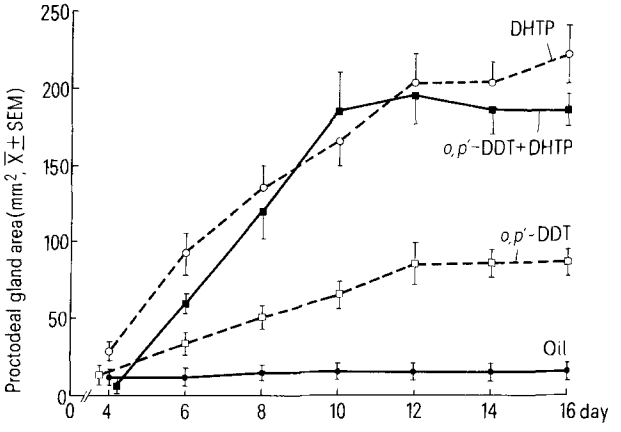
and *o,p'*-DDT, when combined with DHTP, did not inhibit this response (i.e., had no antiandrogenic effect). But *o,p'*-DDT given alone significantly stimulated proctodeal gland growth; on each of days 8, 10, 12, 14, and 16 there was no overlap in the gland sizes of birds injected with *o,p'*-DDT vs oil.

Given that the proctodeal gland cannot be stimulated by estrogen, this result indicates that *o,p'*-DDT is acting as an androgen at this target organ. While *o,p'*-DDT-stimulated glands were smaller than DHTP-stimulated glands, or glands of intact males[12], they grew to about the same size as those of castrated males injected or implanted with the naturally-occurring androgens androsterone or androstenedione[13,14].

The significance of this result is 2-fold. First, some of the deleterious effects of DDT on the reproduction of wild animals[15] may be due to interactions of *o,p'*-DDT with androgen as well as estrogen receptors. Second, since other natural and artificial androgens (as well as estrogens) are known to aggravate certain cancers of the reproductive organs via receptor interactions[16,17], DDT could have a similar effect.



Proctodeal gland growth of castrated male quail injected with *o,p'*-DDT (1 mg/day), 5*α*-dihydrotestosterone propionate (DHTP, 0.5 mg/day), *o,p'*-DDT + DHTP, or oil. *O,p'*-DDT injections began on day 1; DHTP injections began on day 3. See the table for *N*'s.

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2 D.M. Fry and C.K. Toone, Science *213*, 922 (1981).
3 J. Bitman, H.C. Cecil, S.J. Harris and G.F. Fries, Science *162*, 371 (1968).
4 W.A. McBlain, V. Lewin and F.H. Wolfe, Can. J. Zool. *55*, 562 (1977).
5 H. Lutz and Y. Lutz-Ostertag, in: Intersexuality in the animal kingdom, p.382. Ed. R. Reinboth. Springer, New York 1975.
6 W.H. Bulger, R.M. Muccitelli and D. Kupfer, Steroids *32*, 165 (1978).
7 A.E. Wakeling and W.J. Visek, Science *181*, 659 (1973).
8 R.D. Klemm, C.E. Knight and S. Stein, J. Morph. *141*, 171 (1973).
9 B.D. Sachs, Science *157*, 201 (1967).
10 F.A. Beach and N.G. Inman, Proc. natl Acad. Sci. USA *54*, 1426 (1965).
11 R. Massa, D.T. Davies and L. Bottoni, J. Endocr. *84*, 223 (1980).
12 E.K. Adkins and E.E. Pniewski, J. comp. Physiol. Psychol. *92*, 1169 (1978).
13 E.K. Adkins, J.J. Boop, D.L. Koutnik, J.B. Morris and E.E. Pniewski, Physiol. Behav. *24*, 441 (1980).
14 E.K. Adkins, Horm. Behav. *8*, 201 (1977).
15 D.B. Peakall, Scient. Am. *222*, 73 (1970).
16 R.J.B. King, G.J. Cambray, R. Jagus-Smith, J.H. Robinson and J.A. Smith, in: Receptors and mechanisms of action of steroid hormones, part 1, p.275. Ed. J.R. Pasqualini. Dekker, New York 1976.
17 M.G. Mawhinney and J.A. Belis, in: Cellular mechanisms modulating gonadal action, p.331. Eds R.L. Singhal and J.A. Thomas. University Park, Baltimore 1976.

