Sex Attractant Blends for Field Trapping of *Agrotis segetum* Males (Lepidoptera: Noctuidae) in Israel and Germany

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Lures for a monitoring system based on sex attractant trapping of *Agrotis segetum* males were elaborated for Israel and Germany. Various mixtures of (*Z*)-5-decenyl acetate, (*Z*)-7-dodecenyl acetate, (*Z*)-9-dodecenyl acetate, (*Z*)-9-tetradecenyl acetate, decyl acetate and dodecyl acetate were tested in 20 different blends. From comparison of all the trap catches a four-component lure consisting of (*Z*)-5-decenyl, (*Z*)-7-dodecenyl, (*Z*)-9-tetradecenyl and dodecyl acetate is recommended for monitoring of *A. segetum* in both countries.

The turnip moth (or white-line dart moth) *Agrotis* (Scotia) *segetum* Schiff. (Noctuidae) is one of the most destructive noctuid pests, occurs worldwide and causes economic damage to cereals, vegetables and root crops. Therefore monitoring of this pest is very important. This study reports evaluation of different blends of sex attractants for trapping of *A. segetum* in Israel and Germany.

In electroantennogram (EAG) studies males of *A. segetum* gave highest response amplitudes to (*Z*)-5-decenyl acetate (*Z*5-10 : OAc) [2]. In 1978 Bestmann *et al.* [3] found (*Z*)-5-decenyl acetate to be the sex attractant of this moth, based on combined EAD-gaschromatography and mass spectrometry [3, 4]. Two years later Toth *et al.* [5] identified (*Z*)-7-dodecenyl acetate (*Z*7-12 : OAc) and (*Z*)-9-tetradecenyl acetate (*Z*9-14 : OAc), in a 4 : 1 ratio, in pheromone gland extracts, whereas Arn *et al.* [6] in an independent study found evidence for *Z*5-10 : OAc, *E*5-10 : OAc, *Z*7-12 : OAc, (*Z*)-8-dodecenyl acetate (*Z*8-12 : OAc), (*Z*)-9-dodecenyl acetate (*Z*9-12 : OAc) and dodecyl acetate (12 : OAc). In 1982 a group of Swedish chemists and ecologists identified 13 aliphatic acetates and alcohols in gland extracts, *Z*7-12 : OAc being the main component, by means of EAD-GC and mass spectrometry [7]. Using continuous single sensillum recording of the GC-effluent of female abdominal tip extracts, *Z*5-10 : OAc and *Z*7-12 : OAc were found in an amount of 60 pg and 1000 pg, per insect, respectively [8]. In addition, Wakamura identified *Z*5-10 : OAc and (*Z*)-7-decenyl acetate (*Z*7-10 : OAc) in *Agrotis fucosa* [9], a closely related or possibly synonymous *Agrotis* species in Japan.

These different results of the pheromone analysis as well as of the field experiments, reported in the papers mentioned above, suggest that the pheromone in this moth is different in various geographical locations. In a recent paper Arn *et al.* [10] reported the trapping results of *A. segetum* males in four European countries (Denmark, Switzerland, France and Hungary), based on ternary acetate blends consisting of *Z*5-10 : OAc, *Z*7-12 : OAc and *Z*9-14 : OAc [10]. In the present study we have attempted to clarify the problem of the attraction of *A. segetum* males by testing sex attractant blends consisting of a series of homologous acetates in different ratios and bait loadings in Israel and parts of Germany.

Abbreviations: EAG, electroantennogram; EAD-GC, gaschromatography with electroantennogram detector; 10 : OAc, decyl acetate; 12 : OAc, dodecyl acetate; *Z*5-10 : OAc, (*Z*)-5-decenyl acetate; *E*5-10 : OAc, (*E*)-5-decenyl acetate; *Z*7-10 : OAc, (*Z*)-7-decenyl acetate; *Z*7-12 : OAc, (*Z*)-7-dodecenyl acetate; *Z*8-12 : OAc, (*Z*)-8-dodecenyl acetate; *Z*9-12 : OAc, (*Z*)-9-dodecenyl acetate; *Z*9-14 : OAc, (*Z*)-9-tetradecenyl acetate.

