PESTICIDE MIXTURES FOR CONTROLLING THE CITRUS RUST MITE PHYLLOCOPTRUTAOLEIVORA INFESTINGORANGE TREESIN WADI EL-NATROUN, EGYPT

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Abstract - Eight pesticide mixtures were evaluated to determine their efficacy against the eriophyid mite Phyllocoptrutaoleivorainfesting Valencia orange trees,Citrus sinensisL., in Wadi El-Natroun, Egypt. The pesticides hexythiazox, fenpyroximat, chlorfenapyr, abamectin, spirodiclofen and spirotetramat, at their ¾ recommended doses, were mixed individually with petroleum oil (P. oil) at the dose of 1 %. Moreover, abamectin, at its ¾ recommended dose, was mixed with sulfur, at the dose of 0.25 %, besides spirodiclofen at its ¾ recommended dose severally.Each mixture was sprayed 3 times a season for two successive summer seasons.The first inspection, after five days of each spray, showed that none of the mixtures achieved a mortality of 100 %. The second inspection, after ten days of each spray, showed that only the mixture of abamectin + Spirodiclofen achieved a mortality of 100 %. For the third inspection, after fifteen days of each spray, the mortality of 100 % was achieved by the mixtures of abamectin + Spirodiclofen, Abamectin + Sulfur, Abamectin + P. oil, and Hexythiazox + P.oil in both seasons;Spirodiclofen + P. oil in both seasons except at the first spray of the first season; andFenpyroximate + P. oil in addition to Chlorfenapyr + P. oil only at the third spray of the first season. It is worth saying that the mixture of spirotetramat + P. oil didn't show a mortality of 100 % at any inspection. The mean reduction percentage of the three sprays reveals that the effective mixtures, in descending order, are Abamectin + Spirodiclofen, Abamectin + Sulfur, Abamectin + P. oil, Spirodiclofen + P. oil, Hexythiazox + P. oil, Spirotetramat + P. oil, Fenpyroximate + P. oil, and Chlorfenapyr + P. oil. The maximum orange production was obtained by using the mixture of abamectin+ P. oil in the second season.

Keywords - Citrus rust mite, Valencia orange, Egypt, Pesticide mixtures, Infestation reduction

I. INTRODUCTION

The citrus rust mite, Phyllocoptrutaoleivora (Ashmead), is one of the mite species belonging to the family Eriophyidae.It is called the silver mite on lemon and rust mite on oranges; it is also known as a non webbing mite. In fact, it is now found in most citrus-growing areas of the world. Infestation and damage have been studied extensively [1]-[2]-[3]-[4]-[5]-[6].There was positive correlation between the incidence of rusting on fruit and rust mite density [7]. The blemishes caused by the presence of rust mites lower the grade of the fruit and reduce its size[8]. The mite infestation directly affects orange production, quality, and appearance especially when the attack occurs on young fruit [9]-[10].

Chemical control is based on the use of various kinds of substances belonging to different chemical groups, commonly known as acaricides,and sometimes they are also active against insects.The use of pesticides provides a quick and sometimes effective solution to pest problems especially with the choice of safe systemic acaricides with little effect on the natural enemies, environment, crop and humanity [11]-[12]-[13]-[14].

Phyllocoptruta.oleivoracan be a serious pest during the post bloom and summer periods, and thus may require a miticide application during one or both times, depending upon citrus variety, mite presence and risk of population increase [15].Pesticide mixtures were found to have been effective against P. oleivora[16]-[17]-[18].

Therefore, the present investigation was carried out toevaluate the efficacy of different chemical pesticide mixtures on the infestation level of the citrus rust mite,P. olievora, and on Valencia alencia orange production in Wadi El-Natroun, Bohairagovernorate, Egypt during two successive summer seasons.

II. MATERIALS AND METHODS

2.1. Designating orange trees

The area specialized to evaluate each pesticide mixture consisted of three replicates, each of which contained three trees. The trees were 8 years old.

2.2. Tested pesticide mixtures

The evaluated pesticidemixtures and their rates of application are shown in Table (1).

Spraying the pesticide mixtures was performed using a knapsack sprayer, whereby a three-liter dose was designated for each tree. Water at pH level of 6.2 - 6.5 was used to prepair the pesticide dilutions.Spraying was applied at the beginning of summer. Each mixture was sprayed 3 times a season for two successive summer seasons.Theagricultural practices during both seasons were done for the traeted and untreated check trees.

