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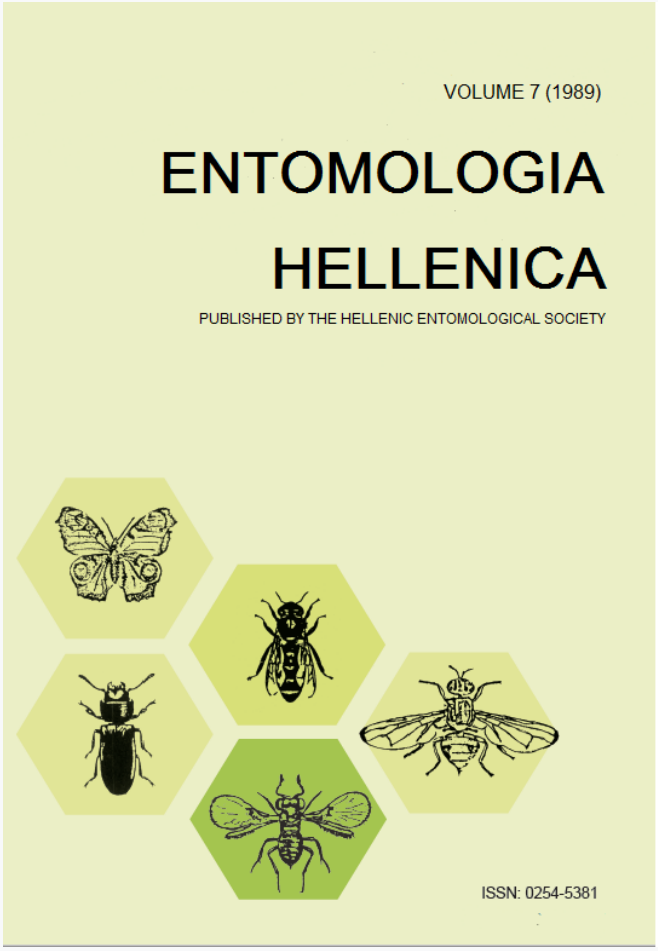

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Control of Insect Pests on Fruit and Field Crops with Hexaflumuron in North Greece[1]

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ABSTRACT

Experiments with hexaflumuron have been made against pests on apples, pears, peaches, potatoes and maize. On apples a predefined spray program was used for the combined control of *Cydia pomonella* (L) (Lepidoptera: Tortricidae), *Phyllonorycter blancardella* (Fabr.) (Lepidoptera: Gracillariidae), *P. corylifoliella* (Hbn) (Lepidoptera: Gracillariidae), *Leucoptera scitella* (Zell.) (Lepidoptera: Lyonetiidae) and *Adoxophyes orana* (F.v. Röslerstamm) (Lepidoptera: Tortricidae). Sprays started when *C. pomonella* adults appeared and were continued every 2, 3 and 4 weeks. Against *Cacopsylla pyri* L. (Homoptera: Psyllidae), *Anarsia lineatella* Zell. (Lepidoptera: Gelechiidae) and *Grapholitha molesta* (Busck) (Lepidoptera: Tortricidae), trials were made to define efficacy and timing, while trials on *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae) and *Sesamia nonagrioides* Lef. (Lepidoptera: Noctuidae) were only for efficacy.

Hexaflumuron promised to be an excellent insecticide since it was at least as good as organophosphate standards, amitraz and the benzoylphenyl ureas (BPU) tested. With fewer sprays it gave seasonal and combined control on apple pests. It is a new BPU insecticide with low mammalian toxicity and fits IPM programs, since its toxicity to predators and parasites is low. Hexaflumuron had no effect on adults of the predator *Coccinella septempunctata* L. (Coleoptera: Coccinelidae) in the potato trial. Sprays must start at the beginning of the oviposition of fruit damaging pests and at the egg or early larva-nymph stage of the foliage damaging pests. The spray must fully cover fruit and foliage.

