LABORATORY AND FIELD STUDIES ON THE EFFECT OF SEQUENTIAL APPLICATION OF PESTICIDES ON SUSCEPTIBILITY AND ON SOME BIOLOGICAL ASPECTS OF MITE *TETRANYCHUS CINNABARINUS* (BOISD.)

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MITES
AND
INSECTICIDES
TETRANYCHUS
CINNABARINUS
SOYBEAN

ABSTRACT : Laboratory and field evaluation on the effect of sequential application of dicofol, omethoate and cypermethrin insecticides on the susceptibility, biology and population density of the mite *Tetranychus cinnabarinus* were studied through the course of the present investigation. The results obtained may be summarized as follows :

1. The susceptibility of adult female mites to dicofol, omethoate and cypermethrin applied sequentially over three generations was studied. Susceptibility was varied due to the type of chemical as well as to the scheme of insecticidal sequences used.
2. Biological studies indicate that the life span of selected mites was extended, this was more pronounced in the schemes of (cypermethrin / cypermethrin / cypermethrin) — and (cypermethrin / dicofol / omethoate) — selected strains. Also, egg production was significantly increased in case of (cypermethrin / cypermethrin / cypermethrin) — selected strain, while decreased in case of (omethoate / omethoate / omethoate) — selected strain. The percent of hatchability was significantly decreased, this was highly occurred in (cypermethrin / omethoate / dicofol) — selected strain.
3. Field studies show that plots sprayed successively three times with dicofol recorded the highest reduction in mite population infesting soybean plants. The contrary was obtained in plots sprayed successively three times with cypermethrin. This indicate the necessity of using specific potent acaricide on soybean in case cypermethrin is used to control the cotton leafworm to avoid outbreak of mite infestation.

ACARIENS
ET
INSECTICIDES
TETRANYCHUS
CINNABARINUS
SOJA

RÉSUMÉ : L'évaluation au laboratoire et dans la nature de l'effet d'une application séquencielle des insecticides dicofol, omethoate et cypermethrine sur la susceptibilité, la biologie et la densité de population de *Tetranychus cinnabarinus* a été étudiée tout au long de nos investigations. Les résultats obtenus peuvent se résumer comme suit :

1. La susceptibilité des femelles adultes au dicofol, à l'omethoate et à la cypermethrine séquenciellement appliqués pendant plus de trois générations a été

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étudiée. La susceptibilité a manifesté des variations dues au type de produit chimique aussi bien qu'au mode de séquences insecticides utilisés.

2. Les études biologiques ont montré que la durée de vie des acariens mis en expérience s'allonge ; cela fut très prononcé pour les modes de séquences insecticides (cypermethrine / cypermethrine / cypermethrine) et (cypermethrine / dicofol / omethoate). Aussi, la production des œufs s'est accrue de manière sensible dans le cas du mode des séquences insecticides (cypermethrine / cypermethrine / cypermethrine), tandis qu'elle a baissé dans le cas du mode (omethoate / omethoate / omethoate). Le pourcentage de capacité de ponte a baissé de manière sensible, et cette baisse fut remarquable pour le mode des séquences insecticides (cypermethrine / omethoate / dicofol).
3. Les études dans la nature ont montré que les parcelles traitées successivement trois fois au dicofol présentent la réduction la plus élevée de la population de l'acarien infestant le soja. L'inverse a été obtenu dans les parcelles traitées successivement trois fois à la cypermethrine. Cela montre la nécessité d'employer sur le soja, dans le cas où on utilise la cypermethrine pour contrôler le ver cotonneux de la feuille, un acaricide au pouvoir spécifique pour permettre l'arrêt de l'infestation de l'acarien.

Introduction

Soybean (*Glycine max.* L.) is one of the most important leguminous crop in the world. In Egypt, great attention has been paid recently to improve total production and quality by increasing the area under soybean cultivation and/or by raising the yield per feddan. This may be achieved by using high yielding varieties and/or by improving agronomic practices such as pest control.

It is well known that soybean plants may be attacked by several arthropod pests during the growing season, including *Spodoptera littoralis, Tetranychus cinnabarinus, Thrips tabaci, Aphis sp., Empoasca sp.* and *Bemisic tabaci* (Mansour et *al.* 1974 and Naguib et *al.* 1979). Many investigators have reported that dicofol is the most effective acaricide for controlling mites, omethoate for *Thrips, Bemisia & Empoasca*, and the synthetic pyrethroid, cypermethrin, for *S. littoralis.*

During the scheme of soybean pest control in Egypt, mite populations may be accidently or indirectly exposed to omethoate or cypermethrin mainly applied for controlling *S. littoralis, Pectinophora gossypiella, Erias insulana, Thrips tabaci* and *Bemisia tabaci*. Accordingly, the present study aimed to investigate the efficacy of repeated application of cypermethrin, omethoate and dicofol either singly or in sequential use against *T. cinnabarinus* under both laboratory and field conditions. The long range effects of chemical treatment on some biological aspects of mites were also estimated.