Table 1: The evaluated mixtures of pesticidesand their rates of application

Common names of mixtures	Formulationa i (%)@	Application rate (ml / 100liter water)
Hexythiazox + P. oil #	5 EC*** + 80 EC	40 + 1000
Fenpyroximate + P. oil	5 EC + 80 EC	40 + 1000
Chlorfénapyr + P. oil	36 SC ** + 80 EC	60 + 1000
Spirodiclofen + P. oil	24 SC + 80 EC	22.5 + 1000
Spirotetramat + P. oil	22.4 SC + 80 EC	80 + 1000
Abamectin + P. oil[#]	1.8 EC + 80 EC	33.7 + 1000
Abamectin + Sulfur	1.8 EC + 80 WG*	33.7 + 250g⌂
Abamectin +Spirodiclofen	1.8 EC + 24SC	33.7 + 22.5

[@] a i (%) = active ingredient percintage.
[#] P. oil = Petroleum oil.
*** EC = Emulsifiable Concentrate.
**SC = Suspensed Concentrate.
*WG = Water Granules.
⌂g = Solid material formulation in grames.

2.3. Sampling technique for the citrus rust mite inspection

Twenty leaves were randomly collected from each replicate to inspect the infestation by the citrus rust mite. The numbers of mites found before the application of each pesticide mixture were recorded. Moreover, The numbers of mites found after 5, 10, and 15 days of the application of each pesticide mixture were also recorded.

The percentages of infestation reduction due to the pesticide applications were calculated according to the equation ofHenderson and Tilton [19]. The untreated area was subjected to the same inspections at the same times as well.

2.4. Statistical analysis

Data were subjected to the analysis of variance ANOVA using ″F″ Test following the complete randomized block design (CRBD), with three replications for each treatment.Mean numbers of the mite individuals of the three replications were previously rounded to the nearest whole numbers.

The least significant differences (L.S.D) at the 0.05 ≤ level were determined according to the computer program COSTAT software[20]and Duncan's Multiple Range. Testes modified by Steel and Torrie [21] were applied to compare the average numbers of the inspected mites at different intervals.

III. RESULTS AND DISCUSSION

3.1. Reduction percentages at different intervals

The lethal effect of the pesticide mixtures against the citrus rust miteduring the two seasons is presented in Tables (2to7).

All the tested pesticide mixtures significantly reduced the rust mite populations detected on Valencia orange trees compared with the untreated check.

Reduction percentages at different intervals reveal that the efficacy of each evaluated pesticide mixture increases as time passesafter the treatmentexcept for the mixtures Chlorfenapyr + P. oil and Spirotetramat + P. oil at the 2nd spray in the second season when the reduction percentages decreased.The activity of these tested mixtures increases with time due to more contact and more effect of their residues on the mites.

Regarding the first inspection, after five days of each spray, all the tested compounds significantly reduced the mitenumbers. The first inspection always showed that none of the mixtures had achieved a mortality of 100% in neither season.

The second inspection, after ten days of each spray, showed that only the mixture of abamectin + Spirodiclofenhad achieved a mortality of 100 % in both seasons.

As for the third inspection, after fifteen days of each spray, the mortality of 100 % was achieved by the mixtures of abamectin + Spirodiclofen, Abamectin + Sulfur, Abamectin + P. oil, and Hexythiazox + P.oil in both seasons;Spirodiclofen + P. oil in both seasons except at the first spray of the first season; andFenpyroximate + P. oil in addition to Chlorfenapyr + P. oil only at the third spray of the first season. Such these mixtures containing abamectin would be useful for the integrated pest

management since the compounds added to abamectin would be effective against other pests.It is worth saying that the mixture of spirotetramat + P. oil didn't show a mortality of 100 % at any inspection, and showed the least reduction perentage throughout the experiment inspections, 76.1%, after five days of the second spray in the first season. The mixture of Abamectin + Spirodiclofenwas the most effective one throughout the two seasons recording the first rank of the mean reduction percentage of the three inspections afterall sprays.