Introduction

Hexaflumuron is a new benzoylphenyl urea (BPU), which inhibits chitin synthesis and interrupts the process of larva moulting and metamorphosis with the result of death. Although it must be ingested to be highly effective, it has also contact and ovicidal activity and appears to act more quickly than other BPUs thus reducing the potential for crop damage (Sbragia et al. 1983). The first discovered BPU, diflubenzuron, was found to reduce reproduction by more than 90% on boll weevil, *Anthonomus grandis* Boheman (Coleoptera: Curculionidae) by affecting mainly its eggs and the newly hatched larvae (Ganyard et al. 1978) and to completely suppress reproduction of large milkweed bug, *Oncopeltus fasciatus* (Dallas) (Heteroptera: Lygaeidae) by inducing sterility in males through impairing their ability to transfer sperm (Redfern et al. 1980). Work with hexaflumuron indicated that significantly high numbers of pupae or adults of *Spodoptera littoralis* (Boisd.) (Lepidoptera: Noctuidae) died and developed adults of *Aedes aegypti* L. (Diptera: Culicidae) had reduced reproduction

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if larvae had been treated with sublethal dosages (Radwan et al. 1985, Darriet 1989).

BPUs can be used in Integrated Pest Management as their mechanism of selectivity appears to be based on toxicological, ecological or behavioral differences between species (Wright and Retnakaran 1987). Hexaflumuron insecticidal activity has been shown against pests on cotton, fruit and vegetable crops. Because the mode of action of BPUs is unique and the product controls pests resistant to other types of insecticides, it should be useful in mixtures or in alternation with insecticides of other chemical classes to delay development of resistance (Komblas and Hunter 1986, Dutton and Komblas 1989).

A number of field tests have been made for the control of pests on fruit crops in the area of Imathia and on potatoes and maize in the area of Thessaloniki. Trials have been made as part of Dow's global program to define hexaflumuron efficacy and the most appropriate timing of applications.

Materials and Methods

In all trials a complete randomised block design was used with 4 replicates. Sprays were made using a Solo applicator and the foliage was fully covered with spray till run-off. In apples and peaches one tree was used per replicate. In pears, 3 trees were used per replicate. Trees were selected to bear a good crop and be apart from neighbouring trees. Trees not meeting these requirements were not included in the trial, but were partly sprayed to avoid unequal build-up of the infestations. In potatoes and maize, plots included 6 rows, each 12 m long.

a. Apples, cv. Starking: for determining the damage of codling moth *Cydia pomonella* (L), the dropped fruit was assessed at regular intervals until harvest, when the total number of damaged and clean apples of the tree was determined. The assessment on the 3 leafminers *Phyllonorycter blancardella* (Fabr.), *P. corrylifoliella* (Hbn.) and *Leucoptera scitella* (Zell.) was carried out by counting the number of mines per 25 randomly selected leaves per plot. Finally for the summer fruit tortrix *Adoxophyes orana* (F.v. Rosserstamm), observations were made on the number of damaged leaves per 25 shoots and infested apples per 100 per plot. b. Peaches, cv. Hall: assessment for damage by the peach twig borer *Anarsia lineatella* Zell. and the oriental fruit moth *Grapholitha molesta* (Busck) was made on 25 mature peaches per tree randomly selected in trial table 5 and all mature fruit (about 50% of crop) in trial table 6. c. Pears, cv. Highland grown in Palmetta system: assessment was made for pear psylla *Cacopsylla pyri* L. on the middle tree of each plot on 5 shoot terminals on the top 20 leaves. Selection of the terminals after the 2nd count was restricted to the upper third of the tree where there was infestation. d. Potatoes: observations were made on 25 randomly selected plants on the 4 middle rows of each plot. All alive larvae and adults of the Colorado potato beetle *Leptinotarsa decemlineata* (Say), were recorded as well as the adults of the seven-spot ladybird beetle *Coccinella septempunctata* L. e. Maize: during the assessment 25 plants from each of the 4 plots were fully examined and the number of larvae (L3-L5) was recorded.

