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Impact of different spraying techniques on chemical control of fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) on cowpea at Sharqia Governorate, Egypt

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Abstract

In the current study, three equipment were used to control fall armyworm, *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) on cowpea (*Vigna unguiculata*). This equipment was a knapsack motor sprayer (Armitsu) (120 L/fed.), knapsack sprayer (Sunflower) fitted hollow cone nozzle (Tx-6) (40 L/fed.), and even a flat fan nozzle (80 L/fed.), and conventional motor sprayer (300 L/fed.), at Facous, Sharqia Governorate. The present study aimed to determine the effects of application technique with different equipment on initial and late biological efficacy using two recommended insecticides, methomyl (Top cromic SP 90% w/w) 300g/fed [Carbamate group] and indoxacarb (Dronz EC 15% w/v) 25cm³/100L [Oxadiazine]. Regarding the efficacy of the two used insecticides results showed that indoxacarb and methomyl on the larval populations of *S. frugiperda* on cowpea were insignificant ("F" value = 14.75), whereas indoxacarb produced reduction percent with the used equipment (95.6%, 93.3%, 89.53% and 74.0%) and methomyl recorded (91.83%, 85.13%, 84.00%, and 69.97%). Also, comparative between the equipment, showed that the most effective equipment was the knapsack motor sprayer which recorded (95.6% for indoxacarb and 91.83% for methomyl) percent reduction, then the knapsack sprayer with Tx-6 recorded (93.27% for indoxacarb and 84.0% for methomyl), subsequent with knapsack fitted with an even flat fan recorded (89.53% for indoxacarb and 85.13% for methomyl), and followed by conventional motor sprayer which recorded (74.0% for indoxacarb and 69.97% for methomyl), respectively "F" value was 14.75 and LSD was 1.73. Also, the sprayer recorded 13 and 20 droplets with methomyl and indoxacarb, respectively. In the case of the knapsack motor sprayer, the loss was 10 and 7 droplets with methomyl and indoxacarb respectively, the knapsack sprayer with Tx-6 went down the lowest as 5 and 2 droplets with methomyl and indoxacarb respectively, whereas the same equipment with even flat fan gave lost 5 droplets with both two insecticides.

Introduction

Cowpea (*Vigna unguiculata*) is an economically important vegetable variety that is rich in amino acids, vitamins, and minerals (Wang *et al.*, 2021). Cowpea prefers high temperatures and humidity during the growth stage, which leads to frequent outbreaks of pests like aphids, and thrips. The fall armyworm, *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) was recorded recently in Egypt (Heinrichs and Muniappan, 2017).

The fall armyworm, *S. frugiperda* can fly up to 100 km./night (Johnson, 1987). Spraying techniques have established a balance between economic expansion and environmental conservation. The mechanized spraying system, usually implemented by highly precise equipment allows for the selective application of insecticides at the desired time and location.

The present work aims to study, the evaluate the spectrum of some ground sprayers such as pneumatic motor sprayers, knapsack motor sprayers fitted with two types of nozzles (Hollow cone Tx-6 and even flat fan), and conventional motor sprayers against fall armyworm on cowpea by using two recommended insecticides, methomyl (Top cromatic SP 90% w/w) 300g/fed. and indoxacarb (Dronz EC 15% w/v) 25cm³/100L at Facous, Sharqia Governorate during 2022 season.

Materials and methods

1. Insecticides used:

Two recommended insecticides were used, methomyl [Carbamate group] (Top cromatic SP 90% w/w) 300g/fed. and indoxacarb [Oxadiazine] (Dronz EC 15% w/v) 25cm³/100L.

2. Field experiments:

Field experiments were conducted during the growing cowpea at Facous, Sharqia Governorate in 2022 to evaluate the efficiency of the two insecticides applied with three equipment against the fall

armyworm, *S. frugiperda*. An area of about 22.5 kerates (3600 m²) of cowpea was used. The experimental area was divided into 8 treatments and a control area, each treatment divided into four replicates 100m² (12.5x8 m). Cowpea was cultivated on 5 May 2022 and treated on 19 July 2022, Samples of 25 leaves were chosen at random from each replicate before treatments and at 1,7 and 10 days after insecticidal application. The samples were transferred to the laboratory in carton bags and the number of larvae of fall armyworm was counted. The percentage of reduction of the larval was calculated according to Henderson and Tilton (1955) formula.

3. Utilize ground equipment:

Three sprayers were evaluated in this study and their characteristic parameters are recorded in Table (1) as follows:

3.1. Knapsack sprayer (Sunflower):

It's made in Poland, the tank is made of Acrylic can't break, works by liver operated and it consists of a pressure regulator, fitted with two types of nozzles (Tx-6 40L/fed. & flat fan 80L/fed.)

