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Efficacy of thermal fog and partial spraying techniques for controlling *Bactrocera zonata* and *Ceratitis capitata* (Diptera: Tephritidae) on mango in Qalyubiya Governorate

Essam, F. Gazia; Mohamed, A. Hindy; Ghada, M.A. Morsi and Safinaz, A. Ahmed
Plant Protection Research Institute, Agricultural Research Centre, Dokki, Giza, Egypt.

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Abstract:

This investigation may be considered one of the rare attempts to make evaluation between thermal fog and partial spray techniques to control both of *Bactrocera zonata* (Saunders) and *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae **)** on tall mango orchards in Egypt . Thermal fog as a new technique gave promising results represented in good distribution and penetration of fog clouds at various parts of tree during the evening or at sun rise under climatic inversion condition, saving time , water consumptions and labors required for chemical application when compared with partial spray technique . Also a drastic difference in the rate of performance (fed. / day) between IGEBA TF 35 handle fogger machine and Hand Heldsprayer CP-3 (17.12 and 1.5 fed./ day), respectively . Data showed that *C. capitata* was more sensitive than *B. zonata* represented in percentages reduction by using thermal fog and partial spray techniques . A highly significant difference was recorded between recommended dose of thermal fog and partial spray techniques for controlling both *B. zonata* and *C. capitata* represented in mean number of captured flies in Mcphail traps . No significant difference between half recommended dose with thermal fog technique and partial spray technique for controlling fruit flies was also noticed . Moreover significant difference in mean numbers of captured flies inside Mcphail traps were recorded four weeks than between two weeks after application of *B. zonata*.

Introduction

Mango orchards areas in Egypt are approximately 150433 fed. Mean production about was 5.0 Tons / Feddan annually (Anonymous , 2014). True fruit flies (Diptera: Tephritidae) include over 4000 species, many of which constitute enormous threats to fruit and vegetable production worldwide (Benelli, 2015). Fruit fly control with full sprays started with inorganic insecticides , such as chlorinated hydrocarbons, organophosphates and synthetic pyrethroids. Addition of protein food baits to insecticide sprays

reduced the amount of pesticide needed for fruit fly control and has been used successfully in many eradication programs . Female flies, need of protein for full ovarian development and egg production (Roger *et al.*, 2015) . *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) has been recognized as a serious insect pest during the last decade attacking a wide range of fruits in Egypt (Fahmy *et al.,* 2013) . *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae) has become invasive throughout the world (De Meyer *et al.,* 2007) . Modern control trends depending mainly on minimizing the hazards of insecticides to the environment , the costs time of control operations and in the mean time increasing the efficacy by using thermal fog technique (Brown and Watson ,1953) .They found that , fog was drifted across a swath of 150 m , but it coud be effective for 400 m . Mathews (1979) stated that fogging was particularly useful for the control of flying insect not only through contact with droplets , but also , by the fumigant effect of volatile pesticide . Lim and Abdul – Aziz Bin Kader (1978) evaluated ground fogging technique by using a new oil based fungicidal formulations against secondary leaf fall *Phytophthora* (Peronosporales : Peronosporaceae) and pod rot in comparison with duster sprayer to dust sulphur for controlling rubber leaf diseases . They concluded that , fogging technique was more rapid and economic at large scale treatments for controlling these diseases than dust sulphur technique . Hindy *et al.* (1995) compared between the traditional chemical spray method and a thermal fog technique for controlling *C. capitata* infested mango orchards in Egypt which gave good distribution and penetration of droplets at various parts of mango trees , saving time required for chemical application with a few amounts of chemical insecticides than traditional ground motor spray. Hindy *et al.* (1999) evaluated the bio-residual activity of summer oil 1 % KZ oil produced from three ground spray equipment against citrus leaf miner. Results indicated that thermal fog technique with a half dose rate and conventional ground motor sprayer as recommended dose rate showed higher mortality of thermal fog technique than the other treatments . Mc Govern *et al*. (1986) indicated that , trimedlure was a powerful attractant for males of *C. capitata* . Hafez and Ezzat (1967) used traps baited with 3 % solution of diammonium phosphate for *C. capitata* . Buttery *et al.* (1983) stated that Hand Heldthermal foggers were highly effective, with more than 90% reduction of both laid eggs and females mosquitoes (Boubidi *et al.,* 2016) .

The aim of the present investigation is to spot light on controlling fruit flies by using thermal fog technique in comparison with partial spraying technique as an attempt to save time of chemical application getting down insecticides , reducing water as a carrier and lowering cost of spray in mango orchards .