The first spray was determined either by counting the number of adults caught in traps or, as with *C. pyri* and *L. decemlineata* by direct counts of eggs, nymphs or larvae. The next spray was usually made after 2, 3 or 4 weeks. Full use was made of the available data (Kyparissoudas 1986, 1988) and of actual year data of monitoring the moth flight with pheromone traps. More details on timing of application are given in Results.

Hexaflumuron (XRD-473, OMS 3031) is a BPU insecticide of the DowElanco and Company, with the chemical name: N-(((3,5-dichloro, 4-(1, 1, 2, 2-tetrafluoroethoxy) phenyl) amino)- carbonyl)-2, 6-diflurobenzamide. Other tested products are indicated in the table of results. In Tables 1 to 10, means followed by the same letter are not significantly different using the Duncan's multiple range test ($P<0.05$) based on log 10 ($x+1$) transformation. Percentage control is based on the Abbott formula.

Results

1. Apples. a. Fixed spray program: in apples, an effort was made to combine the control of the 3 main pests, the codling moth, *C. pomonella,* the leafminers *P. blancardella, P. coryfoliella* and *L. scitella* and the summer fruit tortrix *A. orana* by applying a program of predefined sprays for the whole summer season. The 1st spray was made May 4 in all experimental plots when the adults of the 1st generation of the codling moth appeared in the traps and there was an increase of their number. Hexaflumuron was used every 3 weeks in a total of 6 sprays and every 4 weeks in 5 sprays. Phosalone was used every 2 weeks with a total of 9 sprays. i. Codling moth. the infestation was very high in the untreated plots (Table 1) where

TABLE 1. Control of *C. pomonella* on apples. Fixed spray program, Imathia 1988.

Treatments	g.a.i. /100 l	No. of sprays	% clean fruit	Injuries/ fruit	% control
Untreated	–	–	16 a	1.52	–
Hexaflumuron 5EC	5.0	6	67 b	0.31	80
	7.5	6	68 b	0.31	80
	10.0	6	72 b	0.22	86
Hexaflumuron 5EC	5	5	64 b	0.29	81
	7.5	5	64 b	0.23	85
	10.0	5	77 b	0.20	87
Phosalone 35EC	60.0	9	63 b	0.31	80

TABLE 2. Control of apple leafminers. Fixed spray program, Imathia 1988.

Treatments	g.a.i. /100 l	No. of sprays	Mines/leaf			% control
			P. blanc.	*P. coryf.*	*L. scit.*	
Untreated	–	–	2.10 a	0.34 a	0.57 a	–
Hexaflumuron 5EC	5.0	6	0.21 bc	0.01 c	0.01 c	92
	7.5	6	0.18 bc	0 c	0 c	94
	10.0	6	0.14 bc	0 c	0 c	95
Hexaflumuron 5EC	5.0	5	0.37 b	0.01 c	0 c	87
	7.5	5	0.35 b	0 c	0 c	88
	10.0	5	0.08 c	0.01 c	0 c	97
Phosalone 35EC	60.0	9	1.03 a	0.18 b	0.15 b	55

there was only 16% clean fruit with an average of 1.52 injuries per damaged fruit. Most of the infestation came from the 2nd and 3rd generations of larvae when the fruit was almost fully developed. The best treatment was hexaflumuron 10 g/100 l in 5 sprays. ii. Leafminers: of the 3 species of leafminers the *P. blancardella* was the most prevalent. Infestation at the end of the season (4th generation) reached 3 mines per leaf in the untreated (Table 2). All hexaflumuron rates gave very good results in both spray programs. iii. Summer fruit tortrix moth, *A. orana:* as Table 3 indicates it appeared in significant numbers both in foliage and fruit generations. Hexaflumuron gave excellent results even at the lower rate of 5g/100 l. The above data indicate that combined control of the 3 main pests in apples can be achieved with the rate of 10 g/100 l of hexaflumuron and with 5 sprays made at 4 week intervals. They indicate also the good residual activity of hexaflumuron.

b. Seasonal control of marble leaf miner, *P. blancardella:* the 1st spray was made June 11 at the beginning of the 2nd generation when the male adults trapped started increasing. The next 2 sprays were made at 4 week intervals. The results reported in Table 4 were obtained 28 days after the 1st and 3rd treatment. Hexaflumuron and teflubenzuron at 5g/100 l in 3 sprays gave very good seasonal control.