3.2. Knapsack motor sprayer Armitsu (120L/fed.):

It's made in Japan, tank capacity of 20 liters, it works by the air pressure of spray fitted with 4 tips, the tip is tip 4.

3.3. Conventional sprayer (300L/fed.):

The motor sprayer is composed of a chemical tank of 300 liters capacity and a reciprocating pump powered by a 3 Hp benzene motor. A high spraying volume is used usually this sprayer when the operational pressure ranges between 5 to 15 kg/cm². It is reported that about 3 kg/cm³ of pressure is usually lost throughout the 100m long hose connecting the pump and spray gun. A hollow cone pattern with various spray angles can be formed from the spray gun, according to the spraying application requirements.

Table (1): Characteristic parameters of the utilized sprayers.

Sprayer parameter	Knapsack sprayer (Sunflower)		Knapsack motor sprayer Arimitsu	Conventional sprayer
	Flat fan	Tx-6		
Nozzle type	Flat fan	Hollow cone	Tip 4	Spray gun
Total tank capacity (Liter)	20	20	20	20
Atomization type	Hydraulic		Mist blower	Hydraulic
Spray volume (Liter/Fed.)	80	40	120	300
Spraying type	Target			
Working speed (Km/h.)	2.4			
Nozzle numbers	1	1	1	1
Swath width (m.)	1	0.5	5	3
Flow rate (L./min.)	0.76	0.19	5.71	2.16
Spray height (m.)	1	1	1	1
Spraying pattern	Medium volume	Medium volume	High volume	High volume

4. Sampling line and field trails:

The sampling line consisted of 5 wires fixed on diagonal lines inside each treatment to collect sprayed chemicals between plants. Water-sensitive cards (2.5 × 5 cm) were distributed on cowpea plants at one meter at three levels upper, middle, and lower to determine the actual spray coverage on the treated plants. All cards were numbered, collected, and transferred carefully to the laboratory for measurement and calculation of the deposited droplet number. The size of the droplets was measured by using a scanning program (DepositScan) that can quickly evaluate spray deposit distribution on water-sensitive paper or Kromekote® cards (Zhu *et al.*, 2011).

5. Statistical analysis evaluation treatments:

Bioefficacy was conducted as a reduction percentage according to Henderson and Tilton (1955). Analysis of variance using the statistic software SBSS version 19 was conducted. Means of different treatments were separated by LSD at P= 0.05.

Results and discussion

1. Spraying coverage:

Results obtained in Table (2) and statistical analysis in Table (3) and graphically illustrated in Figures (1, 2, 3, 4, 5, and 6) showed that the effect of spray coverage obtained from three sprayers by using two insecticides on cowpea plants *V. unguiculata* for controlling *S. frugiperda* during season 2022, data showed that the methomyl insecticide with knapsack sprayer fitted with Even flat fan nozzle produce range of volume mean diameter 90.2:123.5 μ with average 110.6 μ and 29 droplets/cm² for three levels of plants (Upper, middle and lower).

The same sprayer fitted with hollow cone Tx-6 produced 83.7:109.1 μ as a range of volume mean diameter with an average 99 μ and 34 droplets/cm², while the knapsack motor sprayer produced, 77.9:94.5 μ with an average 89 μ and 61 droplets/cm², the conventional motor sprayer gave a range 308.1: 914.6 μ with average 645.5 μ and 19 droplets/cm².

In the case of indoxacarb insecticide, the range of volume mean diameter with a knapsack sprayer fitted with an even flat fan nozzle produces a range of volume mean diameter 88.3:128 μ with an average of 110.8 μ and 34 droplets/cm² for three levels

of plants (Upper, middle and lower) but the same sprayer fitted with hollow cone nozzle Tx-6 produced 86.1:104 μ with average 100.9 μ and 35 droplets/cm² when the knapsack motor sprayer produced 83.99 μ

with average 93.4 μ and 67 droplets/cm², the conventional motor sprayer gave range 396:923.2 μ with an average 688.7 μ and 38 droplets/cm².

Table (2): Average of spray coverage means as obtained from three sprayers by using two insecticides on cowpea plants, *Vigna unguiculata* for controlling *Spodoptera frugiperda* at Facous, Sharqia Governorate during the 2022 season.