MATERIALS AND METHODS

1. *Test organism :*

Adult female *T. cinnabarinus* were taken from a pesticide-free mite colony reared in the laboratory on sweet potato cuttings, according to the method adopted by Ghobrial et *al.* (1969). This colony was brought to the laboratory in July 1971 from infested leaves of castor bean grown in Sakha Agricultural Research Station, Kafr El-Sheikh governorate, Egypt.

2. *Pesticides used :*

Dicofol (Kelthane) 18.5 % E.C. 2,2,2-trichloro-1,1-bis (4-chlorophenyl) ethanol ; omethoate (Folimat) 80 % E.C. 0,0-dimethyl-S-(N-methyl carbamoylmethyl)-phosphorothioate and cypermethrin (CCN 52) 10 % E.C. (RS)-α- cyano-3 phenoxybenzyl (ISR)-cis, trans-3-(2,2-dichlorovinyl)-2,2-dimethyl-cyclopropanecarboxylate.

3. *Toxicological tests :*

A leaf-disc dip method (SIEGLER, 1947) was applied to evaluate the susceptibility of adult female mites to the forementioned pesticides. Four sweet potato leaf discs (1.5 cm in diameter) were placed upside down on a filter paper over a wet cotton pad in a petridish 9 cm in diameter. Then 25 adult female mites were placed on the exposed surface of each disc. Treatments were carried out by immersing the infested leaf discs in the test concentration of toxicant for 5 seconds, returning the treated discs to the petridishes, and maintaining them under constant conditions of 27 ± 2°C and 65 ± 5 % R. H. Mortality was counted after 24 hours and corrected for natural mortality by using ABBOTT's formula (1925).

The colony was divided into 10 sub-colonies, one of which was reared far from any pesticidal treatment. Each of the remaining subcolonies was subjected to selection pressure with one toxicant in the first generation at the LC_{25} level. In the next generation, each selected subcolony was subjected to pesticide pressure by using the same compound or a different one, based on a prearranged scheme. This technique was adopted for 3 successive generations by applying the three test compounds in sequential pattern.

Susceptibility in each subcolony was estimated before each selection by using the immersing technique, the toxicity line of each compound was established, and the subcolony was subjected to selection pressure at the LC_{25} level of the test toxicant.

4. *Measurements of some biological aspects :*

The biology of mites subjected to selection pressure for 3 generations was performed at the end of the test (the fourth generation) and compared with that of the unselected mites using the technique of GAABOUB et *al.* 1982. Larval, protonymphal, and deutonymphal periods, adults longevity, pre-oviposition period, oviposition period, egg production and hatchability percentage were measured at 27 ± 2°C and 65 ± 5 % R.H.

5. *Field studies :*

Soybean var. Clark was planted on June 11, 1982 in a field divided into 40 plots (42 m² each). Treatments were distributed in a complete randomized block design with 4 replicates. Cypermethrin, omethoate and dicofol were applied three times either singly or in a sequential scheme on August 1*st* & 23*rd* and on September 6*th*, 1982. A knapsack sprayer, Model CP 3 (200 litres/feddan), was used for applying the pesticidal solutions. Samples of five plant leaves were collected weekly from each plot at random from the inner rows of each plot and the number of moving stages of mites was recorded on each assessment date.

Duncan's multiple range test at the 5 % level was used for statistical analysis of significant differences among treatments. The percentage of reduction in infestation was also calculated for each treatment according to the HENDERSON and TELTON equation (1955).

RESULTS AND DISCUSSION

1. *Effect of pesticide sequences on the susceptibility of T. cinnabarinus :*

Table I shows the changes in susceptibility in adult female mites subjected to repeated selection with dicofol, omethoate and cypermethrin for 3 generations. Summarized results show that dicofol was the most potent toxicant to the laboratory strain (parent) of *T. cinnabarinus* adult females, followed in decreasing order by cypermethrin and omethoate. Repeated selection with both dicofol and omethoate induced clear reduc-

TABLE I. Changes in susceptibility in adult females of *T. cinnabarinus* during selection by dicofol, omethoate and cypermethrin for 3 generations.