TABLE 3. Control of *A. orana* on apples. Fixed spray program, Imathia 1988.

Treatments	g.a.i. /100 l	No. of sprays	Larvae/ terminal	Fruit % infested	% control
Untreated	–	–	3.06 a	28.0 a	–
Hexaflumuron 5EC	5	6	0.43 cd	1.0 d	96
	7.5	6	0.16 de	0.5 d	98
	10.0	6	0.18 de	1.0 d	96
Hexaflumuron 5EC	5	5	0.48 c	3.5 c	88
	7.5	5	0.63 bc	1.0 d	96
	10.0	5	0.13 e	0 d	100
Phosalone 42EC	60	9	1.14 b	8 b	71

TABLE 4. Control of *P. blancardella* on apples with 3 sprays, Imathia 1987.

Treatments	g.a.i. /100 l	Mines/100 leaves T1+28	T2+28	T3+28	Final % control
Untreated	–	98 e	106 e	411 e	–
Hexaflumuron 5EC	2.50	19 bc	33 bc	78 c	81
	5.0	8 a	14 a	34 b	92
	7.5	11 ab	13 a	14 a	97
Diflubenzuron 25WP	13.75	43 d	43 d	64 c	84
Teflubenzuron 15SC	5.0	29 cd	32 bc	28 b	93
Triazonphos 42EC	50.0	47 d	45 d	158 d	61

2. Peaches. Table 5 indicates the results obtained against peach fruit pests with 1 spray. The application was made July 7 after the peak of the male adult trapping of the fruit generation of peach twig borer *A. lineatella*. This was late, since the first eggs had been hatched and it was difficult to control the larvae before they entered the fruit. The numbers of oriental fruit moth, *G. molesta* trapped, started increasing 2-3 weeks after spray. Two sprays should probably have been made, the 1st, 1-2 weeks earlier and the 2nd 3-4 weeks after the 1st spray. However, the results were good, with hexaflumuron and teflubenzuron at the higher rates and with phosalone, against both pests. Table 6 indicates the results against *A. lineatella* with 2 and 3 sprays made 4 and 2 weeks apart, respectively. The 1st spray was made July 6 at the fruit - colour - change stage (time of both pest attack) and when the numbers of adults trapped were rather low, at the beginning of the fruit generation. Ten g/100 l of hexaflumuron in 3 sprays gave rather good control (81%).

3. Pears. a. Seasonal control of pear psylla *C. pyri:* the first spray was made at the egg stage; some young nymphs were also present. Amitraz was sprayed 10 days later. The next 3 sprays were made at monthly intervals, when all stages of the insect were present. The population dropped after the 2nd and 4th spray in both

TABLE 5. Control of peach pests, Imathia 1986.

Treatments	g.a.i. /100 l	% injury *A. lineatella*	*G. molesta*	Total % control
Untreated	–	46 e	14 a	–
Hexaflumuron 5EC	5	24 d	2 e	57
	10	12 bc	10 ab	63
	20	8 a	2 e	83
Teflubenzuron 5EC	10	12 abc	11 ab	62
	20	8 a	5 de	78
Diflubenzuron 25WP	10	20 cd	12 ab	45
	20	18 cd	4 de	63
Phozalone 35EC	60	10 ab	3 e	78

TABLE 6. Control of *A. lineatella*, Imathia 1987.

Treatments	g.a.i. /100 l	No. of sprays	Larvae/ 100 fruit	% control
Untreated	–	–	26 d	–
Hexaflumuron 5EC	5	2	12 bc	54
	10	2	7 ab	73
	20	2	7 ab	73
Hexaflumuron 5EC	5	3	8 abc	69
	10	3	5 a	81
Phosalone 35EC	60	2	9 bc	65
	60	3	8 abc	69

TABLE 7. Control of *C. pyri*, Imathia 1987.