Equipment		Knapsack sprayer				Knapsack motor sprayer		Conventional motor sprayer	
		Flat fan		Tx-6		VMD(μ)	N/cm2	VMD(μ)	N/cm2
Parameter insecticides		VMD(μ)	N/cm2	VMD(μ)	N/cm2	VMD(μ)	N/cm2	VMD(μ)	N/cm2
Methomyl	Upper	123.5	37	109.1	38	94.5	90	914.6	29
	Middle	118.0	26	104.2	35	94.5	58	713.7	18
	Lower	90.2	24	83.7	28	77.9	36	308.1	9
	Average	110.6	29	99	34	89	61	645.5	19
	Lost	71.3	5	107.9	5	96.4	10	902.2	13
Indoxacarb	Upper	128	45	112.5	36.3	98.1	99	923.2	33
	Middle	116.1	31	104.0	36	99.0	62	746.9	68
	Lower	88.3	27	86.1	34	83	41	396	12
	Average	110.8	34	100.9	35	93.4	67	688.7	38
	Lost	73.3	5	81.3	2	100.8	7	926.2	20

VMD: Volume mean diameter μ : Micron N/cm2: Number of droplets/cm2 N%: percent of pesticide

Table (3): Significant difference of all treatments

Source	Dependent Variable	Squares	d.f.	Mean Square	"F"	P.
Insecticide	N	522.722	1	1	7.602	0.008
	VMD	2913.389	1	1	0.272	0.604
Nozzle	N	235.111	1	1	3.419	0.069
	VMD	1244.914	1	1	0.116	0.734
Position	N	8437.750	2	2	61.358	0.000
	VMD	323318.675	2	2	15.075	0.000

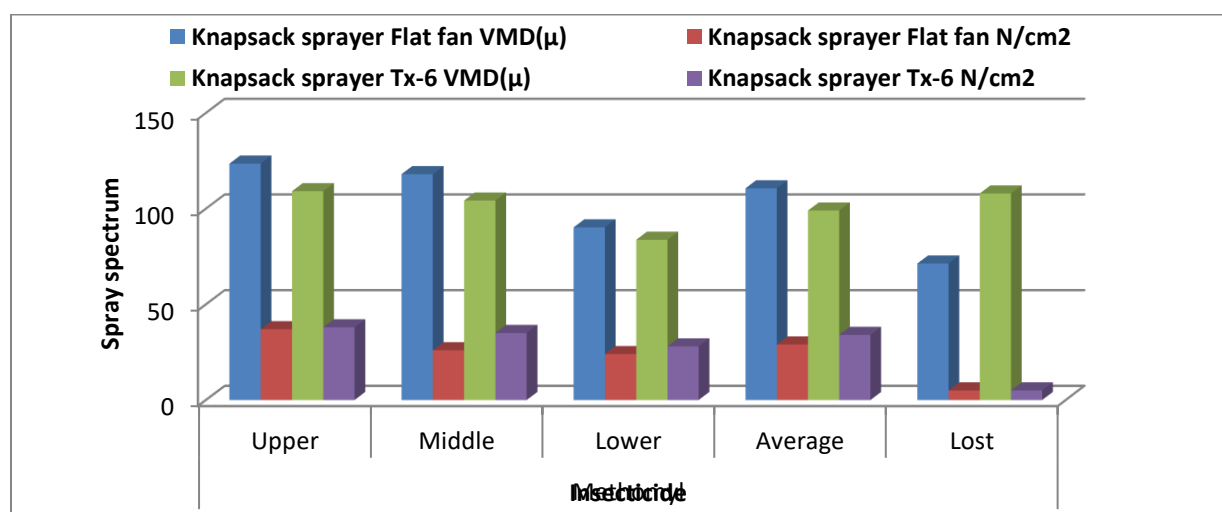


Figure (1): The volume means diameter and number of droplets/cm2 of knapsack sprayer with both even flat fan and hollow cone Tx-6 nozzles at upper, middle, and lower levels of plant with methomyl pesticide