Materials and methods

1. Experimental area:

Experiments were conducted in mango orchards (Season, 2016) at El-Qanater Elkhairia district , Qalyubiya Governorate. Eleven feddans of mango trees were chosen and sprayed during summer , 2016 . The mean number of trees per feddan was about 50 trees. The height of trees in the area under investigation ranged between 6 – 8 meters . Two concentrations (full dose and half dose) of the recommended chemical insecticides for controlling *C. capitata* and *B.zonata* on mango trees (Malathion 57 % EC) + 100 ml of summer mineral oil (KZ- oil 95 % EC) and solar solution as a carrier were used by a Hand Heldthermal fog generator (IGEBA) TF 35. Each treatment was

conducted at 4.0 feddans sprayed cross wind at sun set . An area against wind direction of about half feddan was left untreated for each tested concentration as control area. Untreated ten rows mango trees were left between each two treatments to avoid over lapping due to fog drift. Spraying operations started about 10 days prior reaching physiological ripening stage of mango fruits where they well still less susceptible and / or to avoid infestation with med fly and peach fruit fly . Another spraying technique was partial spraying which consisted of mixed solutions consisted of 500 cm3 (Malathion 57 % EC) insecticide + one liter of food attraction bominal + 18.5 liters water used by Hand HeldKnapsack sprayer CP-3 . The solution was used for spraying trunks of trees at branching area using about 150 – 200 cm3 / tree. Each 20 liters solution sprayed downwind at sun set. Spraying operations were at all rows of mango trees used by target spraying technique.

2. Used Mcphail traps :

Four Mcphail traps (Mcphail, 1937) for each treatment , were used by putting about 200 ml of 3% diammonium phosphate solution in each trap. All prepared traps were distributed in a completely randomized design. The distance between two each adjacent traps was about 15 meters and the traps were hanged at about 1.5 – 2 meters in a shadow place of the trees was added. The traps were weekly inspected , where fresh baited solution along a period of 5 weeks was changed . Captured females and males of *B.zonata* and *C. capitata* were counted and recorded .

3.Statistical analysis:

Table (1) showed the techno operational data of two ground application techniques , calibration and performance rate for machines was according to Hindy (1992) . The percentages reduction of treatments calculating according to formula Hendrson and Tilton (1955) . Data was analyses by using ANOVA in SAS (SAS Institute, 1998) .

Table (1) : Techno- Operational data , spray parameters , insecticides application rates and rate of performance by using " IGEBA® thermal fog generator and CP-3 Hand Heldhydraulic sprayer .

Equipment / **Items**	**Thermal Fog IGEBA® TF 35**	**CP – 3 Knapsack Sprayer**
Manufacture	Germany	U K
Weight , empty in KG.	7.9	3.7
Dimensions .L . W . H in cm.	137.5.27.34	43.33.25
Solution Tank capacity in L.	5.7	20.0
Fuel consumption in L/H .	2.0	-
Effective Horizontal reach out doors , in m.	15.0	0.5
Power supply	4 dry batteries 1.5 V.	ManualPump
Flow rate , approx . in L/ Min	42	43.2
Machine speed km / hr	1.2	1.2
Atomization type	Pneumatic	Hydraulic
Kind of spray	Drift	Target
Direction of Travel	cross wind	Down wind
Rate of performance at (6) working hours (fed / day)	17.12	1 – 1.5
Quantity of Malathion (cc – in tank / treatment	1000 , 500	500 m Malathion + 1 L. Buminal
Quantity of KZ oil cc in tank / treatment	500 ml	-
Quantity of Solar as carrier solution / treatment (l.)	4.2 , 4.7 l / tank / treatment	-
Quantity of water as carrier solution in tank / treatment (l.)	-	18.5
spray time / fed. (Min.)	19.0	60.0

Weather conditions during spraying operations , Temp. 29 C , R. H. 70% WIND VELOCITY 1 – 1.5 m / sec.