Treatments	g.a.i. /100 l	Nymphs/100 leaves		% control	
		T1+28	T3+28	T1+28	T3+28
Untreated	–	354 d	865 d	–	–
Hexaflumuron 5EC	5	56 c	283 c	84	67
	10	22 ab	79 ab	94	91
	20	6 a	58 a	98	93
Teflubenzuron 15SC	10	5 a	104 abc	99	88
Diflubenzuron 25WP	20	42 bc	109 abc	88	87
Amitraz 20EC	60	6 a	146 abc	98	83

TABLE 8. Stage to control *C. pyri*, Imathia 1988.

Treatments	g.a.i. /100 l	Stage	Nymphs/100 leaves	
			Trial 1	Trial 2
Untreated	–	–	64.0 a	123.5 a
Hexaflumuron 5EC	7.5	adult	11.5 bc	14.5 b
	10.0	»	14.5 b	10.5 bc
	7.5	egg	4 e	2.5 de
	10.0	»	4.5 de	3.5 de
	7.5	nymph	3.5 e	2 e
	10.0	»	5.5 cde	5.5 cd

treated and untreated and data are not reported here. Hexaflumuron and the other BPUs gave good results similar to standard Amitraz (Table 7).

b. Stage to control *C. pyri:* an effort was made in the 2 trials presented in Table 8 to identify the stage in which the pear psylla should be controlled. The sprays were made May 2, 12 and 19 when insects were at the stage of adult, of egg and of young nymph, respectively. Both trials showed that the best time for pear psylla control was when the maximum number of the population was found to be at the egg or young nymph stage rather than at the adult stage.

4. Potatoes. Table 9 shows results obtained against Colorado potato beetle, *L. decemlineata* and the effect of treatments on the seven - spot ladybird beetle *C. septempunctata*. The spray was made May 13 when most of the population of *L. decemlineata* was at the egg stage. Quinalphos and cypermethrin-chlorpyrifos mixture were applied May 20 when most eggs started to hatch. Assessments were made May 27 and June 3. Hexaflumuron at 20 to 40 g.a.i./100 l gave very good results (89 to 98% control) against larvae but had very little effect on adults. The best product against both larvae and adults was the cypermethrin/chlorpyrifos mixture. However this mixture and the phos-

TABLE 9. Control of *L. decemlineata* on potatoes, Thessaloniki 1987.

Treatments	g.a.i. /ha	Larvae/100 plants		Adults	*C. septem-punctata*
		T+14	T+21	T+14	
Untreated	–	883 d	954 e	15 b	13 bc
Hexaflumuron 5EC	10	225 cd	405 d	9 c	11 c
	20	102 bc	75 c	15 b	17 b
	30	67 ab	48 b	16 ab	21 a
	40	58 ab	20 b	4 d	13 bc
Quinalphos 25EC	250	145 bc*	123 c**	3 de*	1 d*
Cypermethrin/ Chlorpyrifos 50/50EC	35/350	23 a*	0 a**	0 e*	1 d*

* T+7. ** T+14.

TABLE 10. Control of *S. nonagrioides*, Thessaloniki 1987.

Treatments	g.a.i. /ha	Larvae/100 plants T+14	% control
Untreated	–	888 a	–
Hexaflumuron 5EC	25	118 b	87
	50	71 b	92
Deltamethrin 2.5EC	20	95 b	89
Monocrotophos 60EC	1800	25 b	97

phate quinalphos eliminated practically all adults of the beneficial predator *C. septempunctata*.

5. Maize. One application was made against pink stalk borer *S. nonagrioides* at the onset of the adult flight and an assessment was carried out 2 weeks after the application. Hexaflumuron gave promising results, equal the standard deltamethrin. The best product was monocrotophos at the rate of 1,800 g per hectar (Table 10).

Discussion and Conclusions

Hexaflumuron promises to be an excellent insecticide since it: 1) Controlled effectively a number of pests on fruit, and field crops. Various field tests showed it to be at least as good as organophosphate standards and amitraz but at much lower rates. It was also equal to teflubenzuron and to double rate of diflubenzuron. 2) Was very active against insects like pear psylla and apple leafminers, which are resistant to standard contact insecticides. 3) Fits into insect pest management programs due to its low toxicity or selectivity to parasites and predators. No effect was seen against *C. septempunctata* in the potato trial. 4) Has good residual activity and can be recommended for combined control of pests like codling moth, leaf miners and summer fruit tortrix in apples. 5) Has low mammalian toxicity.