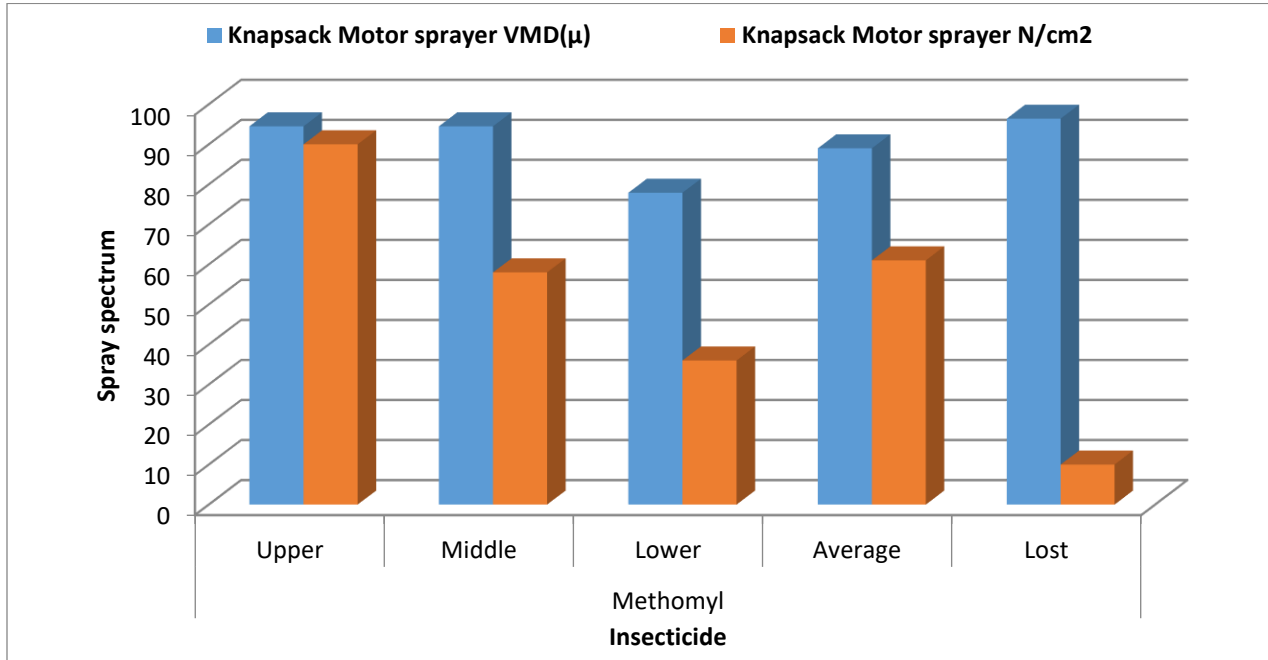


Figure (2): The volume means diameter and number of droplets/cm² of knapsack motor sprayer at upper, middle, and lower levels of plant with methomyl pesticide

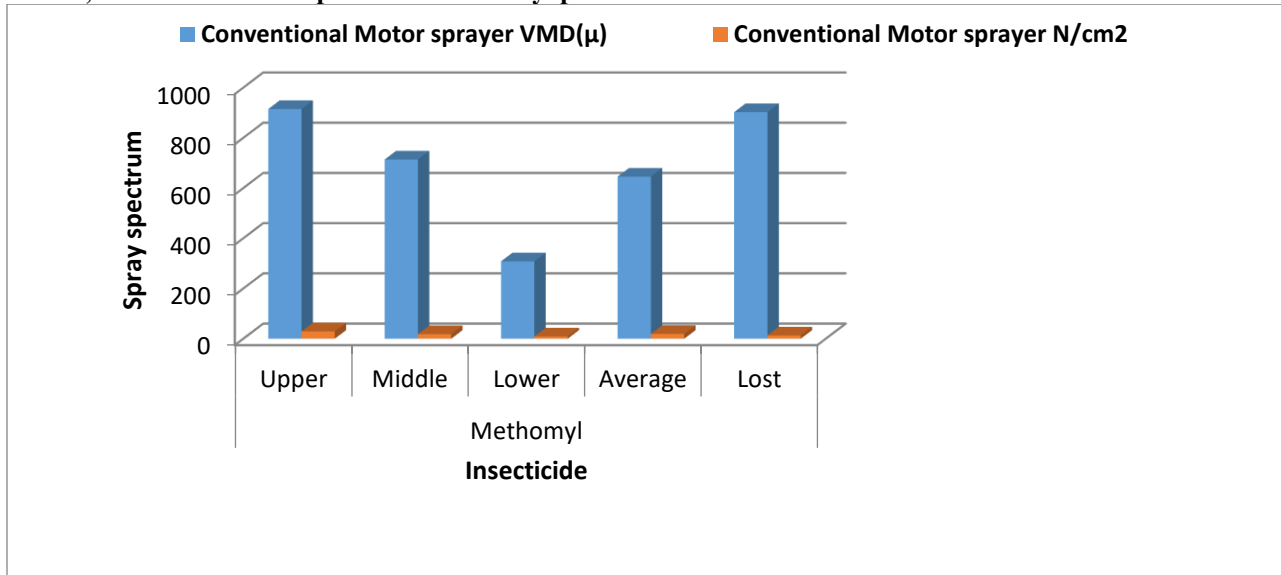


Figure (3): The volume means diameter and number of droplets/cm² of conventional motor sprayer at upper, middle, and lower levels of plant with methomyl pesticide.