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Materials and Methods

The field tests in Israel were run in i) an experimental farm (near Bet Dagan) with mixed crops and ii) an institute location (Volcani Center) with fields and orchards. Dry funnel traps (20 cm ∅ plastic funnels with a protective wooden roof and an attached 2-liter plastic container) [11] were used; rubber septa impregnated with appropriate hexane solutions of the test chemicals served as baits. Many different blends were tested in preliminary experiments – with two replicas each – to rule out some of the many possible combinations (not included in the tables). Subsequently eleven attractant blends, based on combinations of *Z*5-10 : OAc, *Z*7-12 : OAc, *Z*9-12 : OAc, *Z*9-14 : OAc and 12 : OAc were tested. Each experiment consisted of three treatments with four replicas. Traps were hung at a height of 1 m, in a row 25 m apart, and the septa were rotated with every check.

The German experiments were performed near Hochheim (Rhine valley), a small village 30 kilometres from Frankfurt/Main (FRG). This location was found convenient because of a stable and high population of *A. segetum* and good flight activity within the vinyards. The tests in Germany were performed with standard delta-shaped traps (type Biotrap®, Hoechst AG) and rubber tubings as the baits. The same compounds as mentioned before were used with the addition of decyl acetate (10 : OAc). Traps were hung along the rows of the vinyards at a height of about 1.30 m, 15 to 20 m apart one from the other.

The results were analyzed using Duncan's Multiple Range test at the 0.05 level.

The chemicals were purchased from Farchan Chemical Co. or synthesized in the laboratory. The (*Z*)-unsaturated compounds contained 1–2% of the corresponding (*E*)-isomer. Table I shows the composition of the different blends used in Israel (blend types A) and of those used in Germany (B types) as well as the corresponding bait loadings.

Since the experiments in the two countries were performed independently, many results of the different tests cannot be compared directly. Thus, while the Israelian experiments were aimed almost exclusively to develop a monitoring system for *A. segetum,* the German ones were picked out from a number of experiments belonging to a more general study concerned with pheromone trapping of various lepidopterous species and including tests for trap and bait efficiency, trap design, various bait formulations, etc.

Results and Discussions

The experiments in Israel, in the Bet Dagan farm, started with three blends **A 5, A 9** and **A 10** consisting of *Z*5-10 : OAc, *Z*7-12 : OAc, *Z*9-12 : OAc and 12 : OAc (Table II, test 1). From these blends **A 5** was the most efficient one indicating the importance of *Z*7-12 : OAc and 12 : OAc. In test 2 (Table II) **A 5** was kept as a reference probe and was compared with **A 1** and **A 8.** The single component blend **A 8** (*Z*5-10 : OAc) caught only two males, whereas **A 1** and **A 5** were statistically equivalent. In preliminary experiments **A 5** was more efficient then **A 1,** therefore blend **A 5** was preferred as reference in the following tests. In test 3 (Table II) blends **A 2,** addition of *Z*9-14 : OAc, and **A 9,** removal of 12 : OAc, were compared with **A 5.** The trap catch of **A 5** was the highest one, although the difference was of no statistical significance. In test 4 (Table II) blends **A 3,** removal of *Z*5-10 : OAc, and **A 6**, which contained larger amounts of *Z*5-10 : OAc and *Z*7-12 : OAc and component *Z*9-12 : OAc was replaced with *Z*9-14 : OAc, were compared with **A 5**. Blend **A 3** was clearly inferior to both **A 5** and **A 6** proving the essential role of *Z*5-10 : OAc for trapping *A. segetum* males. The lures **A 5** and **A 6** were statistically equivalent, however, trap catches of **A 6** were larger and increased consistently with time. This effect probably was due to the larger dosage of chemicals in **A 6**. In the last test in the Bet Dagan farm (test 5, Table II) the best lure **A 6** was compared with blends **A 4**, removal of *Z*9-14 : OAc, and **A 11**, removal of *Z*9-14 : OAc and 12 : OAc. Both **A 4** and **A 11** caught only a few moths.