To obtain good results applications should be made: 1) Against fruit damaging pests like codling moth, peach twig borer, oriental fruit moth etc. at the onset of the adult generation as shown by pheromone traps, or when the first eggs appear, taking advantage of the ovicidal action and killing the eggs before the entrance of the hatched larvae into the fruit. 2) Against the foliage damaging pests at the egg and early larva stage to take advantage of both the ovicidal and larvicidal effect. 3) To fully cover with spray fruit and foliage. At the beginning of the season when fruit and foliage develops fast, sprays should be made more frequently, or another insecticide with better contact action should be used.

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KEY WORDS: Hexaflumuron, Chitin inhibitor, Benzoylphenyl urea, Fruit, Field crops, Integrated pest management, Insecticide

Καταπολέμηση Εχθρών των Οπωροφόρων και Φυτών Μεγάλης Καλλιέργειας με το Hexaflumuron στη Β. Ελλάδα

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ΠΕΡΙΛΗΨΗ

Πειράματα έγιναν με το hexaflumuron κατά εχθρών της μηλιάς, αχλαδιάς, ροδακινιάς, πατάτας και του καλαμποκιού. Στη μηλιά χρησιμοποιήθηκε ένα πρόγραμμα προκαθορισμένων ψεκασμών για τη σύγχρονη καταπολέμηση της καρποκάψας, *Cydia pomonella* (L.), των φυλλορυκτών, *Phyllonorycter blancardella* (Fabr.), *P. corylifoliella* (Hbn.), και *Leucoptera scitella* (Zell.) και του φυλλοδέτη *Adoxophyes orana* (F.v. Roslerstamm). Κατά της ψύλλας της αχλαδιάς *Cacopsylla pyri* L., του βλαστορύκτη της ροδακινιάς, *Anarsia lineatella* Zell. και της καρποκάψας της ροδακινιάς, *Grapholitha molesta* (Busck) τα πειράματα έγιναν για να προσδιορισθεί η αποτελεσματικότητα και ο χρόνος εφαρμογής, ενώ οι δοκιμές εναντίον του δορυφόρου της πατάτας, *Leptinotarsa decemlineata* (Say) και του εντόμου του καλαμποκιού *Sesamia nonagrioides* Lef. έγιναν μόνο για αποτελεσματικότητα.

Το hexaflumuron υπόσχεται να είναι ένα εντομοκτόνο με εξαιρετικά καλή αποτελεσματικότητα αφού στα πειράματα ήταν τουλάχιστον τόσο καλό όσο τα οργανοφωσφορικά εντομοκτόνα, το amitraz και οι βενζοϋλοφαινυλικές ουρίες (BPU) που εδοκιμάσθηκαν. Με λιγότερους ψεκασμούς έδωσε συνδυασμένη καταπολέμηση εχθρών της μηλιάς για όλη τη θερινή περίοδο. Είναι μια νέα βενζοϋλοφαινυλουρία, μικρής τοξικότητας στα θηλαστικά, τα ωφέλιμα παράσιτα και τα αρπακτικά των εντόμων και ταιριάζει σε προγράμματα ολοκληρωμένης καταπολέμησης. Το hexaflumuron δεν είχε καμμιά επίδραση στα ακμαία του αρπακτικού *Coccinella septempunctata* L. στη δοκιμή της πατάτας. Οι ψεκασμοί πρέπει να αρχίζουν στην αρχή της ωοτοκίας για τους εχθρούς που προκαλούν ζημιές στο φρούτο και στο στάδιο του αυγού ή της προνύμφης-νύμφης για τους εχθρούς που προκαλούν ζημιές στο φύλλωμα. Οι ψεκασμοί πρέπει να καλύπτουν πλήρως τα φρούτα και το φύλλωμα.