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Development and Implementation of Integrated Pest Management to Programs of Apple Trees in Reclaimed Lands in Egypt:
I - The Fig Scale Insect (FSI), *Russellaspis (Asterolecanium) pustulans* (Cockerell)

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Abstract

The fig scale insect (FSI), *Russellaspis (Asterolecanium) pustulans* (Cockerell) (Homoptera : Asterolecanidae) is a serious pest of apple trees „*Pyrus malus* (Mill)" in new reclaimed lands in Egypt. Both nymphs and adult females were found on apple trees all over the year.

The distribution studies of the FSI on various parts of apple trees were carried out in a private farm located in El-Mansoria Center at El-Giza Governorate in Egypt. The distribution studies is equally important, particularly when oriented spraying are practiced. The data showed that 51,6 and 46.6% of adults and nymphs stages respectively of the FSI were concentrated on trunks, while, 48.4 and 53.4% respectively were distributed between main branches, new branches and new leaf petioles. The same trend was observed with the distribution of parasites. The FSI population was concentrated in the direction of water pipe in new reclaimed lands.

Two methods were carried out to control this pest: the whole tree spraying and the oriented spraying. In the whole tree spraying, the whole tree was sprayed. About 7 liters of pesticide solution at winter time (after pruning) and 15 liters at summer time (before pruning). In the oriented spraying (spraying of infested branches), about 2.5 liter at winter time (after pruning) and 6 liters at summer time (before pruning) spraying solution per tree were sufficient to cover the infested branches.

Both spraying methods (oriented and whole tree spraying) gave complete protection for 5 months (in winter) and 4 months (in summer) after which, reinfestation was observed.

The whole tree spraying were the more expensive variants (235 and 162 LE/feddan) while the oriented spraying variants (106 and 71 LE/feddan) were relatively safe to the environment and also gave good reduction against the FSI pest and is very important in Integrated Pest Management (IPM) methods.

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1 Introduction

The fig scale insect (FSI), *Russellaspis (Asterolecanium) pustulans* (Cockerell) (Homoptera : Asterolecanidae) is infested fruit trees other than fig such as peach, plum, pear, apple, apricot, mango, guava and *Ficus cycamorus* (HALL 1922 and 1923) and (DEAN and MICHAEL 1970). The FSI became a very dangerous pest - attacking apple trees „*Pyrus malus* (Mill)" in Egypt. The FSI settle on the stems, green shoots, stalks on the fig leaves, midribs and even sometimes on the fruits. When it settles on green shoots or on the stalk or midrib of a leaf, it starts sucking the plant juices and thus the tree gets weak and might even die in the case of heavy infestation (HABIB 1943 and 1957). The injury is caused by different immature and mature stages, it occurs beneath the outer bark near the base of twigs or branches. The FSI causes shedding of the lower leaves, where, the mature stages occur near the tips and cause local swellings and the shedding of the upper leaves. Also it causes leaves and twigs wilt, defoliation and dieback of the affected branches and possibly the death of young trees and large portions of older ones if the infestation persists or considerable yield loss (PICKLES, 1941). In winter, females laid an average of about 90 eggs/female. In summer, the number of eggs raised up to about 195 eggs/female on fig. The crawlers were moved from the infesting fig branches to the small twigs of the fig trees (EL-MINSHAWY *et al.*,1972). Crawlers lose their legs and antennae during the first moult, piercing mouth parts in plant tissues and causing the epidermal layer to swell up forming a sort of cup, (KASIM, 1995).

The main purpose of these studies was to reduce the amounts of pesticides by using the oriented spraying or their alternatives to reach the same pest control results and furthermore save the environment.

2 Materials and Methods

2.1 Tested insecticides

The insecticides used in the present experiments were:

1. Conventional toxicants :

Malathion 57% EC: An emulsifiable concentrate, formulated by American Cyanamid Co., containing 57% a.i., O,O-dimethyl-S- (1,2-dicarbethoxyethyl) dithiophosphate.