Results and discussion

1. Comparison between thermal fog and partial spray techniques :

Data in Table (1) clearly showed that thermal fog technique offer tangible benefits when compared with partial spray technique. Less materials per feddan was applied . Consequently more safe time of application , less spray labor . No water was needed in treatments for fog , while in partial spraying large quantities of water is required . The swath width in fog was about 15 m. moved and penetrate the trees in 19 Min / feddan . But the swath width was about 0.5 meter in each tree in partial spray technique , the time to spray one feddan about one hour. Performance rate of one machine of thermal fog technique could covered 17.12 feddans / one tank but in other side partial spray technique made by Hand Heldspryer CP-3 covered from 1 – 2.5 feddans / day . Fog machines could be done at temperature inversion conditions , usually either early morning or at evening , so that , the fog remains close to the ground and drifted slowly to different levels of mango trees but partial spray technique a localized solution was used for spraying tree trunks at branching area using about 100 – 200 cm3 / tree . Technically thermal fog technique could gave good droplets distribution , penetration and full coverage on mango trees certainly if used pyrthroid – insecticides which induce knock down effect more than phosphorus – insecticides and give good protection against flying fruit insects than partial spray technique. These results agree with Hindy *et al* . (1995) who stated that thermal fog gave promising results represented in good distribution and penetration on droplets at various parts of tall mango trees , saving time required for chemical application and less consumed amount of chemical insecticide due to moving fog clouds on ground through mango trees and air drifted was about 37.1 % opposed to 77.5 % in case of using conventional sprayer as drift spray and lost spray between plants . Also data in Table (1) illustrated that , the productivity (fed. / hour) between thermal fogger machine and CP- 3 sprayer were 4.28 , and 0.14 respectively . On the other hand , the rate of performance (fed. / day) between thermal fogger machine and CP- 3 sprayer were 17.12 and about 1–1.5, respectively. Thermal fogger revealed a drastic differences in rate of performance which it had been made more quick control for large areas of mango orchards in short time than CP- 3 sprayer with spraying a partial sprayer .

2. Captured *Bactrocera zonata* flies inside Mcphail traps :

Mcphail traps were made of plastic powered with food attractant diammonium phosphate 3 % which attract both male and female of *B. zonata* and *C. capitata* into the orchards . It could not attract the fruit flies from vast distances out side the mango orchard, therefore these traps captured only the flies in mango orchards under investigation . Data indicated in Table (2) revealed that , no flies were captured into traps at recommended dose with thermal fog technique until the end of two weeks after applications . Data showed in Figure (1) mean reduction rates in flies population *B. zonata* at recommended dose rate with thermal fog technique and partial spraying technique was 80 % and 47. 5, respectively. After the first and second weeks of thermal fog at recommended dose of *B. zonata* was zero , so the percentage reduction 100 %.These results are in accordance with Mahmoud *et al*. (2017) who stated that, for controlling *B. zonata* and *C. capitata* in Egypt it was recommended to increase area and time of spraying from three to four or five times . No significant difference between half recommended dose treatment with thermal fog technique and partial spraying technique

treatment was recorded. The following mean reduction percentages were 37.73 and 47. 5, respectively (Figure, 1). In the third and fourth weeks after application a drastic increase in flies population was recorded after application in both of control and half recommended dose of thermal fog, and partial spraying technique, respectively. However in case of recommended dose of thermal fog technique the population of flies was very low at the same period. This may be attributed to the effect of space fumigation controlled flying insects such as *B. zonata*. Fogging at higher volume rates and with a greater proportion of larger droplets sometimes referred to as a wet fog will leave deposit on foliage. This may provide a longer residual effect, but at high flow rates foliage close to the nozzle is liable to be damaged by an overdose of large droplets. Although less effective as a space treatment. Fogging is particularly useful for the control of flying insects (Boubidi *et al*., 2016), moreover Matthews (1979) stated that mortality occurred through contact with droplets but also by the fumigation effect of a volatile pesticide. So the pesticide in a gas form is capable of reaching flies hidden on lower leaf surfaces inducing irritation of pest and hence slip out of their hiding place and receive a lethal dose from air borne fog droplets. The effect space fumigation was produced when stable aerosols smaller than 5 m was generated and coated on the leaves with very fine film of droplets ranged between 1–30 µm in both upper and lower surface of plant leaves through the good penetration of very fine droplets sizes under inversion condition occur .

3. Captured flies *Ceratitis capitata* inside Mcphail traps :

Data in Table (3) showed that *C. capitata* was more sensitive for treatments when compared with *B. zonata* in Table (2) . There was no significant difference among the two tested treatments of thermal fog technique and partial spraying technique . According Figure (2) the reduction percentages were 90.5 and 71.4 and 92.8 at recommended dose, half recommended dose and partial spraying technique, respectively . After the first , second and third weeks of treatments the population of *C. capitata* was zero , so the percentage reduction reached 100 % . The mean number of captured *C. capitata* flies inside Mcphail trap in control were less than the mean number of captured *B. zonata* inside traps . Also no significant difference among weeks after application were noticed . Boubidi *et al*. (2016) evaluated the efficiency of truck mounted ULV and thermal fogger chance that a droplet will come in contact with a mosquito in the sentinel cage in a thermal fog application versus a ULV application . We concluded that in the event of out breaks of fruit flies on mango orchards during summer season partial spray technique is unlikely to have significant impact on transmission but that despite being highly labor – intensive , thermal fog technique dispensed from portable sprayers was the method of choice. Clearly this was not practicable on any large scale but might be useful in the event of potential " hot – spots " of local transmission . Thermal fog technique for controlling insect pests infesting fruit trees gave promising results represented in less consumed amounts of chemical insecticides , saving time required for application and thorough spray droplet distribution penetration and deposition . Also from our data , could be concluded that data obtained from this study are promising , but may be , further investigations are required to make respective accumulation of fog spray's with little doses to obtained more control operations than one treatment .