Pesticide	Generation	LC_{25} ppm	LC_{50} ppm	Slope	Resistance ratio at LC_{50} (RR)*
Dicofol	P	44	135	1.35	—
	F_1	50	320	0.95	2.37
	F_2	92	270	1.52	2
	F_3	76	560	0.7	4.15
Omethoate	P	500	1600	1.4	—
	F_1	500	2100	1.1	1.31
	F_2	1000	4100	1.1	1.31
	F_3	1100	6600	0.85	4.13
Cypermethrin	P	130	880	0.8	—
	F_1	500	1000	2.15	1.14
	F_2	220	820	1.16	0.93
	F_3	100	350	1.17	0.4

$$* \text{ RR} = \frac{LC_{50} \text{ for selected generation}}{LC_{50} \text{ for parents}}$$

tion in susceptibility of adult female mites to such toxicants (resistance ratio was 4.15 : 1 and 4.13 : 1 / in F_3, respectively). Susceptibility of the cypermethrin-selected strain was decreased in the F_1 and then increased in both the F_2 and F_3 generations. The mites of F_3 were 2.5 times more susceptible than their parents.

TABLE II. Changes in susceptibility to pesticides in adult females of *T. cinnabarinus* during selection with pesticides in sequential use.

Generation	Pesticide	LC_{25} ppm	LC_{50} ppm	Slope
P	Dicofol	44	135	1.35
F_1	Omethoate	580	2600	1.02
F_2	Cypermethrin	220	1000	0.99
P	Omethoate	500	1600	1.4
F_1	Dicofol	40	260	0.82
F_2	Cypermethrin	350	940	1.57
P	Cypermethrin	130	880	0.8
F_1	Dicofol	68	300	1.07
F_2	Omethoate	1050	4500	1.07
P	Dicofol	44	135	1.35
F_1	Cypermethrin	200	700	1.26
F_2	Omethoate	1150	3400	1.47
P	Omethoate	500	1600	1.4
F_1	Cypermethrin	180	450	2.5
F_2	Dicofol	70	350	1.0
P	Cypermethrin	130	880	0.8
F_1	Omethoate	660	3200	0.99
F_2	Dicofol	100	240	1.78

Table II shows the effect of sequential application of pesticides on the susceptibility of *T. cinnabarinus* to these compounds. It is obvious that dicofol was more effective when tested against F_1 mites previously selected with either omethoate or cypermethrin than those selected with dicofol. The same result was obtained when cypermethrin was tested against mites selected in the parent generation with dicofol or with omethoate. However, omethoate was less effective on mites of the generation whose parents were exposed to dicofol or cypermethrin than those tested against the omethoate-selected strain.

As regards the *2nd* filial generation (table II) it is obvious that the susceptibility to cypermethrin of mites selected in parent and F_1 generations with dicofol and omethoate was slightly decreased when compared with those previously selected with cypermethrin alone (LD_{50} of cypermethrin in F_2 was 820 ppm in C — selected strain, table 1). This was true when omethoate was tested (cypermethrin/dicofol) — and (omethoate) — selected strains, and when dicofol was tested against (omethoate / cypermethrin) — and (dicofol) — selected strains. On the other hand (dicofol / cypermethrin) — selected strain was more susceptible to omethoate than was the omethoate selected strain. The same result was recorded when dicofol was tested against (cypermethrin / omethoate) — and (dicofol) — selected strains.

Data presented in table III show the susceptibility to dicofol, omethoate and cypermethrin of F_3 adult female mites selected during the preceding three generations with these compounds in sequential use. Summarized results show that the susceptibility of F_3 mites varied considerably, depending on the scheme of pesticide sequences used in selection, and on the toxicant used in the susceptibility test. Taking the susceptibility of parents as a base line for comparison, the response to dicofol of mites selected with the three toxicants in sequential used was decreased by 1.85 to 3.41 fold, whereas those selected with dicofol only showed a susceptibility decrease of 4.15 fold. Also, the susceptibility to omethoate was decreased by 2.67 to 5.5 fold in mites selected sequentially with the three test pesticides compared to a

TABLE III. Susceptibility to dicofol, omethoate and cypermethrin of adult female mites (F_3 generation) selected in P, F_1 and F_2 with pesticides in sequential use.