2. Natural control agents:

a Mineral oils:

a.1 Light mineral oil (Masrona 95% EC): Masrona oil miscible type formulated by Masrona Co., containing 95% paraffinic oil w/ w and 5% inert ingredients, unsulfonated residue content reached 92%.

a.2 Heavy mineral oil (Albolium 80% EC): Albolium oil miscible type formulated by Kafr El-Zayat Co., containing 80% mineral oil + 20% water and emulsifier.

b Sulfur (Micronized 85% WP)

2.2 Distribution studies

The distribution studies were carried out in a private farm located in the El-Mansoria Center at El-Giza Governorate, Egypt. Twenty infested apple trees (Anna/MM106),

nearly of the same age (ca. 7 years) and size (height 2-2.5 m), were used. Methods of sampling developed by (EL-KIFL *et. al.*, 1978) and as adopted by (MANGOUD 1994 and 2000). Counting starting from January 2000. Twenty new branches (20-25 cm. long) and twenty leaf petioles from the new branches were examined. Twenty of trunks and twenty of main branches were selected at random from all parts of the tree. The samples were kept separately in polyethylene bags and transferred to the laboratory for counting the scale insect by the aid of a stereomicroscope. The nymphs and adult stages (non-gravid and gravid females) and their parasites (*Marietta exitiosa* and *Metaphycus* sp.) were counted. Samples were randomly taken biweekly. Examination of trunk and main branches in the field were mad by a hand lens.

2.3 Methods of application

2.3.1 Whole tree spraying

In this experiment, the whole tree was sprayed. About 7 liters at winter time (after pruning) and 15 liters at summer time (before pruning) of spraying liquid per tree were sufficient to insure complete coverage.

2.3.2 Oriented spraying (spraying of infested branches)

In this experiment, only the infested branches were sprayed. About 2.5 liter at winter time (after pruning) and 6 liters at summer time (before pruning) spraying solution per tree were sufficient to cover the infested branches.

2.4 Control tactics

Each treatment containing 16 trees (4 replicates) were used. Other 16 trees were also used as untreated check (control). The experiments were carried out in a private farm located in El-Mansoria Center at El-Giza Governorate, Egypt. A knapsack sprayer CP-20 of 20L capacity accomplished spraying. Per-spraying counts were made just before spraying and the post-spraying count were made biweekly.

2.5 Experimentation

Several control programs were designed (Table 1). They were intended to include programs that are completely devoid of synthetic pesticides in one end to programs completely loaded with synthetic pesticides at the other end. In between both ends programs varied in the size of the chemical component.

Table 1: Various programs designed for the control of the FSI.

No.	Program
A	Untreated
B	Spraying with light oil 2% (before pruning).
C	Spraying with heavy oil 2% (after pruning).
D	Spraying with sulfur 0.25% + light oil 2% (before pruning).
E	Spraying with sulfur 0.25% + heavy oil 2% (after pruning).
F	Spraying with malathion 0.2% + light oil 2% (before pruning).
G	Spraying with malathion 0.2% + heavy oil 2% in winter.

A = Untreated B+C +D+E = No synthetic pesticides G = Recommended

2.6 Statistical Analysis

In field tests, percent reduction in infestation was calculated according to the equation of (HENDERSON and TILTON 1955).

2.7 Sanitation

Pruning was carried out in half December, it was practiced to remove most of the infested shoots and branches. All pruned parts of the apple trees were collected and burned directly after pruning. Also the dropped leaves in winter were buried in holes deep enough then covered with sand or clay to enrich the soil with organic matter and to eliminate a source of infestation. Removal of weeds, which may harbor major pests, was of prime importance.

2.8 Irrigation

In this farm dripping system was practiced. It was observed that the infestation of FSI was more severe at the side where the dripping nozzles were mounted.

2.9 Fertilization

The fertilization regime of the orchard is described in Table 2.

