـع اسـتخدام تقنيـة HAAT في حـين أن أقـل قيمـة لترسـيب الـرش عـلى السـطح السـفلى لأوراق النبـات كانـت مـع اسـتخدام تقنيـة PHAT بأعـداد قطـرات تراوحـت بـين ١٩ إلى ٢٤ و ١٤ إلى ٣٥ قطـرة /سـم^{٢} بأحجـام قطـرات تراوحـت بـين ١٠٠إلى ١٠٣و ٩٣ إلى ١٠٣ ميكـرون لمبيـد بـوبروفيزين وفينبيروكسـيمات عـلى التـوالي. أظهـرت النتـائج أيضـاً أن الـرش باسـتخدام تقنيـة CAT أعـطى أقـل قيمـة مـن انجـراف قطـرات الـرش خـارج حـدود المعاملـة وأقـل فاقـد عـلى الأرض مقارنـة بتقنيـات الـرش الأخـرى المستخدمة.