Pesticides * used for selection in P, F_1 & F_2	Pesticides tested in F_3								
	Dicofol			Omethoate			Cypermethrin		
	LC_{50} ppm	Slope	RR **	LC_{50} ppm	Slope	RR	LC_{50} ppm	Slope	RR
D + D + D	560	0.7	4.15						
O + O + O				6600	0.85	4.13			
C + C + C							350	1.17	0.4
D + O + C	460	1.14	3.41	8800	0.77	5.5	800	1.22	0.91
O + D + C	330	1.49	2.44	4800	1.16	3	920	1.31	1.05
C + D + O	290	1.43	2.15	5200	1.34	3.25	800	0.85	0.91
D + C + O	330	1.53	2.44	7800	1.47	4.88	860	1.58	0.98
O + C + D	250	1.48	1.85	8000	1.6	5	260	1.27	0.3
C + O + D	260	1.61	1.93	4300	1.11	2.67	1000	1.06	1.14

* D = Dicofol.
O = Omethoate.
C = Cypermethrin.

$$RR = \frac{LC_{50} \text{ of compound A for } F_3}{LC_{50} \text{ of compound A for P}}$$

4.14 fold decrease in mites subjected to repeated selection with omethoate.

As regards the susceptibility to cypermethrin, it is obvious that repeated selection with this compound for 3 generations induced a 2.5 fold increase in sensitivity of adult female mites. On the other hand, the susceptibility to cypermethrin of mites selected with pesticides in sequential use showed about a 2.3 fold increase when the mites were subjected to selection pressure with omethoate and cypermethrin, and then dicofol. The response of the remaining sub-groups to cypermethrin was only slightly changed (0.91 to 1.14 fold compared to that of parents).

2. *Effect of pesticide sequences on some biological aspects :*

Data presented in table IV show that all biological aspects were significantly affected by pesticidal selection with the exception of the preoviposition period, protonymphal and deutonymphal periods. Selection with pesticides prolonged the larval period, and this was especially noticed in the subcolony subjected to repeated selection with dicofol. Insignificant increase or decrease in such period was recorded.

The protonymphal period was extended significantly in the subcolony selected with the (cypermethrin / dicofol / omethoate) scheme compared with that in the subcolony exposed to repeated selection with omethoate and cypermethrin. However, similar results were recorded in deutonymphal longevity in the subcolony selected with (omethoate / cypermethrin / dicofol) scheme and with that selected with cypermethrin only.

Adult longevity was significantly prolonged in six selected subcolonies, especially with those selected with the (cypermethrin / dicofol / omethoate) scheme. Repeated selection with omethoate reduced longevity from 5.38 ± 1.49 to 4.4 ± 1.02 days.

The oviposition period was prolonged significantly in mites selected with (omethoate / cypermethrin / dicofol) and (cypermethrin / cypermethrin / cypermethrin) schemes.

Concerning life span, it is obvious that pesticidal selection affected this aspect significantly. The life span was extended significantly in six subcolonies, namely those treated with (cyper-

TABLE IV. Duration of immature stages and life cycle of *T. cinnabarinus* as influenced by different pesticides in sequential use (in days).

Treatments	Larval period	Protonymphal period	Deutonymphal period	Adult longevity	Life span	Pre-oviposition period	Ovi-position period	Egg production	% of hatchability
D + D + D	3.1 ± 0.19*a	1.85 ± 0.15ab	2.5 ± 0.31ab	7.13 ± 2.16a	15.4 ± 0.91ab	1.25 ± 0.25**	8 ± 2.89ab	31.5 ± 13.63ab	95.7 ± 2.58abc
O + O + O	2.61 ± 0.16ab	1.5 ± 0.13b	2.54 ± 0.4ab	4.4 ± 1.02c	12.5 ± 0.34d	1.2 ± 0.2	5.6 ± 1.08d	16.4 ± 3.65e	92.54 ± 5.74bc
C + C + C	2.2 ± 0.09b	1.5 ± 0.12b	2 ± 0.15b	7.08 ± 1.68ab	16 ± 1.23a	1 ± 0.00	9 ± 1.24a	39.14 ± 6.92a	97.87 ± 1.15ab
D + O + C	3 ± 0.21a	2 ± 0.15ab	2.27 ± 0.18ab	5.91 ± 1.46bc	13.4 ± 0.73bcd	1.14 ± 0.14	7.14 ± 1. 3bc	18.71 ± 3.28de	91.81 ± 3.53c
O + D + C	2.25 ± 0.12b	1.89 ± 0.15ab	2.12 ± 0.17ab	5.64 ± 0.99c	13 ± 0.81cd	1.22 ± 0.15	6.11 ± 1.11cd	22.78 ± 6.43cd	94.36 ± 3.71abc
C + D + O	3.05 ± 0.19a	2.08 ± 0.26a	2.7 ± 0.15ab	8.38 ± 1 a	15.8 ± 1.07a	1.25 ± 0.16	6.75 ± 0.88bcd	28.13 ± 6.16bc	92.29 ± 6.1bc
D + C + O	3 ± 0.16a	2.08 ± 0.29a	2.25 ± 0.18ab	7.6 ± 1.22a	14.9 ± 0.49abc	1.38 ± 0.18	6 ± 0.89cd	27.25 ± 4.06bc	94.35 ± 2.34abc
O + C + D	2.89 ± 0.22a	1.88 ± 0.2 ab	2.9 ± 0.31a	7.13 ± 1.91a	15.3 ± 0.89ab	1 ± 0.00	9.5 ± 1.33a	30.5 ± 6.91b	90.35 ± 3.32c
C + O + D	2.32 ± 0.13b	1.69 ± 0.15ab	2.71 ± 0.19ab	,.56 ± 1.43a	15.3 ± 0.89ab	1.2 ± 0.2	7.2 ± 0.38bc	27.6 ± 5.37bc	81.92 ± 11.29d
Untreated check	2.21 ± 0.09b	1.82 ± 0.13ab	2.79 ± 0.21ab	5.38 ± 1.49c	12.9 ± 0.32d	1.25 ± 0.25	6.75 ± 0.18bcd	29.25 ± 8.25b	100 ± 0.0 a