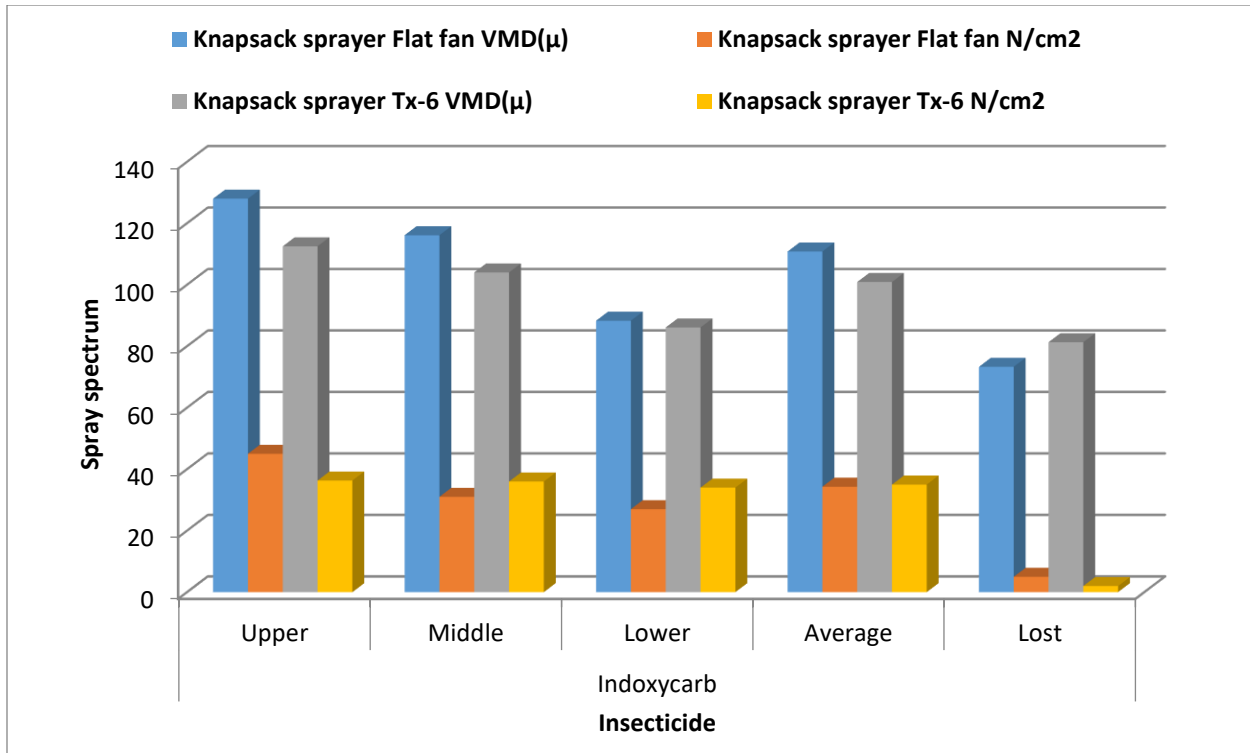


Figure (4): The volume means diameter and number of droplets/cm² of knapsack sprayer with both of even flat fan and hollow cone Tx-6 nozzles at upper, middle, and lower levels of plant with Indoxacarb pesticide

