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An aspect of resistance management in *Tribolium castaneum* (Coleoptera: Tenebrionidae) against some insecticides

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Abstract:

Most of the stored product insects acquire resistance against many chemical pesticides used in control of these important insects *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) beetle. Some laboratory experiments were conducted to determine the common resistance and resistance of the insect mentioned against four insecticides that belong to two groups: the organophosphorus (OP) pesticides including malathion, chlorpyriphos and pirimiphos-methyl and carbamate pesticides including methomyl using the thin film residue. The study also included the use of anise volatile plant oil as stimulant of the studied insecticides. The results obtained indicated that pirimiphos- methyl was the most toxic insecticide and about 5.9, 8 and 84 times as toxic as methomyl, chloropyrifos and malathion, respectively. Results also revealed that increasing the period of exposure from 24 to 48 hours resulted in an increase the mortality of beetles. Furthermore, selection pressure on susceptible *T. cstaneum* adults from chlorpyrifos induced moderate tolerance and selection with malathion and primiphos- methyl showed moderate resistant (< 40- fold), whereas pressure from methomyl achieved high resistant (>40- fold). The resistant strains have very little or no cross-resistance to the pyerthroids insecticides, permethrin and only less than two-fold cross-resistance to the OP insecticide chlorpyrifos. The level of cross-resistance in resistant strains varies with a compound. For synergism studies results refers to greater synergism of all insecticides was achieved in the resistant strains. Also results indicated that there was net gain towards synergism in the resistant strains compared to that of susceptible strains. The findings obtained include the possibility of using anise oil to synergies the action of tested insecticides to reduce, delay and prevent resistance in the flour beetle against pesticides understudy.

Introduction

Pest resistance to the action of chemical pesticides reduced crop productivity, increases the cost of control, deteriorates the quality of stored products and increases the loss of them. The incidence of pesticide resistant is a growing problem in stored product protection. Resistance to one or more pesticides has been reported in at least 500 species of insects and mites (Georehiou, 1990). An insecticide resistance problem in different stored product insects has been reported from many countries including Australia, Bahrain, Canada, Central African Republic, China, Cyprus, Egypt, Ethiopia, Gambia, Germany, Greece, Guyana, India, Japan, Kenya, Malawi, Malaysia, Moracco, Nepal, Nigeria, Pakistan, Philippines, Senegal, Somalia, South Africa, Syria, Taiwan, Uganda, United kingdom, USA and Zambia (Dyte and Halliday, 1985; Prickett, 1987; Rassman, 1988; Sayaboc *et al.*, 1992; Yao and Lo, 1995; DARP, 2003; Benhalima *et al.*, 2004 and Abo-Elkasem *et al.*, 2018).

Stored product insect pests were found to be resistant against several insecticides including bioresmethrin, carbaryl, chlorpyrifos, chlorppyrifos-methyl, cynophos, cyfluthrin, cyholthrin, cypermethrin, DDT, deltamethrin, diazinon, dichlorous, ethylene dibromide, fenitrothion, lindane, malathion, methyl promide bromide, permethrin, phosphine, phoxin, pirimiphos-methyl, promecarb, propoxure, pyrethrins, temephos, tetrachlovinphos (DARP, 2003). The publications documented the extend of the resistance to different groups of conventional insecticides in stored product insect pests around the world. This frustrating situation indicates the powerlessness of conventional pest management strategies against insect pests of stored products. The development of cross-resistance (to different members of the same pesticide group) and multi-resistance (to different pesticides groups) in insect strains of many important insect species is a serious concern all over the world (Dyte and Halliday, 1985; Zettler and Cuperus, 1990; Chaudhry, 1997 and Talukder, 2009).

More than 20000 species of pre- and post-harvest pests destroy approximately. One-third of the world's food production valued annually at more than 100 billion dollars among which the highest losses (43% of potential production) occur in developing Asian and African countries (Talukder, 2009). *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) and *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) are of the insect species which cause misfortune wastages to wheat grains and their products (Abo-Elkasem *et al.*, 2018). Many researchers recorded pyrethroid cross-resistance *T. castaneum* and *Rhyzopertha dominica* (Fabricius) (Coleoptera: Bostrichidae) (Collins, 1990; Guedes *et al.*, 1996; Daglish *et al.*, 2003 and Abo-Elkasem *et al.*, 2018). The increasingly serious problems of resistance to pesticides and contamination of the biosphere associated with the large scale use of broad spectrum synthetic pesticide have directed the need for development of alternative strategies, such as: biorational chemicals, biological control agents and physical and ecological methods (Heyde *et al.*, 1984; Talukder and Howse, 1995; Hermawan *et al.*, 1997 and Talukder and Miyata, 2002).