Two experiments were performed in the Volcani Center location. In test 1 (Table III) the reference probe **A 5** was compared with blends **A 7**, removal of *Z*9-12 : OAc, and **A 10**, removal of *Z*7-12 : OAc and 12 : OAc. In test 2 (Table III) the most efficient blend from the farm experiments, **A 6**, was compared with **A 5** and **A 3**. As before, blend **A 6** was clearly the most efficient lure, better then all the other combinations tested.

The performance of the trapping experiments in Germany differed from the Israelian tests. Different

Table I. Composition of the attractant blends for *Agrotis segetum* used for trapping in Israel (type **A**) and Germany (type **B**). The bait loading is given in μg.

Blend	Z5–10:OAc	Z7–12:OAc	Z9–12:OAc	Z9–14:OAc	10:OAc	12:OAc
A 1	10	20	100	–	–	–
A 2	10	10	100	100	–	100
A 3	–	10	100	–	–	100
A 4	100	100	–	–	–	100
A 5	10	10	100	–	–	100
A 6	100	100	–	100	–	100
A 7	10	10	–	–	–	100
A 8	10	–	–	–	–	–
A 9	10	10	100	–	–	–
A 10	10	–	100	–	–	–
A 11	100	100	–	–	–	–
B 1	1	2	100	–	100	–
B 2	25	25	–	25	–	–
B 3	100	100	–	100	–	–
B 4	1	2	50	–	50	–
B 5	33	33	–	33	–	–
B 6	–	10	100	100	–	100
B 7	10	–	100	100	–	100
B 8	10	10	–	100	–	100
B 9	10	10	100	–	–	100
B 10	10	10	100	100	–	–

Table II. Field trapping of *Agrotis segetum* in Israel, Bet Dagan farm, 1982.

Test	Bait*	Start (nights)	Check dates					Total No. males
			11.5	14.5	17.5			
1	**A 5**	9.5	1	9	14			24
	A 9	(8)	0	1	7			8
	A 10		1	0	0			1
			20.5	23.5	26.5	30.5		
2	**A 1**	17.5	3	10	27	34		74
	A 5	(13)	6	7	28	38		79
	A 8		1	0	1	0		2
			2.6	7.6	9.6			
3	**A 2**	30.5	9	18	11			38
	A 5	(9)	7	46	14			67
	A 9		4	30	12			46
			14.6	18.6	22.6	27.6		
4	**A 3**	9.6	10	6	0	5		21
	A 5	(18)	32	33	38	71		174
	A 6		13	55	67	105		240
			30.6	4.7	11.7	21.7	30.7	
5	**A 4**	27.6	1	0	4	3	0	8
	A 6	(31)	10	31	23	44	28	136
	A 11		1	0	2	0	1	4

* Four replicas for each treatment.

Table III. Field trapping of *Agrotis segetum* in Israel, Volcani Center location, 1982.

Test	Bait*	Start (nights)	Check dates							Total No. males
			21.5	24.5	30.5					
1	**A 5**	17.5	4	8	23					35
	A 7	(13)	0	1	9					10
	A 10		0	0	0					0
			1.6	7.6	13.6	16.6	22.6	29.6	7.7	
2	**A 3**	30.5	4	3	0	1	1	1	1	11
	A 5	(38)	0	10	10	13	2	5	0	38
	A 6		0	16	15	16	70	42	26	184

* Four replicas for each treatment.

Table IV. *Agrotis segetum* trapping in Germany, vinyards in Hochheim near Frankfurt/Main, 1983.