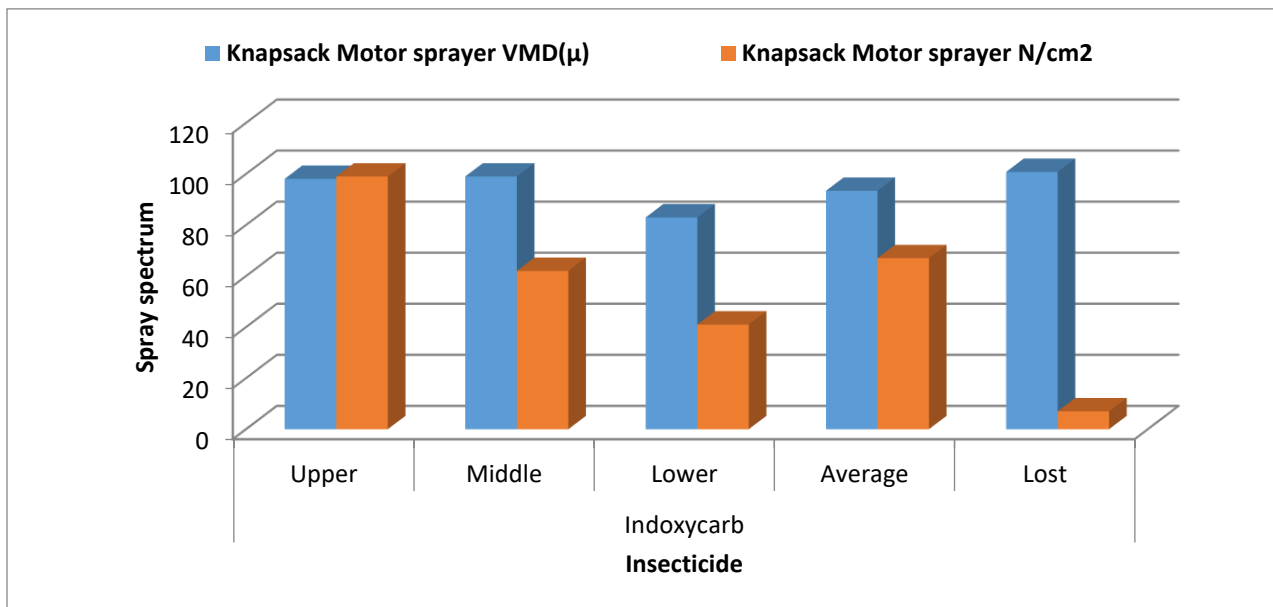


Figure (5): The volume means diameter and number of droplets/cm² of knapsack motor sprayer at upper, middle, and lower levels of plant with indoxacarb pesticide.

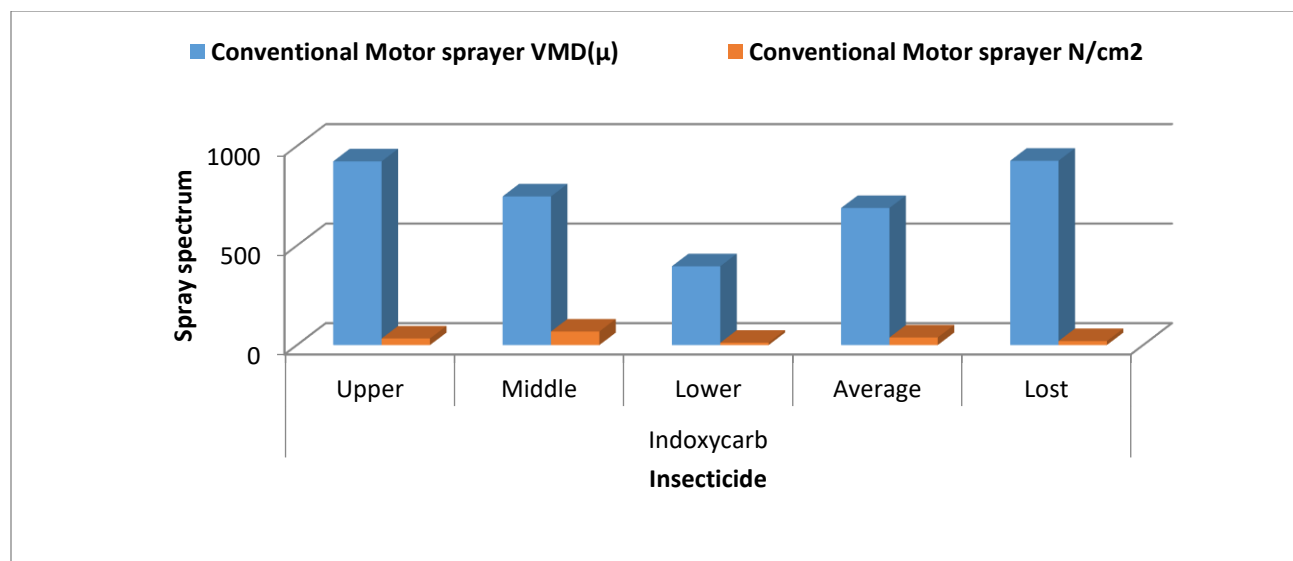


Figure (6): The volume means diameter and number of droplets/cm2 of conventional motor sprayer at upper, middle, and lower levels of plant with indoxacarb pesticide.

2. Droplets lost:

Results in Tables (4 and 5) recorded those droplets lost during control were the highest with conventional motor sprayer and were recorded 13 and 20 droplets with methomyl and indoxacarb, respectively. In the case of the knapsack motor sprayer, the

loss was 10 and 7 droplets with methomyl and indoxacarb respectively, knapsack sprayer with Tx-6 went down the lowest as 5 and 2 droplets with methomyl and indoxacarb respectively, whereas the same equipment with even flat fan gave lost 5 droplets with both two insecticides.

Table (4): Standard deviation of the mean of droplets number for used equipment with insecticides.