Therefore, the current study was designed to determine the extent of resistance and cross-resistance of one of the important harmful insects of stored products namely *T. castaneum* adults to chemical pesticides chlorpyrifos, malathion, pirimiphos methyl, methomyl and permethrin using thin film method in addition to evaluate role of volatile plant oil, anise as synergetic agent as well as the negative cross-resistance between the tested insecticides to reduce, delay or prevent this phenomenon.

Materials and methods

1. Insect strains:

The test insects were susceptible adults of red flour beetles *T. castaneum* , 2-3 weeks old was reared in a Laboratory of Stored Product Department , Sakha, Kafr El-Sheikh without insecticidal pressure or contamination for twelve generations. The insects were reared in a mixture of wheat seeds and wheat flour under laboratory conditions of 26 ± 1°C and 65± 5% RH. medium contained also 5% dried yeast.

2. Isolation of anise volatile oil:

Seeds of anise *Pimpinella anisum* L. Fam. Umbelliferae were purchased from the market, washed and dried under 50 °C. The volatile oil was extracted by steam distillation using an oil trap.

3. Insecticides:

3.1. Lannate:

Common name; Methomy1

Chemical name: S-methy1 N-(methyl carbamoyl oxy) thioacetimidate.

Oxime carbamate produced by it 11 Chemical Co. (90% soluble liquid).

3.2. Dursban:

Common name: Chlorpyrifos

Chemical name:

0,0-diethy-1-0-3,5,6 - trichloro -2 pyridy1 phosphorothioate.

48% E.C. produced by Dow Chemical Co.

3.3. Actellic:

Common name: Pirimiphos methyl

Chemical name:__ 2-diethyl-amino-6-methyl pyrimidin-4-yl 0.0-dimethyl phosphorothioate.

E.C. 50% produced by ICI Co.

3.4. Malathion:

Common name: Malathion

Chemical name: O.o-dimethyl phosphorodithioate ester of diethyl. mercaptosuccinate

E.C.57% produced by Sumitomo Chemical Co.

3.5. Permethrin:

Common name: Permethrin

Chemical name: (3-phenoxyphenyl)-methyl (+ or -) cis-trans-3- (2,2-dichloroethy 1) -2,2) dimethy1-cyclopropane-caropoxylate.

A synthetic pyrethroid produced by FMC corp. and ICI Americas

4. Bioassay procedures:

4.1. Exposure to treated surface (Thin film residue):

Stock dilution (W/V) of each toxicant was prepared by dissolving the desired quantity of material in acetone and subsequent serial dilutions were prepared with acetone. Toxicity tests were carried out on films achieved by spreading aliquot of one ml of each concentration, at the bottom of a petri-dish of 9 cm in diameter and left to dry. After complete dryness of the insecticide film, ten adult beetles (2-3 weeks old) were placed in each of the treated petri dishes. The same number of insects also was confined on petri dishes treated with acetone only and served as control. Mortality was recorded after 24h of exposure and corrected by Abbott's formula (1925). The LC50 values for all insecticides were calculated by the method of Litchfield and Wilcoxon (1949).

4.2. Resistance and cross-resistance studies:

Adults of susceptible strain (2-3-week-old) were exposed to the LC25 for tested insecticides for 24 hrs. by thin film technique. The survival insects were transferred into clean jars containing clean and sterilized medium which was preheated in an oven at 70 °C for 2 hrs. After 15 day the parent adult individuals were eliminated. After 60 day the adults of the new generation were treated in the same manner as mentioned before and so on. At every generation LC50's of the tested insecticides were determined using thin film technique. To determine the cross-resistance patterns, concentration response tests for each resistant strain to each insecticide were carried out and compared with those from susceptible strain.

