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Effects of mating disruption against the Mediterranean corn borer, *Sesamia nonagrioides*, on the European corn borer *Ostrinia nubilalis*

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Abstract: In many Mediterranean areas, two stalk borers, *Sesamia nonagrioides* and *Ostrinia nubilalis* affect maize yield. The efficacy of mating disruption techniques against the first corn borer has been evaluated in recent years. In the present paper the effect of such a control method on populations densities of *O. nubilalis* is reported. Densities of *O. nubilalis* in fields treated with *S. nonagrioides* pheromone released from PVC dispensers were always lower than in untreated fields. However, *O. nubilalis* populations were not lower than in untreated fields when the pheromone blend was applied with a liquid formulation and was composed of two components. The influence of using a liquid formulation, which has higher release rates, may explain the different effects. Additionally, trap catches of *O. nubilalis* were reduced when the pheromone of *S. nonagrioides* was added to the pheromone of *O. nubilalis* in traps and, inversely, catches of *S. nonagrioides* were reduced when the pheromone of *O. nubilalis* was added to traps baited with the pheromone of *S. nonagrioides*.

Key words: Maize, pheromone, mating disruption, *Sesamia nonagrioides*, *Ostrinia nubilalis*.

Introduction

The Mediterranean corn borer (MCB), *Sesamia nonagrioides* Lefèbvre (Lepidoptera: Noctuidae) and the European corn borer (ECB), *Ostrinia nubilalis* Hübner (Lepidoptera: Crambidae), are two sympatric corn borers that cause major losses in maize in the Mediterranean Basin. In northeast Spain the insects go through two complete broods and a partial third one. Whereas the first adult flight of MCB occurs earlier (May) than that of ECB (June), the second flight is concurrently observed in late July or early August (Alfaro, 1972; Riba et al., 1992). Larval and pupal development is mostly completed inside the stem or the ear, so they are poorly sensitive to insecticides, particularly the MCB, and alternative control methods have been tested.

Among non-chemical control tactics, synthetic pheromone sprays have been tested to disrupt the mating of MCB with good results. Sex pheromone of MCB was first identified as composed of two components, Z11-16:Ac and Z11-16: OH, by Sreng et al. (1985). Later Mazomenos (1989) completed the composition with two additional components, Z11-16:Ald and 12:Ac and determined the optimal component ratio to be 69:8:8:15. More recently, Sans et al. (1997) determined the proportion 77:8:10:5 as optimal for an MCB population of northeast Spain in EAG, wind tunnel and field studies. Sex pheromone of ECB is a blend of two isomers, Z11-14:Ac and E11-14:Ac (Klun et al., 1973; Klun & Cooperators, 1975) in a ratio that varies according to geographic areas. In the study area, Sans et al. (1993) observed the so-called Z strain of ECB (97Z: 3E) to be predominant. The respective pheromone blends are routinely used to monitor the flight of the two corn borers.

The effects of releasing a high amount of pheromone on the non-target biotic environment have rarely been studied. Some studies have investigated the effects of releasing pheromones in the environment for mating disruption purposes on insects taxonomically close to the target species (Johnson et al., 1991; Ferrao et al., 1998) and also on its parasitoid complex (Niwa & Daterman, 1989). However, there are no studies to assess the impact of the mating disruption technique on non-target species that share food resources with the targeted species, as in the case of ECB and MCB in maize.

In fact, the coexistence of more than one species that concurrently bore the stem of the same host species (e.g. maize, rice, or sugarcane) is a common feature in many areas of the world and leads to interspecific competition for food. Some of the species usually belong to Pyralidae or Crambidae (e.g. *O. nubilalis*, *Chilo* spp., *Diatraea* spp., *Scirpophaga* spp.), whereas sympatrically occurring stem borers belong to Noctuidae (e.g. *Sesamia* spp. and *Busseola* spp.). Several of the cited stem borers are targeted in mating disruption programmes and the effect that such a control method may have on the potential competitors of the target pest should be known in order to better understand the impact of releasing pheromones on the crop pest complex. Potential interference between sympatrically occurring species that share at least one pheromone component has been reported by several authors (e.g. Deland et al., 1994). Allomonal effects of pheromones on competing species are far less documented in the literature. Among bark beetles, aggregative pheromones are used to inhibit the attraction of competing species to the host (Blum, 1996).