Table 2: Evaluation of the pesticide mixtures after the 1st spray in the first season

Pesticide mixtures	Mean numbers of the mite individuals (M), and reductionpercentage (R %) at different intervals.							Mean R %	rank
	b. @	5 days		10 days		15 days			
	M	M	R%	M	R%	M	R%		
Hexythiazox + P.oil	188	47 b*	81.0	15 de	94.7	0 b	100.0	91.9	5
Fenpyroximate + P. oil	192	51 b	79.9	25 bc	91.4	8 b	97.0	89.4	7
Chlorfenapyr + P. oil	186	52 b	78.8	29 b	89.7	12 b	95.4	88.0	8
Spirodiclofen + P. oil	194	43 b	83.2	14 de	95.2	0 b	100.0	92.8	4
Spirotetramat + P. oil	189	51 b	79.9	20 cd	93.0	4 b	98.5	90.5	6
Abamectin + P. oil	202	42 b	84.2	10 e	96.7	0 b	100.0	93.6	3
Abamectin + Sulfur	201	39 b	85.3	12 de	96.0	0 b	100.0	93.8	2
Abamectin +Spirodiclofen	224	17 c	94.2	0 f	100.0	0 b	100.0	98.1	1
Untreated check	188	248 a		286 a		264 a			
LSD 0.05	17.66	14.5		7.85		12.81			

Table 3: Evaluation of the pesticide mixturesafter the 2nd spray in the first season

Pesticide mixtures	Mean numbers of the mite individuals (M), and reductionpercentage (R %) at different intervals.							Mean (R %)	rank
	b. @	5 days		10 days		15 days			
	M	M	R%	M	R%	M	R%		
Hexythiazox + P. oil	178	46 b*	77.7	14 cd	93.5	0 d	100.0	90.4	5
Fenpyroximate + P. oil	194	48 b	78.7	35 b	85.2	17 b	93.0	85.6	7
Chlorfenapyr + P. oil	188	52 b	76.2	32 b	86.0	18 b	92.3	84.8	8
Spirodiclofen + P. oil	199	52 b	77.5	13 d	94.6	0 d	100.0	90.7	4
Spirotetramat + P. oil	191	53 b	76.1	22 c	90.5	9 c	96.2	87.6	6
Abamectin + P. oil	205	47 b	80.5	9 d	96.4	0 d	100.0	92.3	3
Abamectin + Sulfur	150	29 c	83.4	10 d	94.5	0 d	100.0	92.6	2
Abamectin + Spirodiclofen	196	12 d	94.7	0 e	100.0	0 d	100.0	98.2	1
Untreated check	229	266 a		279 a		286a			
LSD 0.05	18.4	12.0		8.15		4.84			

Table 4: Evaluation of the pesticide mixtures after the 3rd spray in the first season

Pesticide mixtures	Mean numbers of the mite individuals (M), and reductionpercentage (R %) at different intervals.							Mean (R %)	rank
	b. @	5 days		10 days		15 days			
	M	M	R%	M	R%	M	R%		
Hexythiazox + P. oil	202	45b*	83.3	23 bc	92.3	0 b	100.0	91.9	5
Fenpyroximate + P. oil	208	47 b	83.0	26 b	91.9	0 b	100.0	91.6	6
Chlorfenapyr + P. oil	198	45 b	83.0	25 b	91.8	0 b	100.0	91.6	6
Spirodiclofen + P. oil	222	51 b	82.8	14 cd	95.9	0 b	100.0	92.9	4
Spirotetramat + P. oil	202	52 b	80.7	28 b	91.0	7 b	98.0	89.9	7
Abamectin + P. oil	238	40 bc	87.4	11 d	97.0	0 b	100.0	94.8	3
Abamectin + Sulfur	202	30 cd	88.9	8 de	97.4	0 b	100.0	95.4	2
Abamectin + Spirodiclofen	226	17 d	94.4	0 e	100.0	0 b	100.0	98.1	1
Untreated check	144	192 a		223 a		258 a			
LSD 0.05	18.2	13.69		9.82		9.0			

b. @ = Mean number of the mite individuals before spray. *Means followed by the same letter in each column are not significantly different at $P< 0.05$ level.

Table 5: Evaluation of the pesticide mixturesafter the1st spray in the second season