4.3. Synergism studies:

To assess the effect of anise oil on the toxicity of tested insecticides, the dilutions of each insecticide and oil were mixed in the ratio of 1:10 after which the petri dishes were treated with different concentrations. After evaporation of acetone, ten adults of *T. castaneum* were introduced into each dish. Mortality was recorded after 24 h of exposure. The LC50 values for each combination was calculated by the method of Litchfield and Wilcoxon (1949). Synergistic ratio (S.R) was calculated according to Metcalf (1967) as follows:

$$SR=\frac{\text{LC50 of insecticide alone}}{\text{LC50 of insecticide in mixture}}$$

Results and discussion

1. Toxicity of various insecticides against laboratory susceptible strain of *Triboleum castaneum*:

Table (1) presents toxicity data of various insecticides to susceptible adults of *T. castaneum*. According to the LC50 values, it is quite clear that pirimiphos-methyl was the most toxic insecticide and about 5.9, 8 and 84 times as toxic as methomyl, chlorpyrifos and malathion, respectively. Results also revealed that increasing the period of exposure from 24 to 48 hr. resulted in an increase in the mortality of the beetles. This conclusion agrees with the result of Fathia (1967), Abo-Elkasem *et al.*, 2018 and Abo Arab and Salem (2019). The red flour beetle *T. castaneum* is one of the most damage insect species invading warehouses and mills around the world (Rees, 2004; Almaši, 2008 and Mahroof and Hagstrum, 2012). Regarding the control of that and some other stored product pests, a variety of factors decide the effectiveness of contact insecticides, the most important of which is insect resistance (Subramanyam and Hagstrum, 1996; Kljajić and Perić, 2005, 2006; Boyer *et al.*, 2012 ; Opit *et al.*, 2012 and Kljajić *et al.*, 2009). Differences in the responses of the tested insect to insecticides may ascribe to the behaviourstical and alimentary habituations.

Table (1): Toxicity of various insecticides against *Triboleum castaneum* after 24 and 48 hrs. exposure to treated surface using thin film technique.

	24 hrs.				**28 hrs.**			
	LC50 ug/cm^2	**Confidence Limits**		**Slope**	**LC50 ug/cm^2**	**Confidence Limits**		**Slope**
Malathion	0.126	0.099	0.158	2.86	0.08	0.07	0.09	3.03
Chlorpyrifos	0.012	0.0097	0.014	2.7	0.0097	0.009	0.011	3.4
Methomyl	0.0088	0.005	0.016	1.13	0.002	0.001	0.004	1.27
Pirimiphos-methyl	0.0015	0.001	0.002	2.4	0.0009	0.0008	0.00094	1.39

2. Development of resistance to tested insecticides in susceptible *Triboleum castaneum*:

The development of resistance in the laboratory susceptible strain of *T. castaneum* after successive exposure to chlorphyrifos, malathion, methomyl and pirimiphos-methyl, for 5 generations was studied.

2.1. Against chlorpyrifos:

The chlorpyrifos selection pressure for 5 generations failed in building up more than 7.6-fold resistance as shown in Table (2). This result indicates that the development of resistance against chlorpyrifos is slower than that of each of the tested insecticides.

Table (2): Comparative levels of resistance in *Triboleum castaneum* selected by chlorpyrifos for 5 generations.

Generation	S[1]		R[2]		R F
	LC50 ug/cm^2	Slope	LC50 ug/cm^2	Slope	
1	0.012	2.7	0.028	2.13	2.37
2	0.012	2.7	0.075	2.36	6.21
3	0.012	2.7	0.084	3.13	7.03
4	0.012	2.7	0.089	3.3	7.43
5	0.012	2.7	0.091	3.4	7.6

S = Susceptible strain R = Resistant strain

$$RF = \text{Resistance factor} = \frac{\text{LC50 of R strain}}{\text{LC50 of S strain}}$$

2.2. Against malathion:

Data in Table (3) showed the rate of development of resistance against malathion. Maximum resistance level obtained within five generations was 35-fold. It is also observed from the same table that malathion resistance in *T. castaneum* was relatively slow in developing. This finding agrees with Parkin (1965) who reported that malathion resistance in stored-product insects was relatively slow in developing.

Table (3): Comparative levels of resistance in *Triboleum castaneum* selected by malathion for 5 generations.

Generation	S		R		R F
	LC50 ug/cm^2	Slope	LC50 ug/cm^2	Slope	
1	0.126	2.86	0.205	1.4	1.63
2	0.126	2.86	0.370	1.37	2.94
3	0.126	2.86	1.04	1.4	8.25
4	0.126	2.86	4.25	2.0	33.75
5	0.126	2.86	4.41	3.2	35.0

R = Resistant strain S = Susceptible strain RF = Resistance factor

2.3. Against methomyl:

It is clear from Table (4) that methomyl selection pressure succeeded in building up resistance in the strain. Maximum resistance level obtained within 5 generations was 78.6-fold. It is also observed in contrary to malathion that methomyl resistance in *T. castaneum* was relatively fast.