* Mean ± S. E.
** Not significant in differences.
By Duncan's Multiple Range Test means followed by the same letter are not significantly different at 5 % probability level.

methrin / cypermethrin / cypermethrin), (cypermethrin, dicofol, omethoate), (dicofol, dicofol, dicofol), (omethoate, cypermethrin, dicofol), (cypermethrin, omethoate, dicofol) and (dicofol, cypermethrin, omethoate). Insignificant effect was recorded in the remaining three treated subcolonies (omethoate, omethoate, omethoate), (dicofol, omethoate, cypermethrin) and (omethoate, dicofol, cypermethrin) as compared to untreated control.

Repeated selection with cypermethrin significantly increased egg production. The contrary was recorded in three selected subcolonies, namely those selected with (omethoate, omethoate, omethoate), (dicofol, omethoate, cypermethrin) and (omethoate, dicofol, cypermethrin).

Egg hatchability was significantly decreased as a result of pesticide selection. The degree of effect depended on the arrangement of the pesticide sequence schemes used. The lowest percent of hatchability (81.92 %) was recorded in the subcolony subjected to selection with (cypermethrin, omethoate, dicofol). Results concerning the effect of repeated selection with omethoate on biology of mites confirm those obtained by GAABOUB et *al.*, 1982.

3. *Field studies :*

Data presented in Table V show that pesticidal application significantly reduced the population of *T. cinnabarinus* on soybean plants. The effect on mite population depends on the sequence of applied toxicants. Plots treated with (dicofol, dicofol, dicofol) recorded the highest reduction in mite infestation, followed in descending order by (dicofol, cypermethrin, omethoate) and (ome-

TABLE V. Effect of sequential use of pesticides on population of *T. cinnabarinus* infesting soybean.

Treatments	Precount before treatments	Mean number of * moving stages per 5 leaves	% of ** reduction in infestation
Untreated check	231	115 a	—
C + O + D	298	78.25 b	47.25
C + C + C	59	57.36 c	— 95.29
C + D + O	366	54.78 c	69.94
O + C + D	227.5	47.86 d	57.74
O + O + O	290	41.61 e	71.18
D + O + C	46	36.75 f	— 60.48
D + C + O	293.5	33.14 g	77.32
D + D + D	344.5	27.22 h	84.13
O + D + C	57	16.5 i	41.85

* Average of 9 counts.
** Using Henderson & Telton equation.

thoate, omethoate, omethoate). These treatments induced 84.13 %, 77.32 % and 71.18 % reductions in mite populations, respectively.

Mite population were increased in plots sprayed three times with cypermethrin. The same result was arrived at by EL-DAHAN et *al.*, 1981. The increase was expected as the laboratory studies revealed low toxic action of cypermethrin, and repeated selection with this toxicant prolonged the oviposition period and consequently the egg production. In addition, the use of cypermethrin in the *3rd* spray in pesticidal sequence gave poor results in mite control. However, when cypermethrin was used in the *2nd* spray and then followed by either omethoate and/or dicofol good results with respect to mite control were recorded. In conclusion, if cypermethrin is recommended for control of *S. littoralis* in soybean fields, it must be followed by an acaricidal spray to prevent the buildup of mite populations. Table V shows also that three sprays with omethoate gave good control against mite populations infesting soybean plants, in spite of low toxicity of this chemical against adult females in laboratory tests. This result should be examined in light of the biological data, which indicate that repeated selection with omethoate induced high reduction in egg production.

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