Influence of three synergists on the action of some insecticides against parental and resistant strains of the Egyptian cotton leafworm

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Summary. Piperonyl butoxide, MGK 264 and DEF acted as synergists when used together with endrin and methomyl against the Egyptian cotton leafworm *Spodoptera littoralis*. The synergistic effect was higher with resistant strains than with the parental strain. The three substances tested as synergists actually antagonized the action of phospholan and cypermethrin on the parental strain, though they had some activity as synergists with these insecticides on resistant strains. The synergistic effect of DEF was higher than that of piperonyl butoxide or MGK 264, particularly on resistant strains.

The use of many insecticides has begun to suffer from a lowering of their potency due to insects acquiring an increased tolerance as successive generations are subjected to them. Synergists are of practical importance in increasing the efficiency of insecticides and increasing the spectrum of activity. In addition, they might restore the activity of an insecticide against resistant strains of insects. Also, it is often more economical to use synergists with an insecticide than to use the insecticide alone[1].

The purpose of this work is to study the action of 3 synergists, piperonyl butoxide, MGK 264 and DEF, on the efficiency of 4 insecticides used against the parental strain and against endrin-, phosfolan-, methomyl- and cypermethrin-resistant strains of *Spodoptera littoralis* BOISD (Lepidoptera, Noctudidae).

Materials and methods. The test insect was obtained from a parent strain, collected from the field and cultured in the laboratory for 2 generations, and from endrin-, phosfolan-, methomyl- and cypermethrin-resistant strains of *Spodoptera littoralis* maintained in the same laboratory. The insect was reared[2] under conditions of 25 ± 2 °C and 65 ± 5% relative humidity. The tests were done at levels of resistance of 16.98-, 8.11-, 9.13- and 13.89-fold, for endrin, phosfolan, methomyl and cypermethrin, respectively.

4th instar larvae, 40–45 mg each, were treated topically with 1 µl of acetone solution of the insecticide or an insecticide/synergist combination. The toxicants were applied to the dorsal region of the thorax. At least 5 replicates of 10 larvae each, were used at each concentration level. Mortality counts were taken 24 h after treatment. Data were corrected

The effect of the 3 synergists piperonyl butoxide (PB), MGK 264 and DEF on the toxicity of some insecticides against parental and resistant strains of *Spodoptera littoralis* BOISD. (Lepidoptera, Noctuidae)

Treatment	Parent strain LD_{50}(µg/g)	Slope	FS[a]	Resistant strain LD_{50}	Slope	FS
				R_e-strain[b]		
Endrin	18.62	3.54		216.23	3.05	
Endrin + PB	6.17	3.68	3.01	52.48	3.06	6.02
Endrin + MGK 264	6.03	3.50	3.08	71.94	3.0	4.39
Endrin + DEF	5.50	3.87	3.38	37.15	3.29	8.51
				R_p-strain[c]		
Phosfolan	19.05	3.75		154.53	4.42	
Phosfolan + PB	84.53	2.33	0.22	87.10	3.44	1.77
Phosfolan + MGK 264	47.86	2.50	0.39	87.10	3.38	1.77
Phosfolan + DEF	20.37	4.72	0.93	72.44	2.72	2.13
				R_m-strain[d]		
Methomyl	2.88	3.47		26.50	3.35	
Methomyl + PB	1.82	3.33	1.58	5.37	2.90	4.89
Methomyl + MGK 264	2.19	2.74	1.31	6.61	4.41	3.91
Methomyl + DEF	2.04	2.04	1.41	5.01	2.40	5.24
				R_c-strain[e]		
Cypermethrin	0.28	3.16		3.89	3.25	
Cypermethrin + PB	1.02	3.72	0.27	1.82	3.88	1.99
Cypermethrin + MGK 264	0.71	4.11	0.39	1.82	4.83	2.13
Cypermethrin + DEF	0.76	4.05	0.36	1.55	4.77	2.50

[a]Factor of synergism (FS) = $\frac{LD_{50} \text{ of insecticide alone}}{LD_{50} \text{ of synergized insecticide}}$; [b]$R_e$, endrin-resistant (16.98-fold), [c]R_p = phosfolan-resistant (8.11-fold); [d]R_m = methomyl-resistant (9.13-fold), [e]R_c = cypermethrin-resistant (13.89-fold).

for natural mortality[3], and calculation of dosage mortality curves and estimation of LD_{50} (median lethal dose) values were subjected to probit analysis[4]. To determine the nature of the response to the insecticides and insecticide/synergist mixtures, the slope of the dosage mortality curves was also calculated.