2.10 Weather Factors

The weather factors selected in this study to test their effects on the population of apple insects and their natural enemies were: day maximum temperature (D. Mx. T), day minimum temperature (D. Mi. T) and daily mean relative humidity (D. M.R. H.). Daily records of these weather factors in Giza and Qualyobia Governorates were obtained from the General Authority for Meteorology at Kobri, El-Kobba, Cairo, Egypt.

Table 2: Fertilization regime for apple orchards grown in new reclaimed lands.

Period	Drip Irrigation		
	Ammonium sulfate g/tree	Super phosphate g/tree	Potassium sulfate g/tree
Autumn*	100	500	100
	Ammonium nitrate g/m3water	Phosphoric acid ml/m3 water	Potassium sulfate g/m3 water
Winter*	250	25	125
These doses are applied weekly from mid February to complete fruit set.			
Spring*	125	25	250
Two successive sprays with foliar fertilizer (300 g. cheated Fe. + 150 g,. cheated Mn.+ 300 g. cheated Zen. + 300 ml Urea/600 L water) were applied in April and May after foliation and fruit set.			
Summer	250	-	75
These doses are applied weekly until harvesting			

- Organic fertilizer is added in autumn to orchard at a rate of 40-50 kg/tree.
- Foliar fertilizers are applied twice weekly by dripping. These doses are applied weekly from mid February to complete fruit set.

3 Results and Discussion

3.1 Distribution studies

The distribution studies of the FSI on various parts of apple trees is equally important, particularly when oriented spraying are practiced. The data in Table (3), showed that 51.6 and 46.6% of adults and nymphs stages of the FSI were concentrated on trunks, while, 48.4 and 53.4% were distributed between main branches (34.3 and 38.1%), new branches (11.5 and 12.0%) and new leaf petioles (2.6 and 3.3%). Also found that 48.1% and 58.0% of mature and immature stages of the parasites on trunks, while, 51.9% and 42.0% distributed between main branches (36.3 and 32.1%), new branches (12.3 and 8.3%) and new leaf petioles (3.3 and 1.6%). The FSI population was more abundant in the lower part of the canopy of the apple trees in the direction of water pipe in new reclaimed lands. On branches the FSI preferred the oldest part of the older branches.

Pickles (1941) found that *Asterolecanium pustulans* infesting outer bark near the base of twigs of branches caused shedding of the lower leaves.

Table 3: Distribution of the FSI together with parasites/tree expressed as average number/two weeks during 2000 season.

Infested site	Mean number of:				Percent of:			
	R. pustulans		Parasites		R. pustulans		Parasites	
	Adults	Nymphs	Matures	Immatures	Adults	Nymphs	Matures	Immatures
Whole tree	309.0	492.8	43.0	67.9	100	100	100	100
Trunk	159.4	229.7	20.7	39.4	51.6	46.6	48.1	58.0
Main branch	105.9	187.6	15.6	21.8	34.3	38.1	36.3	32.1
New branch	35.4	59.1	5.3	5.6	11.5	12.0	12.3	8.3
New leaf petiole	8.3	16.4	1.4	1.1	2.6	3.3	3.3	1.6

3.2 Control tactics

Trunk and some branches of apple trees (in the direction of water pipe) are attacked by the FSI. Oriented spraying in winter (after pruning) and in summer (before pruning) are more effective and safer to the environment.

3.3 Methods of applications

3.3.1 Oriented spraying (spraying of infested branches) after pruning

One trial was carried out in January 2000 (after pruning). The average maximum and minimum temperatures in the field were (20.3 and 10.5°C) and relative humidity was 71%.

In this trial, the infested branches were sprayed as an oriented spraying after pruning (3 treatments) programs C, E and G (Table 1).

The average pre-spraying numbers of adult and nymphs of the FSI were 17.2-22.1 and 31.1-35.4 insects/branch and the average numbers of mature and immature of the parasites were 3.1-4.8 and 4.9-7.8/branch (Table 4).

The three treatments, (heavy oil + sulfur, heavy oil + malathion and heavy oil alone) gave 96.8, 91.5 and 91.3% average reduction in infestation in this trial against adult females (gravid and non-gravid females), respectively and gave 99.4, 96.4 and 96.8% average reduction against nymphs, respectively (Table 4).