Test	Bait	Start (nights)	June							July						August						Total
			6.	9.	13.	20.	23.	27.	30.	5.	8.	13.	19.	22.	27.	2.	5.	12.	22.	24.	29.	No. males
1[a]	**B 1**	30.5	10	8	4	2	4	0	0	0	0											28
	B 2	(39)	26	24	21	73	20	40	18	10	19											251
	B 3		35	29	18	67	59	86	49	26	43											412
2[b]	**B 4**	30.5	11	9	6	13	5	5	2	3	0	0	0	0	2	4	0	1	0	0	0	61
	B 5	(91)	24	11	5	51	50	69	38	8	21	22	0	9	3	37	25	42	40	22	21	498
			September								October											
			1.	5.	8.	12.	15.	19.	22.	26.	3.	7.	11.	17.	21							
3[c]	**B 6**	29.8	14	5	3	2	2	0	0	2	0	1	0	0	0							29
	B 7	(53)	0	0	0	0	0	0	1	0	0	0	0	0	0							1
	B 8		16	7	6	9	2	9	9	9	8	2	3	0	3							83
	B 9		18	5	4	7	5	14	12	12	10	4	1	2	1							95
	B 10		7	3	8	4	3	2	2	0	1	1	3	0	0							34
	B 3		14	5	8	7	2	5	4	6	10	5	4	2	2							74

[a] Ten replicas, [b] five replicas, [c] three replicas each.

trap and bait types were used, and checks were done at intervals of 3 to 7 days. Thus, in some cases the sticky traps were overloaded with trapped moths. Therefore, the catch rate of the German experiments could have been higher under optimized test conditions.

In the first test (Table IV) the attractivity of a three-component mixture consisting of *Z*5-10 : OAc, *Z*7-12 : OAc and *Z*9-14 : OAc in two different dosages **B 2** and **B 3**, was compared with a four-component blend containing *Z*5-10 : OAc, *Z*7-12 : OAc, *Z*9-12 : OAc and 10 : OAc (**B 1**). The two blends **B 2** and **B 3** showed good attractivity and comparable efficiency, whereas **B 1** caught only about a tenth of the number of males.

The second test (Table IV) which in the beginning was run simultaneously with test 1 compared another ternary combination **B 5**, containing equal parts of *Z*5-10 : OAc, *Z*7-12 : OAc and *Z*9-14 : OAc, with **B 4**, similar to **B 1** but with lower dosage of the components. The ternary blend **B 5** was more attractive to *A. segetum* males then blend **B4** by a factor of eight.

Since test 1 and test 2 were started at the same time (30. 5. 83), their results up to the 8th of July (end of test 1, Table IV) can be compared directly when the catch rates are corrected with respect to the ten replicates and the five replicates in test 1 and test 2, respectively. In this case the total number of males caught were 14, 125, 206, 54 and 277 for **B 1**, **B 2**, **B 3**, **B 4** and **B 5**, respectively. Again, the ternary *Z*5-10 : OAc, *Z*7-12 : OAc and *Z*9-14 : OAc blends **B 2**, **B 3** and **B 5** were the most effective ones. The catch rates of 125, 206 and 277 male insects are not proportional to the bait loadings of a total of 75, 300 and 100 µg in **B 2**, **B 3** and **B 5**, respectively. The decrease of the males caught (277 to 206) going from the 100 µg bait **B 5** to the 300 µg bait **B 3** is not very significant and furthermore can also be explained with a saturation of the relatively small delta traps by the insects and by inhomogeneity of the moth population. Finally, the results from **B 2** and **B 3** are of greater significance since they were run with 10 replicates.

The third experiment (test 3, lower part of Table IV) was carried out at the same location, but later in the season with a lower population density. In this test 12 : OAc was added as the fourth component to the ternary blends giving the baits **B 6**, **B 7**, **B 8** and **B 9**. The most attractive lures contained *Z*5-10 : OAc, *Z*7-12 : OAc, 12 : OAc and *Z*9-12 : OAc (**B 9**) or *Z*9-14 : OAc (**B 8**), respectively. When *Z*5-10 : OAc (**B 6**) or *Z*7-12 : OAc (**B 7**) were not included in the baits, the trap catch decreased sharply (Table IV), indicating the essential role of these components. The removal of 12 : OAc from the mixture also resulted in lower trap catches (**B 10** and **B 3** in Table IV), however, this effect was smaller when the dosage of *Z*5-10 : OAc and *Z*7-12 : OAc was increased (100 µg each in **B 3**).