Pesticide mixtures	Mean numbers of the mite individuals (M), and reductionpercentage (R %) at different intervals.							Mean (R %)	rank
	b. @	5 days		10 days		15 days			
	M	M	R%	M	R%	M	R%		
Hexythiazox + P. oil	101	24c*	83.7	13 cd	91.8	0 c	100.0	91.8	5
Fenpyroximate + P. oil	100	32 bc	80.8	16 c	89.8	10 b	92.6	87.7	7
Chlorfenapyr + P. oil	107	30 bc	80.8	19 bc	88.7	10 b	93.1	87.5	8
Spirodiclofen + P. oil	125	31 bc	83.0	8 de	95.9	0 c	100.0	93.0	4
Spirotetramat + P. oil	142	38 b	81.7	24 b	89.2	13 b	94.8	88.6	6
Abamectin + P. oil	160	34 bc	85.4	5 ef	98.0	0 c	100.0	94.5	3
Abamectin + Sulfur	158	33 bc	85.7	5 ef	98.0	0 c	100.0	94.6	2
Abamectin + Spirodiclofen	152	26 c	88.3	0 f	100.0	0 c	100.0	96.1	1
Untreated check	128	187a		201a		174a			
LSD 0.05	19.96	9.05		6.17		5.04			

Table 6: Evaluation of the pesticide mixtures after the 2nd spray in the second season

Pesticide mixtures	Mean numbers of the mite individuals (M), and reductionpercentage (R %) at different intervals.							Mean (R %)	rank
	b.@	5 days		10 days		15 days			
	M	M	R%	M	R%	M	R%		
Hexythiazox + P. oil	137	52 b*	83.3	20 b	91.3	0 c	100.0	91.5	5
Fenpyroximate + P. oil	104	40bcd	83.1	18bc	89.7	4 b	92.6	88.5	7
Chlorfenapyr + P. oil	120	50 bc	81.7	13 cd	93.6	7 b	88.8	88.0	8
Spirodiclofen + P. oil	123	45bcd	83.9	12 cd	94.2	0c	100.0	92.7	4
Spirotetramat + P. oil	117	41bcd	84.6	13 cd	93.4	7 b	88.5	88.8	6
Abamectin + P. oil	155	39cd	88.9	10 d	96.2	0 c	100.0	95.0	3
Abamectin + Sulfur	134	33 d	89.2	8 d	96.5	0 c	100.0	95.2	2
Abamectin + Spirodiclofen	150	33 d	90.3	0 e	100	0 c	100.0	96.8	1
Untreated check	119	271 a		201a		62a			
LSD 0.05	19.35	11.41		6.07		3.1			

Table 7: Evaluation of the pesticide mixtures after the 3rd spray in the second season

Pesticide mixtures	Mean numbers of the mite individuals (M), and reductionpercentage (R %) at different intervals.							Mean (R %)	rank
	b. @	5 days		10 days		15 days			
	M	M	R%	M	R%	M	R%		
Hexythiazox + P. oil	141	36bc*	81.6	12 bc	92.2	0 c	100.0	91.3	5
Fenpyroximate + P. oil	121	33bcd	80.4	17 b	89.9	4 bc	95.9	88.7	7
Chlorfenapyr + P. oil	136	40 b	78.8	19 b	87.3	6 b	94.5	86.9	8
Spirodiclofen + P. oil	138	29bcde	84.9	12 bc	92.1	0 c	100.0	92.3	4
Spirotetramat + P. oil	119	26cde	84.2	12 bc	90.8	5 b	94.7	89.9	6
Abamectin + P. oil	148	25cde	87.8	8 bc	95.1	0 c	100.0	94.3	3
Abamectin + Sulfur	128	21 de	88.1	7 bc	95.0	0 c	100.0	94.4	2
Abamectin + Spirodiclofen	152	19 e	91.0	0 c	100.0	0 c	100.0	97.0	1
Untreated check	201	279 a		221 a		161 a			
LSD 0.05	23.65	12.29		11.01		4.13			

b. @ = Mean number of the mite individuals before spray. *Means followed by the same letter in each column are not significantly different at $P< 0.05$ level.

The presented results are in agreement with a previous study which proved that the miticide, abamectin, combined with 0.2% petroleum oil controlled the rust mite P. oleivora(Ashmead) for 20 weeks in a trial conducted on late Valencia oranges in Numbour, Queens land, Australia [22].

Another previous study showed that petroleum oil (P. O.) was effective against the citrus rust mite P. oleivora (Ashmead) at higher doses when it was tested in Florida [23].

Fenpyroximate with oil, in an earlier investigation, provided significantly better control of rust mites on leaves compared with fenpyroximate alone [18].