Table (4): Comparative levels of resistance in *Triboleum castaneum* selected by methomyl for 5 generations.

Generation	S		R		R F
	LC50 ug/cm^2	Slope	LC50 ug/cm^2	Slope	
1	0.0088	1.13	0.017	2.13	1.88
2	0.0088	1.13	0.132	2.30	15.0
3	0.0088	1.13	0.181	2.2	20.54
4	0.0088	1.13	0.629	3.3	71.43
5	0.0088	1.13	0.692	3.4	78.6

S = Susceptible strain R = Resistant strain RF = Resistance factor

2.4. Against pirimiphos-methyl:

Selection pressure with pirimiphos-methy1 (Table 5) had increased the LC50 nearly 30.6 times by the time F5 generation was reached. During the first 2 generations of selection, the LC50 increased by 15 times, from the original 0.0015 ug/cm^2 to 0.023 ug/cm^2.

Table (5): Comparative levels of resistance in *Triboleum castaneum* selected by pirimiphos-methyl for 5 generations.

Generation	S		R		R F
	LC50 ug/cm^2	Slope	LC50 ug/cm^2	Slope	
1	0.0015	2.4	0.0016	2.5	1.07
2	0.0015	2.4	0.023	1.9	15.31
3	0.0015	2.4	0.034	1.9	22.45
4	0.0015	2.4	0.041	1.75	27.55
5	0.0015	2.4	0.046	1.7	30.6

S = Susceptible strain R = Resistant strain RF = Resistance factor

In conclusion, selection pressure on susceptible *T. castaneum* adults from chlorpyrifos induced moderate tolerance and selection with malathion and pirimiphos-methy1 induced moderate resistance (< 40 - fold), whereas pressure from methomyl induced high resistance (> 40 - fold) as shown in Table (6).

Table (6): Rates of development of resistance in the red flour beetle *Triboleum castaneum* after insecticidal pressure and selection for 5 generations.

Resistant strain of:	R F
Chlorpyrifos (Rc)	7.6
Malathion (Rm)	35.0
Methomyl (Rmo)	78.6
Pirimiphos-methyl (Rp)	30.6

Rc = Chlorpyrifos - resistant strain. Rm = Malathion - resistant strain.
Rmo = Methomyl - resistant strain. RF = Resistance factor Rp = Pirimiphos - methyl resistant strain.

These results revealed that the development of resistance against chlorpyrifos is slower than that of pirimiphos-methl, malathion and methomyl. Currently, there are 122 insect pest species which are resistant to malathion (DARP, 2003). Malathion resistance in stored product insect-pests has been reported from all over the world (Rassman, 1988; Sayaboc *et al*., 1992 and Zettler and Cuperus, 1990). Malathion specific resistance is widespread and stable in natural populations even in the absence of pesticide exposure. *T. castaneum* showed the greatest ability to develop resistance to pirimiphos-methyl and malathion exhibiting the highest frequency of resistant individuals mainly to malathion (Pacheco *et al*., 1994).

2.5. Cross-resistance:

A comparison of susceptibility of susceptible and resistant strains, susceptible strain (S) , chlorpyrifos - resistant strain(Rc) , malathion - resistant strain (Rm) , methomyl - resistant strain(Rmo) and pirimiphos - methyl resistant strain (RP) of *T. castaneum* to each of the tested insecticides is given in Tables (7, 8, 9 and 10). The resistant strains had very little or no cross-resistance to the pyrethroid insecticide, permethrin and only less than two-fold cross-resistance to the OP insecticide, chlorpyrifos. The level of cross-resistance in resistant strains varies with a compound, e.g. in chlorpyrifos- resistant strain, the level for each compound was 67.9-fold for methomyl and 13.8-fold for pirimiphos-methyl (Table 7). The level of cross-resistance in malathion resistant strain were 67.9-fold for methomyl and 14.3-fold for pirimiphos - methyl as shown in Table (8) .

Table (7): Cross resistance patterns in chlorpyrifos resistant red flour beetles.

Insecticide	LC50 ug/cm^2		Resistance factor (RF)
	S	Rc	
Pirimiphos-rnethyl	0.0015	0.021	13.8
Malathion	0.126	1.07	8.5
Methomyl	0.0088	0.598	67.9
Permethrin	0.519	0.078	0.15

Table (8): Cross resistance patterns in malathion resistant red flour beetles.