Insecticide	Equipment	Nozzle	position	Mean	Std. deviation
Methomyl	Knapsack sprayer	Even flat fan	Upper	37.3333	2.51661
			Middle	26.0000	3.60555
			Lower	24.3333	2.08167
		Tx-6 nozzle	Upper	38.0000	1.00000
			Middle	35.0000	5.00000
			Lower	28.0000	3.60555
	Knapsack motor sprayer	Upper	89.6667	4.50925	
		Middle	58.3333	4.16333	
		Lower	36.0000	3.60555	
	Conventional Motor	Upper	29.0000	1.00000	
		Middle	18.0000	2.00000	
		Lower	9.0000	3.00000	
Indoxacarb	Knapsack sprayer	Even Flat Fan	Upper	44.6667	4.93288
			Middle	31.3333	4.16333
			Lower	27.0000	2.64575
		Tx-6 nozzle	Upper	50.0000	4.58258
			Middle	36.3333	5.13160
			Lower	34.0000	3.60555
	Knapsack motor sprayer	Upper	94.5000	6.53452	
		Middle	60.3333	3.66970	
		Lower	38.5000	4.23084	
	Conventional motor	Upper	31.0000	2.96648	
		Middle	20.3333	3.14113	
		Lower	10.3333	3.50238	

Table (5): Standard deviation of mean of volume mean diameter for used equipment with insecticides.

Insecticide	Equipment	Nozzle	Position	Mean	Std. deviation
Methomyl	Knapsack sprayer	Even flat fan	Upper	123.5333	7.53945
			Middle	118.0000	2.42487
			Lower	90.2333	4.32474
		Tx-6 nozzle	Upper	109.0667	7.51820
			Middle	104.2000	5.38145
			Lower	83.6667	3.27159
	Knapsack motor sprayer	Upper	94.5333	7.65789	
		Middle	97.0333	1.62891	
		Lower	77.9000	1.77764	
	Conventional motor	Upper	914.5667	11.16348	
		Middle	713.6667	15.39556	
		Lower	308.1000	8.44808	
Indoxacarb	Knapsack sprayer	Even flat fan	Upper	127.9667	6.78552
			Middle	116.1333	4.99233
			Lower	94.3000	3.57911
		Tx-6 nozzle	Upper	112.5000	6.10246
			Middle	104.0333	5.35195
			Lower	86.1333	3.66379
	Knapsack motor sprayer	Upper	98.1000	98.1000	
		Middle	99.0333	99.0333	
		Lower	82.9667	82.9667	
	Conventional motor	Upper	923.1667	7.05715	
		Middle	746.8667	15.37346	
		Lower	395.9667	18.01398	

3. Evaluation spectrum:

Data of pre-and post-treatment counts of larval of fall armyworm, *S. frugiperda* on cowpea are given in Table (6) and graphically illustrated in Figure (7). Results of percentages of reduction of larva after spray application of two compounds indoxacarb (Dronz EC 15% W/V) 25 cm³ /100L and methomyl (Top cromatic SP 90% w/w) 300g/fed]. These results showed that the average percentages of reduction were varied (Abd Elmageed *et al.*, 2022). The highest effective compounds were

indoxacarb with knapsack motor (95.60%), methomyl with knapsack Tx-6 (93.27%), indoxacarb with knapsack flat fan (89.53.4%), methomyl with knapsack flat fan (85.13%), indoxacarb with knapsack Tx-6 (84.0%), indoxacarb with conventional motor (74.0%) and methomyl with conventional motor (69.97%), respectively (Soliman *et al.*, 2023). Data in Tables (4 and 5) indicated the standard deviation of the mean of droplet number and mean of volume mean diameter for used equipment with used insecticides.

Table (6): Average reduction percentage of fall armyworm *Spodoptera frugiperda* after being treated with insecticides (Methomyl and indoxacarb) by using three sprayers at two experiments.

Equipment	Knapsack sprayer				Knapsack motor sprayer	Conventional motor sprayer	Control	"F" value	L.S.D			
	Tx-6		Flat fan									
Spraying volume	40 L/fed.		80 L/fed.		120 L/fed.	300 L/fed.						
Insecticides and dosages	Methomyl 300 gm/fed.	Indoxacarb 25 cm.3/100 L	Methomyl 300 gm/fed.	Indoxacarb 25 cm.3/100 L	Methomyl 300 gm/fed.	Indoxacarb 25 cm.3/100 L	Methomyl 300 gm/fed.	Indoxacarb 25 cm.3/100 L				
% Reduction	Before	146	150	155	162	143	145	168	159	167	14.75	1.73
	1 day	92.4	95	93.6	92.2	96.1	93.2	82.5	74.7	179		
	7 days	87	97.2	88.6	96.1	92	99	71.7	77.9	206		
	10 days	72.6	87.6	73.2	80.3	87.4	94.6	55.7	69.4	215		
	Before	146	150	155	162	143	145	168	159	167		
	average	84.00	93.30	85.13	89.53	91.83	95.60	69.97	74.00	192		