The three tested chemicals in Table (4) showed toxic effect against the parasites (over 93% average reduction) in the apple farm in this trial.

The three treatments gave complete protection for 5 months after which, reinfestation was observed.

These results agree with the idea of oriented spraying by El-Metwally and Shraf El-Din (1989) and also in agreement with results obtained by Mangoud (1994).

3.3.2 Whole tree spraying (after pruning)

One trial was carried out in January 2000 (after pruning) in the same time and in the same farm.

In this trial, the whole tree were sprayed after pruning (3 treatments) programs C, E and G, where programs C and E are experimental programs compared with recommended ones (program G) (Table 1).

The average pre-spraying numbers of adult and nymphs of the FSI were 19.7-22.8 and 31.1-35.2 insects/branch and the average numbers of mature and immature of the parasites were 3.9-4.4 and 6.8-7.1/branch (Table 4). In this trail, the spraying solution covered the whole tree.

This trail gave similar results to those obtained from the oriented trail. Results in Table (4) indicated that, heavy oil + sulfur and heavy oil alone gave 97.0, 91.4% average reduction in infestation in this trial against adult females (gravid and non-gravid females), respectively and gave 99.6 and 97.2% average reduction against nymphs, respectively. Heavy oil + malathion (recommended program) gave 92.9 and 96.8% average reduction against adults and nymphs, respectively

The three tested chemicals in Table 4 showed toxic effect against the parasites (over 94% average reduction) in the apple farm in this trial.

The three treatments gave complete protection for 5 months after which, reinfestation was observed.

As mentioned in materials and methods, 2.5 liters were sufficient for spraying the infested branches in the oriented spraying technique, while, covering of the whole tree needed 7 liters (after pruning). In other words, the treatment of infested branches is more economic (about 2.8 times), and safer to the environment than the spraying of the whole tree.

3.3.3 Oriented spraying (spraying of infested branches) before pruning

One trial was carried out in May 2000 (before pruning). The average maximum and minimum temperatures in the field were (38.3 and 25.4°C) and relative humidity was 78%.

In this trial, the infested branches were sprayed as an oriented spraying after pruning (3 treatments) programs B, D and F (Table 1).

The average pre-spraying numbers of adult and nymphs of the FSI were 35.6-40.8 and 49.6-55.4 insects/branch and the average numbers of mature and immature of the parasites were 6.4-7.1 and 8.9-10.0/branch (Table 5).

The three treatments, (light oil + sulfur, light oil + malathion and light oil alone) gave 98.0, 95.1 and 94.7% average reduction in infestation in this trial against adult females (gravid and non-gravid females), respectively and gave 99.7, 98.9 and 98.3% average reduction against nymphs, respectively (Table 5).

The three tested chemicals in Table (5) showed toxic effect against the parasites (over 96% average reduction) in the apple farm in this trial.

The three treatments gave complete protection for 4 months after which, reinfestation was observed.

Table 4: Effect of application methods on the FSI and its parasites/branch (after pruning) during 2000 season.

Treatment	Rate of applic. 1/litre	Pre spraying count				Average number				Average reduction %			
		FSI		Parasites		FSI		Parasites		FSI		Parasites	
		A	N	M	I	A	N	M	I	A	N	M	I
Oriented Spraying:													
Heavy oil	20 ml	17.2	31.1	3.1	5.2	2.3	1.4	0.2	0.5	91.3	96.8	95.6	93.6
Heavy oil + Sulfur	20 ml +2.5 g	22.1	35.4	4.8	7.8	1.1	0.3	0.1	0.4	96.8	99.4	98.6	96.6
Heavy oil +Malathion	20 ml +2 ml	19.8	31.4	3.3	4.9	2.6	1.6	0.0	0.0	91.5	96.4	100	100
Whole Tree Spraying:													
Heavy oil	20 ml	21.8	32.4	3.9	6.8	2.9	1.3	0.2	0.6	91.4	97.2	96.5	94.1
Heavy oil +Sulfur	20 ml +2.5 g	19.7	35.2	4.2	6.9	0.9	0.2	0.5	0.5	97.0	99.6	99.2	95.1
Heavy oil +Malathion	20 ml +2 ml	22.8	31.1	4.4	7.1	2.5	1.4	0.0	0.0	92.9	96.8	100	100
Control	-	23.1	36.2	5.5	7.3	35.6	51.1	8.1	10.9	-	-	-	-