Insecticide	LC50 ug/cm^2		Resistance factor (R F)
	S	Rc	
Methomyl	0.0088	0.598	67.9
Permethrin	0.519	0.016	0.03
Chlorpyrifos	0.012	0.021	1.76
Pirimiphos-rnethyl	0.0015	0.022	14.30

In methomyl - resistant strain, the levels of cross-resistance were 5-fold for malathion and 18.4-fold for pirimiphos - methyl (Table 9). The levels of cross-resistance in pirimiphos-methyl resistant strain were 8-fold for malathion, 50-fold for methomyl as shown in Table (10).

Table (9): Cross-resistance patterns in methomyl- resistant red flour beetles.

Insecticide	LC50 ug/cm^2		Resistance factor (R F)
	S	Rc	
Permethrin	0.519	0.093	0.18
Malathion	0.126	0.63	5.0
Pirimiphos-rnethyl	0.0015	0.028	18.4
Chlorpyrifos	0.012	0.023	1.89

Table (10): Cross-resistance patterns in pirimiphos-rnethyl- resistant red flour beetles.

Insecticide	LC50 ug/cm^2		Resistance factor (R F)
	S	Rc	
Malathion	0.126	1.008	8.0
Methomyl	0.0088	0.44	50.0
Permethrin	0.519	0.005	0.01
Chlorpyrifos	0.012	0.018	1.49

In malathion resistant of *T. castanium*, cross-resistant to the pyrethroid, permethrin was not detected (Zettler and Jones, 1977). Attia and Frecker (1984) reported that, OP-resistant strain of *O. surinamensis* showed low level of resistance to dichlorovos, bioresmethrin and pyrethrins (< 10-fold). Bansode and Campbell (1979) found that, malathion resistant strain of the red flour beetle *T. castanium* did not show cross-resistance to 4 other organophosphorus insecticides but exhibited tolerance to these insecticides (0.8-1-fold).

Generally, in order to have effective control methods available in the eventuality that resistance in insects increases to the extent that present chemical controls are no longer effective, it is important to test new materials and methods against strains of insects. The tested OP compound, chlorpyrifos-methyl might satisfy the criteria of these materials against the red flour beetle in this respect. No indication of resistance to chlorpyrifos-methyl was found in different strains of *T. castanium* (Halliday *et al*., 1988; Zettler and Cuperus, 1990 and Zettler, 1991). Mribeiro *et al.* (2003) surveyed insecticide resistance and synergism in Brazilian population of *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae) using the discriminating concentrations established from LC_{95}'s estimated for a standard susceptible population against chlorpyrifos-methyl, malathion and pirimiphos-methyl and three pyrethroids (Cypermettirin, deltamethrin and permethrin). Collins *et al.* (2003) investigated the resistance that had emerged against fumigants and protectants. Andric *et al.* (2015) stated that in insecticides choices need to be made carefully, considering the target species of stored product insects and their susceptibility to malathion and other insecticides. Attention should also be focused on a crucial role of insecticide selection of different stored grain insect populations in order to enable predictions of resistance evolution in individual populations and, based on such knowledge, sound choices of the most adequate resistance management strategy. There is cross-resistance to permethrin in two strain, but no clear evidence of cross-resistance to pirimiphos-methyl and chlorpyrifos-methyl was found in any of the strains tested (Lorini, 1997).

3. Synergism studies:

Many workers used synthetic synergists to overcome the resistance of *T. castaneum* to insecticides such as Ardley (1976), Dhingra and Sarup (1983), Hasan *et al.* (1983), Udeaan and Kalra (1983) and Binns (1986). In this work anise oil was isolated from the seeds of (*Pimpinella anisum* L.) and tested for its activity as synergist for the toxicity of the tested insecticides in susceptible and resistant strains. Table (11) presents effects of anise oil on the toxicity of the tested insecticides to resistant and susceptible strains. Greater synergism of all insecticides was achieved in the resistant strains. Notably high synergistic ratios were obtained for methomyl (2.93 x), malathion (2.15 x), pirimiphos-methyl (2.O x) and chlorpyrifos (1.75 x). However, a comparison of the synergistic ratios for the resistant strains and susceptible strain indicates that there was a net gain toward synergism in the resistant strains, e.g. the synergism of methomyl was increased from 1.04 in the S strain to 2.93 in the Rmo strain. Therefore, the addition of anise oil strongly synergized all the tested insecticides and reduced the resistance factors of resistant strains. The reduction was greatest for methomyl and pirimiphos-methyl, as shown in Table (11). However, it did not enhance the susceptibility of the resistant strains of the extent of reaching the susceptible strain level.