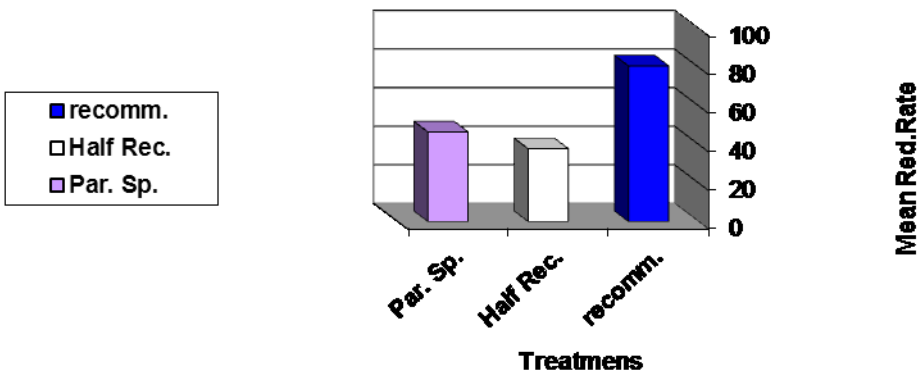

Figure (1): Mean reduction rate of *Bactrocera zonata* by using thermal fog techique compared to partial techique.

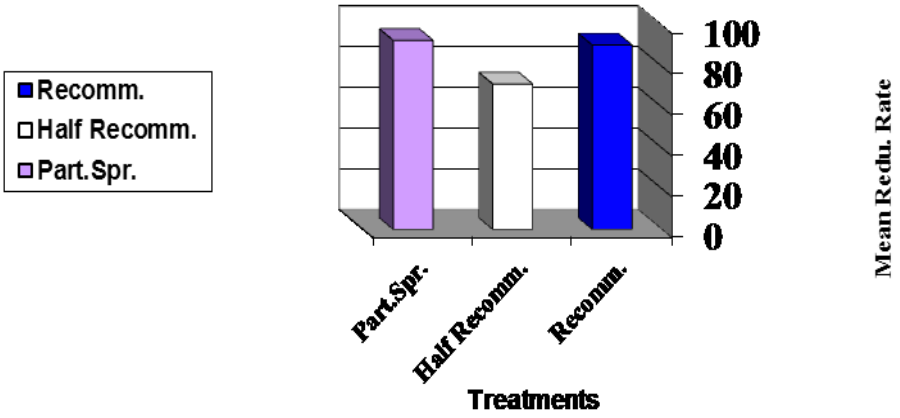

Figure (2): Mean reduction rate of *Ceratitis capitata* by using thermal fog techique compared to partial spray techique.

Table (2): Mean number captured and reduction rate of *Bactrocera zonata* inside Mcphail traps by using thermal fog techique compared to partial spray techique on mango orchard at Elkanater Elkhairia district , Qualubyia Governorate during season 2016.

Date		After applications					Mean	% Redu.
Treatments		One week	Two weeks	Three weeks	Four weeks	Five weeks		
Thermal fog	Recommended dose	0	0	3.25	3.25	1.25	1.55	80.7
	Half Recommended dose	1.75	2.75	10.75	9.25	0.5	5	37.7
Partial spray		1.25	0	11.25	8.5	0.5	4.3	47.5
Control		2.25	4.25	19.66	12.75	1.25	8.03	
LSD		1.963						

Table (3): Mean number captured and reduction rate of Ceratitis capitata inside Mcphail traps by using thermal fog techique compared to partial spray techique on mango orchard at Elkanater Elkhairia district , Qualubyia Governorate during season 2016

Date		After applications					Mean	% Redu.
Treatments		One week	Two weeks	Three weeks	Four weeks	Five weeks		
Thermal fog	Recommended dose	0	0	0	1	0	0.2	90.5
	Half Recommended dose	2.5	0.5	0	0	0	0.6	71.4
Partial spray		0.25	0	0.5	0	0	0.15	92.8
Control		2.75	1.5	3.75	1.25	1.25	2.1	
LSD		0.666						

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