A = Adult females (gravid and non gravid females)
N = Nymphs
M= Matures
I= Immatures

3.3.4 Whole tree spraying (before pruning)

One trial was carried out in May 2000 (after pruning) in the same time and in the same farm.

In this trial, the whole tree were sprayed after pruning (3 treatments) programs B, D and F (Table 1).

The average pre-spraying numbers of adult and nymphs of the FSI were 40.1-45.2 and 49.6-53.2 insects/branch and the average numbers of mature and immature of the parasites were 5.9-7.2 and 8.8-10.6/branch (Table 5). In this trail, the spraying solution covered the whole tree.

This trail gave similar results to those obtained from the oriented trail. Results in Table (5) indicated that, light oil + sulfur and light oil + malathion and light oil alone gave 99.7, 99.7 and 96.6% average reduction in infestation in this trial against adult females (gravid and non-gravid females), respectively and gave 99.9, 99.7 and 99.6% average reduction against nymphs, respectively.

The three tested chemicals in Table (5) showed toxic effect against the parasites (over 97% average reduction) in the apple farm in this trial.

The three treatments gave complete protection for 4 months after which, reinfestation was observed.

The tested chemicals gave better results in summer than in winter but the residual effect in winter was larger as in summer. This may be due to the positive correlation between the tested chemicals and temperature. Also, it may be due to the movements of crawlers in relation to uptake and the higher activity of gravid and non-gravid females.

Oriented spray in summer (before pruning) or in winter (after pruning) proving more effective.

As mentioned in materials and methods, 6 liters were sufficient for spraying the infested branches (before pruning) in the oriented spraying technique, while, covering of the whole tree needed 15 liters (before pruning). In other words, the treatment of infested branches is more economic (about 2.5 times), and safer to the environment than the spraying of the whole tree.

Table 5: Effect of application methods on the FSI and its parasites/branch (before pruning) during 2000 season.

Treatment	Rate of Applic. 1/litre	Pre spraying count				Average number				Average reduction %			
		FSI		Parasites		FSI		Parasites		FSI		Parasites	
		A	N	M	I	A	N	M	I	A	N	M	I
Oriented Spraying:													
Heavy oil	20 ml	35.6	49.6	6.4	9.8	2.5	1.2	0.2	0.5	94.7	98.3	97.8	96.1
Heavy oil + Sulfur	20 ml + 2.5 g	40.8	55.4	7.1	10.0	1.1	0.2	0.05	0.1	98.0	99.7	99.5	99.2
Heavy oil + Malathion	20 ml + 2 ml	38.1	51.9	6.8	8.9	2.5	0.8	0.0	0.0	95.1	98.9	100	100
Whole Tree Spraying:													
Heavy oil	20 ml	41.8	53.2	7.2	10.6	1.9	0.3	0.3	0.2	96.6	99.6	97.9	98.6
Heavy oil + Sulfur	20 ml + 2.5 g	45.2	51.7	6.7	9.6	0.2	0.05	0.06	0.1	99.7	99.9	99.2	99.2
Heavy oil + Malathion	20 ml + 2 ml	40.1	49.6	5.9	8.8	1.1	0.2	0.0	0.0	97.9	99.7	100	100
Control	-	46.2	57.2	7.4	10.1	61.5	79.1	10.6	13.2	-	-	-	-

A = Adult females (gravid and non gravid females), N = Nymphs, M= Matures, I= Immatures

Hindi *et al.*, (1964) found that the emulsion of local mineral oils, miscible oils and also their mixture with malathion were effective against the scale insects. Koehler (1964) obtained good results by carbaryl, dimethoate and oil against, Asterolecanium sp.