From the Israelian as well as from the German experiments it is clear that *Z*5-10 : OAc is an essential component for efficient trapping of *A. segetum* in both countries, although it does not attract males alone in Israel (**A 8**). In both countries, however, *Z*7-12 : OAc seems to be the main active component, its absence (**A 10** and **B 7**) resulted in a nearly complete loss of attractancy (Tables II, III and IV). One of the components, *Z*9-12 : OAc or *Z*9-14 : OAc, is also essential for efficient trapping of *A. segetum* males, but both seem to function similarily in the blends and can be substituted mutually without significant loss of activity. However, the use of *Z*9-14 : OAc rather then *Z*9-12 : OAc is recommended mainly due to its longer longevity because of a lower volatility. The saturated acetate 10 : OAc was tested in Germany only and seems to have an inhibitory effect (Table IV, **B 1** and **B 4**). On the other hand, the saturated acetate 12 : OAc increased the efficiency of the attractant mixtures, comparing **A 5** with **A 9** and **A 4** with **A 11** (Table II), but is not essential for trapping. (No comparable test in Germany.)

The most efficient lure in Israel was **A 6**, followed by **A 5** and **A 1** (Tables II and III). In Germany the best lures were **B 5**, **B 3**, **B 8** and **B 9** (the latter identical with **A 5**), the highest trap catch was achieved with **B 5**. However, since experiment 3 (Table IV) was performed at a time of decreasing flight activity, the efficiency of **B 8** and **B 9** (Table IV), which was higher than that of **B 3**, is comparable with that of **B 5** or even estimated to be better (Table IV).

In the German tests only *A. segetum* males were trapped whereas in the Israelian tests other Lepidoptera species were caught in some cases. When *Z*5-10 : OAc was removed from the blend **A 6** (preliminary field tests), mainly *Plusia chalcites* males and only a few *A. segetum* were trapped. It seems that *Z*5-10 : OAc is an inhibitor to *P. chalcites* which is attracted by a blend of *Z*7-12 : OAc and *Z*9-14 : OAc as expected from previous work [12]. Blend **A 2** caught 27 *Ephyloria lorey* males in addition to the 38 *A. segetum* males (Table II).

The numbers of insects caught, corrected for the replicates and the check intervals, in Israel were about the same as those in Germany, even with the different dosage of the chemicals in the baits. The best lure in Israel, **A 6**, contained a total of 400 µg compared to the 100 µg and 220 µg of attractants **B 5**, **B 8** and **B 9**, used in Germany. Due to the hot summer in Israel, where the release rate of the attractants is higher than in moderate climate zones, higher bait loadings are recommended in order to achieve longer activity of the traps.

The approximate flight activity of *A. segetum* in both countries can be deduced by following the trap catches *versus* the check dates. In Germany, the lure efficiency of **B 3** and **B 5** proceeded almost parallel from beginning of June till the first week of July, showing a maximum on June, 27 (test 1 and 2, Table IV). Later, only **B 5** was checked showing a second broad maximum around August, 12 (test 2, Table IV). These data reflect the appearance of two generations of this species; the trap catches in test 3, *e.g.* those of **B 3**, **B 8** and **B 9**, show the declining population in the late season of September and October (test 3, Table IV).

In Israel, most of the tests were shorter in time, therefore the flight activity of *A. segetum* can be analysed only from tests 4 and 5 (Bet Dagan farm) and test 2 (Volcani Center). Following the best lure **A 6** (test 4, Table II and test 2, Table III) a maximum was observed between June, 22–27. A second shallow maximum was found on July, 21 (test 5, Table II).

Interestingly the first maximum of flight activity (June 22–27) coincided in both countries.

Conclusion

The best lure for monitoring *A. segetum* males in Israel and Germany is a four component blend consisting of *Z*5-10 : OAc, *Z*7-12 : OAc, *Z*9-14 : OAc and 12 : OAc. Interestingly, the field results indicated that in this case the geographically separated populations of *A. segetum* in the two countries are attracted to similar attractant mixtures which is contrary to findings reported for *A. segetum* in a number of European countries [10] where different lures were found.

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