Obviously, in the present study, the mixture of fenpyroximate with petroleum oil (P. oil) was effective but was not as effective as the mixture of

abamectin + P. oil. The presented results agree with the preceding results in whichthe residual control of fenpyroximate on fruit applied either alone or with oil was not as effective as Micromite® (difluobenzuron) or Agri-Mek® (abamectin) with oil against the citrus rust mite[18]. The present study also shows that petroleum oil is proved to be of great importance especially when mixed with abamectin and/or hexythiazox.Mineral oils can control a range of pests and can replace the synthetic pesticides in organic-based control [24].Mineral oils are currently regarded as more environmentally friendly than synthetic pesticides. Such oils are again becoming an essential part of many Integrated Pest Management (IPM) programs. The integration of mineral oils is mainly because they are effectively non-toxic to vertebrates, and degradable. Moreover they have never been associated with resistance or outbreaks of secondary pests. Generally, chemical control is the most used method for mite control in citrus; in Southwestern Colombia, abamectin was the most widely product used to control P. oleivora[25].In a previous study, treatments including abamectin reduced the citrus rust mite densities through 61 days after treatment; it was found that abamectinhas been less harmful to the predatory mite, Amblyseiusswirskii, and so it would be useful for preserving the biological-control agents [10].

3.2. General mean of reduction percentages of the three sprays

The mean reduction percentage of the three sprays in the first season Table(8)reveal that the effective mixtures, in descending order, are Abamectin + Spirodiclofen, Abamectin + Sulfur, Abamectin + P. oil, Spirodiclofen + P. oil, Hexythiazox + P. oil, Spirotetramat + P. oil, Fenpyroximate + P. oil, and Chlorfenapyr + P. oil.The second seasonTable(9)asserted the same results of the first season results.

Table 8: The general mean of reduction of the mite individuals during the first season.

Pesticide mixtures	Reduction mean (%) of spray No.			General mean of reduction(%)	rank
	1	2	3		
Hexythiazox + P. oil	91.9	90.4	91.9	91.4	5
Fenpyroximate + P. oil	89.4	85.6	91.6	88.9	7
Chlorfcnapyr + P. oil	88.0	84.8	91.6	88.1	8
Spirodiclofen + P. oil	92.8	90.7	92.9	92.1	4
Spirotetramat + P. oil	90.5	87.6	89.9	89.3	6
Abamectin + P. oil	93.6	92.3	94.8	93.6	3
Abamectin + Sulfur	93.8	92.6	95.4	93.9	2
Abamectin + Spirodiclofen	98.1	98.2	98.1	98.1	1

Table 9: The general mean of reduction of the mite individuals during the second season.

Pesticide mixtures	Reduction mean (%) of spray No.			General mean of reduction(%)	rank
	1	2	3		
Hexythiazox + P. oil	91.8	91.5	91. 3	91.5	5
Fenpyroximate + P. oil	87.7	88.5	88.7	88.3	7
Chlorfenapyr + P. oil	87.5	88	86.9	87.5	8
Spirodiclofen + P. oil	93	92.7	92.3	92.7	4
Spirotetramat + P. oil	88.6	88.8	89.9	89.1	6
Abamectin + P. oil	94.5	95	94.3	94.6	3
Abamectin + Sulfur	94.6	95.2	94.4	94.7	2
Abamectin + Spirodiclofen	96.1	96.8	97	96.6	1

3.3 Effect of the pesticide mixtures on production

Fruit production of the treated trees (Tons/fed.) for each treatment,Table (10), was more than that of the untreated check by about 34 - 54 %.In another orchard, the release of certain predatory mites and abamectin application showed the least damage caused by P. oleivora mite on fruit [26]. In a previous experiment, petroleum oil spray reduced chemical pesticide usage, and increased the species richness of natural enemies. Petroleum oil had negative effect on neither fruit yield nor quality, and can form the basis of pest management program for navel orange [27].

Table 10: Orange production in the two seasons

Pesticides mixtures	Mean production	
	1st season	2nd season
Hexythiazox + P. oil	17.6ab	18.0 b
Fenpyroximate + P. oil	16.5 c	17.0 d
Chlorfenapyr + P.oil	16.4 c	16.5 e
Spirodiclofen + P. oil	18.0 a	18.0 b
Spirotetramat + P.oil	17.2 b	17.5 c
Abamectin + P. oil	18.0 a	18.5 a
Abamectin + Sulfur	17.8 a	18.0 b
Abamectin + Spirodiclofen	18.0 a	18.3ab
Untreated check	12.0 d	12.3 f
LSD 0.05	0.45	0.49

* Means followed by the same letter in each column are not significantly different at P< 0.05 level.

In conclusion, thestudied pesticides can be used in thismethod, at their ¾ recommended doses, aiming to reduce their harmful effect on humanity and the environment.

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