Hamon (1977), found that spraying of diazinon and malathion in oil emulsions and of dimethoate and oxydemeton-methyl gave the best control against the FSI. El-Kifl *et al.*, (1980) concluded that two applications gave better results against, A. pustulans when malathion, dimethoate or parathion were added to a mineral oil (Volck oil) than when Volck oil was used alone. Cen (1986), found that the application of malathion, dichlorvos and Fenvalerate gave high mortality against the FSI during hatching. Eraki (1991), reported that super Masrona oil was the most effective oil against adults. Ali (1993) found that tokuthion, basudin, malathion, sumithion, IGR and Indian lilac gave 73.7, 66.1, 65.2, 58.5, 55.9 and 6.1% reduction in infestation of the Russellaspis pustulans, respectively. Mangoud (1994) found that prothiophos, malathion, diazinon and Shecrona oil gave 92-96% reduction in infestation against nymphs of the R. pustulans. He also found that fenitrothion and buprofezin gave less effect against females.

3.4 Relative cost and efficiency of the tested programs (per feddan)

Estimated costs for different tested programs for controlling FSI are presented in Table (6).

Cost estimation (the costs of one spray) :

The needed amount of pesticide was calculated as follow:

The cost estimation calculated was based on the following:

Cost = (Rate of application) x (amount of pesticide liquid/tree) x (number of trees/unit area (feddan)) x (price of formulated insecticides).

After applying this formula to calculate the costs of each program in Egyptian pounds we find the following:

A= Whole tree spraying (after pruning):

a- [0.002 x 7 (liter/tree) x 250 (tree/fed.) x 20 L E/L] = 70 LE.

b- Labors = 6 (persons/fed.) x 7 L E = 42 LE (pounds).

c- Machinery = 50 LE.

Total costs = a + b + c = 70 + 42 + 50 = 162 LE.

B= Oriented spraying (after pruning):

a- [0.002 x 2.5 (liter/tree) x 250 (tree/fed.) x 20 L E/L] = 25 LE.

b- Labors = 3 (persons/fed.) x 7 L E = 21 LE (pounds).

c- Machinery = 50 pounds/2 fed.= 25 LE.

Total costs = a + b + c = 25 + 21 + 25 = 71 LE.

C = Whole tree spraying (before pruning):

a- [0.002 x 15 (liter/tree) x 250 (tree/fed.) x 20 L E/L] = 150 LE.

b- Labors = 6 (persons/fed.) x 7 L E = 42 LE (pounds).

c- Machinery = 50 LE.

Total costs = a + b + c = 150 + 42 + 50 = 235 LE.

D = Oriented spraying (before pruning):

a- [0.002 x 6 (liter/tree) x 250 (tree/fed.) x 20 L E/L] = 60 LE.

b- Labors = 3 (persons/fed.) x 7 L E = 21 LE (pounds).

c- Machinery = 50 pounds/2 fed.= 25 LE.

Total costs = a + b + c = 60 + 21 + 25 = 106 LE.

Programs C and A (whole tree spraying) are the most expensive (i.e. estimated cost as 235 and 162 LE) followed by programs D and B (oriented spraying) 106 and 71 LE/feddan (Table 6).

Programs D and B had the lowest costs than all programs. Therefore, it is suggested that programs D and B could be recommended for the control of FSI as they are more safe to the environmental less costly and more efficient.

Table 6: Comparison between different FSI programs concerning efficiency and costs environmental impact.

Item	A	B	C	D
Efficacay*	98.9	97.5	95.8	95.3
Control agent**	70	25	150	60
Labor	42	21	42	21
Machinery	50	25	50	25
Total costs	162	71	235	106

A = Whole tree spraying (after pruning)
B = Oriented spraying (after pruning)
C = Whole tree spraying (before pruning)
D = Oriented spraying (before pruning).
* Average % reduction for all treatments.
** Average price of used control agents in the first season.

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