L.S.D: Least significant difference

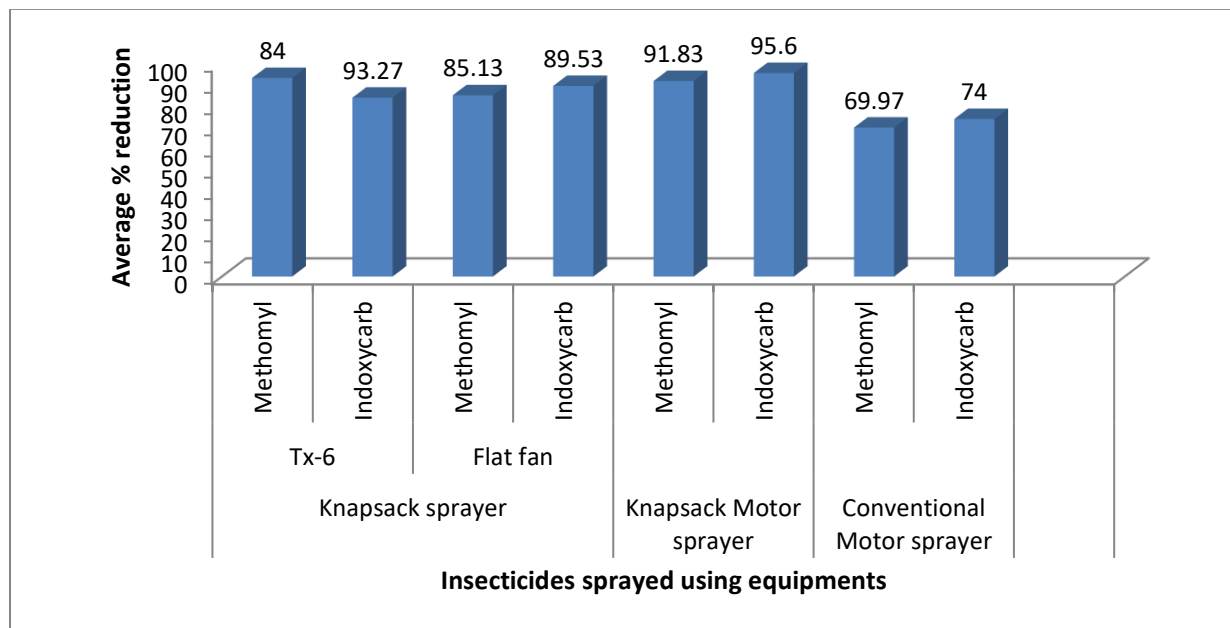


Figure (7): Reduction percent of fall armyworm, *Spodoptera frugiperda* after being treated with two insecticides methomyl and indoxacarb sprayed using three sprayer equipment at Facous, Sharqia Governorate during the 2022 season.

The statistical analysis revealed that the two compounds of insecticides, indoxacarb, and methomyl on the larval populations of *S. frugiperda* on cowpea were

insignificant ("F" value = 14.75) (Salem *et al.*, 2023), while Indoxacarb using reduction percent with the three equipment's (95.6%, 93.3%, 89.53%, 74.0%) and methomyl

recorded (91.83%, 85.13%, 84.00% and 69.97%). Also, comparative between the equipment, the statistical analysis showed that the most effective equipment was the knapsack motor (95.6% for indoxacarb and 91.83% for methomyl) then knapsack Tx-6 recorded (93.27% for Indoxacarb and 84.0% for methomyl) then knapsack flat fan-recorded (89.53% for indoxacarb and 85.13% for methomyl) and conventional motor recorded (74.0% for indoxacarb and 69.97% for methomyl), respectively, LSD was 1.73 (Salloum, 2019).

Data in Table (2) indicated that the results of the spray spectrum from the knapsack motor sprayer contained a large range of number droplets 61 drops of methomyl insecticide and 67 droplets with indoxacarb insecticide and this number of droplets gave excellent coverage on leaves of cowpea plants, the same equipment had average droplet sizes of (89 and 93.4 μ) which very close to the typical stone needed to kill the fall armyworm, so, it gives satisfactory percent reduction to the mentioned pest, and the percentage reduction is recorded 91, 83 with methomyl insecticide 95.60 with indoxacarb insecticide. This gives the chance for droplets to make full coverage of cowpea leaves, which made it reflects the percent reduction in the number of armyworm larvae (Ammar and Salloum, 2021). Knapsack sprayer fitted with TX-6 nozzle comes in the 2nd order of reduction percent and then the same sprayer with Even flat fan nozzle in the 3rd. A conventional motor later with gave insignificant spray spectrum and large droplet size which fall on land, and very poor droplet numbers, which gave poor percent reduction, Al-Shannaf and Ammar (2011), and it was significantly obtained the results of the static analysis as Table (3).

The results agreed with Ammar (2003), Derksen *et al.* (2001), and Eita *et al.* (2020).

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