Table (11): Comparative synergism of insecticides by anise oil in adults of susceptible(s) and resistant (Rc, Rm, Rme, Ro) strains of *Triboleum castaneum*.

Insecticide (I)	Strain	I+synergist (oil)	LC50 ug/cm^2	SR	RF
Chlorpyrifos (C)	S	C only	0.012	-	-
		C + oil	0.011	1.12	-
	Rc	C only	0.091	-	7.6
		C + oil	0.052	1.75	4.8
Malathion (M)	S	M only	0.126	-	-
		M + oil	0.07	1.8	-
	Rm	M only	4.41	-	35
		M + oil	2.05	2.15	28.9
Methomyl (MO)	S	Mo only	0.0088	-	-
		Mo + oil	0.0063	1.4	-
	Rmo	Mo only	0.692	-	78.6
		M + oil	0.236	2.93	37.5
Pirimiphos-methyl (P)	S	P only	0.0015	-	-
		P + oil	0.0014	1.04	-
	Rp	P only	0.046	-	30.6
		P + oil	0.023	2.0	15.9

SR = Synergistic ratio RF = Resistant factor

Therefore, non-chemical methods with special reference to biological control including behavioral, botanical and microbial control can be practiced solely or in combination as effective alternative to chemical control. Few natural products such as volatile oils and their constituents can also be used to control stored grain insects. Further, volatile repellents after evaporation in the medium after insects from feeding and cause high mortality rate in insects (Deb, 2019). The development of resistance can be delayed by using binary combinations of insecticides, keeping in view the importance of synergism as well as the concern about environmental hazards and emergence of resistance these insecticides (Riaz *et al*., 2019). Researchers are currently seeking new classes of naturally occurring pesticides might be compatible with newer pest control approach. Plant-derived materials have been found to be highly effective, more readily, biodegradable, less likely to contaminate the environment and to have lower potential to produce resistance, making them viable alternatives to synthetic pesticides (Talukder and Howse, 1995; Shaaya *et al*., 1997; Talukder and Miyata, 2002; Park *et al*., 2003 and Khan and Chumbs, 2003). The essential oil of *Artemisia annua* L. was found to be toxic and repellent against *T. castaneum* and *Callosobruchus maculatus* Fabricius (Coleoptera: Chrysomelidae) (Tripathi *et al*., 2000). The essential oil vapours distilled from anise, cumin, eucalyptus, oregano and properties, causing 100% mortality of the eggs of *T. confusum* and *Ephestia kuehniella Zeller* (Lepidoptera: Pyralidae) (Tunc *et al*., 2000).

The best way to manage pesticide resistance is to focus on three strategies: avoid, delay, and reversal. Avoid the development of pesticide resistance problems with the use of Integrated Pest Management (IPM) programs, which reduce reliance on chemical control. Delay resistance by using pesticides only when needed, as indicated by monitoring, and when pests are at a susceptible stage. Delay can also be achieved by using pesticides from different chemical classes (e.g., Organophosphates, carbamates, pyrethroids, biologicals, etc.) and rotating their use. Reversal of some resistance can occur by allowing time between applications of a class of pesticide to permit resistant populations to become diluted by pesticide-susceptible individuals. Key elements of resistance management include minimizing pesticide use, avoiding tank mixes, avoiding persistent chemicals, and using long-term rotations of pesticide from different chemical classes (US pest Management Guidelines, 2019).

The current study estimating the resistance and cross-resistance of some chemical pesticides belonging to three different chemical groups namely malathion primiphos-methyl, methomyl, chlorpyrifos and permethrin in the red rust flour beetle *T. castaneum*. The study used anise oil to break the resistance phenomenon in the insect by mixing anise oil with studied pesticides and estimating the synergistic factor. The result obtained showed the insect’s rapid acquisition of resistance to some pesticides and its tolerance to other as well as the absence of cross-resistance between some pesticides, as well as a clear stimulating effect of anise oil. The study suggests using anise oil as synergist agent for the studied pesticides. As well as using pesticides that have a negative cross-resistance to break the insect resistance in question for the tested pesticides. Ultimately, a key to the successful management of resistance to insecticides is its early detection and proper characterization. All resistance data are being stored in an integrated database for future reference on trends and frequencies of resistance. The present study suggested application of sequence of different groups to prevent or delay the resistance and cross-resistance to certain insecticides specially that used in the current study.

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