Synergistic action was studied by mixing the insecticide and the synergist at a ratio of 1:5, and the degree of synergism was determined by estimating the factor of synergism (FS)[5] as follows:

$$FS = \frac{LD_{50} \text{ of insecticide alone}}{LD_{50} \text{ of synergized insecticide}}$$

where unity = no interaction, > 1 = synergism and < 1 = antagonism. Technical grades of the insecticides, endrin 95%, phosfolan 63.6%, methomyl 99% and cypermethrin 99% were used in this study. 3 synergists were used; piperonyl butoxide (PB), MGK264 (octylbicycloheptene dicarboximide) and DEF (S,S,S-tributylphosphorotrithioate).

Results and discussion. An appreciable level of synergism was found, with similar FS-values, for the 3 synergists when tested with endrin on the parent strain. The synergistic effect was even higher in the endrin-resistant strain, particularly with DEF which gave an FS-value of 8.51. The synergistic effect of PB, MGK264 and DEF on the toxicity of endrin to *S. littoralis* is well confirmed by several workers[6-8].

The organophosphate phosfolan was generally antagonized when combined with any of the 3 synergists and tested on the parent strain of the cotton leafworm. The level of antagonism was lower in the phosfolan/DEF combination, approaching unity. An antagonistic effect on both parental and phosfolan-resistant strains of *S. littoralis* was reported by El-Guindy and Mady[9]. However, a slight synergistic effect was evident in the phosfolan-resistant strain tested in this work, which may be attributed to the level and/or type of resistance established in the studied strain.

As for the carbamate methomyl, its toxic action was slightly synergized with all 3 synergists when tested on the parent strain. The level of synergism was much higher in the methomyl-resistant strain.

The toxicity of the synthetic pyrethroid, cypermethrin, when mixed with PB, MGK264 and DEF, was antagonized on the parent strain, but there was a synergistic effect against the resistant strain of *S. littoralis*. Interaction between cypermethrin and the 3 tested synergists, in the parent and resistant strains, was similar to that of the insecticide phosfolan.

The synergistic effect of DEF on the toxicity of the insecticides tested was higher than that for the other 2 synergists, particularly on resistant strains. Bigley[10] reported that DEF had a greater effect on resistant than on susceptible houseflies, since resistant flies contain more of the active degrading enzymes, and he suggested that DEF increases the toxicity of the insecticide by blocking aliesterase, resulting in more available toxicant at the site of action.

In view of the diversity in the chemical structures of the compounds used and the variations in the enzyme activity of the susceptible and resistant strains, it is not entirely surprising that the pattern of synergism is complex, varying considerably with the compounds under consideration, the nature of the synergist employed and the type of resistance established. Veldstra[11] stated that a correlation between the structure of the synergist and that of the toxicant may need to exist before synergism occurs. Such a correlation would explain in part why some pesticides are more readily synergized than others.

1 R.B. Roberts, E.L. Lyon, C.K. Duckles and M. Look, J. econ. Ent. *65*, 1277 (1972).
2 M.E. El-Defrawi, A. Toppozada, N. Mansour and M. Zeid, J. econ. Ent. *57*, 591 (1964).
3 W.S. Abott, J. econ. Ent. *18*, 265 (1925).
4 D.J. Finney, in: Probit analysis, 2nd edn, p.318. Cambridge University Press, London 1952.
5 P.R. Chadwick, Pyrethrum Post *6*, 30 (1961).
6 M.M. Abdel-Sattar, Ph. D. thesis. Faculty of Agriculture, Al-Azhar University, Cairo 1981.
7 M.W. Guirguis, M.A. El-Tantawi, K.A. Gouher and D.A. Regheb, Proc. 4th Conf. Pest Cont., NRC, Cairo *1*, 493 (1978).
8 R.A. Khalid, M. Sc. thesis. Faculty of Agriculture, Ain Shams University, Cairo 1966.
9 M.A. El-Guindy and S.M. Mady, Bull. ent. Soc. Egypt. Econ. Ser., in press (1982).
10 W.S. Bigley, J. econ. Ent. *59*, 60 (1966).
11 H. Veldstra, Pharmac. Rev. *8*, 339 (1956).