The work reported here aimed to investigate the effects of releasing MCB pheromone blend for mating purposes on its competitor, the ECB.

Materials and Methods

Application of the pheromone blend. Several field trials were carried out from 1990 to 1999 to evaluate the effectiveness of the mating disruption technique against MCB. For this, maize fields variably sized between 4 and 12 ha were treated with MCB pheromone blend or left untreated as control. The number of pheromone components, the formulation and the doses applied varied during the experimental period to improve the efficacy of the method according to the results obtained in the previous years and those obtained in behavioural studies (Sans et al., 1997; Lopez et al., 1999). Pheromone blend composition, component ratio, formulation, doses and the generations targeted were modified as summarised in Table 1.

Field trials may be divided into three categories according to the blend composition and formulation. In the first three experimental years, the 69:8:8:15 proportion and PVC dispensers were used. In the following two years, the proportion was modified to 77:8:10:5 as determined by Sans et al. (1997) for a local population, but the same PVC dispensers were used. Finally, in last three years, two liquid formulations with two components were sprayed to make the application easier.

Effects on ECB population density. ECB population densities were estimated by dissecting 180 maize plants (9 sets of 20 plants each) and recording the number of larvae per plant in each treated or control field after the end of the second flight (late August-early September) and before harvesting (early October).

Pheromone trap catches. Funnel pheromone traps located at least 50 m apart were placed in a maize field from June 5 to October 15. The traps were baited with one of the three treatments: (i) MCB pheromone (200 μg of the 69:8:8:15 blend) (ii) ECB pheromone (100 μg of the 97:3 blend, Z11-14:Ac, E11-14:Ac), and (iii) MCB and ECB pheromones. Polyethylene vials and red rubber septa were used for the MCB and ECB pheromone blends respectively. Each treatment was replicated 3 times. The number of MCB and ECB males caught in each trap was recorded weekly. Additionally, catches of *Mythimna unipuncta* (a species that shares the major pheromone component with MCB) were recorded.

Monitoring of pheromone release rate. In the years 1990-1996, the amount of pheromone was calculated in the PVC dispensers. Samplings were made at 0, 10, 30 and 60 days. In each sampling 3 dispensers were collected from the maize field. Each dispenser was extracted with hexane in ultrasounds for 30 min (3 x 30 ml). The extract was analysed by GC using a packed column (OV-101, 2 m x 2 mm i.d.). The amount of Z11-16:Ac was quantified using an internal standard (tridecyl acetate).

In 1998 and 1999 the amount of pheromone in the maize leaves was evaluated. Samplings were made every 2 days from the day of application until the 10^{th} day after treatment. In each sampling 40 maize leaves were picked randomly in the field. Only leaves among the top five were collected. In the laboratory the leaves were separated into groups of 10 leaves. From each leaf a square of 10 cm^2 was cut, and the total of 100 cm^2 for the 10 leaves was extracted with 50 ml of pentane in ultrasounds for 30 min. Thus, four replicates were made in each field on every sampling date. The extract was concentrated to 1 ml and analysed by GC using a capillary column (SP-2330, 30 m x 0.25 mm x 0.2 µm). The amount of Z11-16:Ac was calculated using an internal standard (tridecyl acetate).

Statistical analyses. The data of ECB larvae per plant and the percentage of attacked plants were submitted to a one-way ANOVA. Trap catches were analysed by a two-way (week and type of bait) ANOVA. When needed, means were compared using Duncan's Multiple Range Test (P<0.05).

Table 1. Conditions in which field trials of mating disruption against MCB were carried out. [a]Values in brackets show the number of dispensers per ha, [b]Pheromone components were synthesised by the first firm and formulated by the second firm.

Year	Pheromone blend		Formulation	Doses gr/ha[a]	Commercial supplier	Generations targeted
	Components	Ratio				
1990	Z11-16:Ac Z11-16:OH Z11-16:Ald 12:Ac	69:8:8:15	PVC	49(100)	Agrisense	1st & 2nd
1993	as in 1990	69:8:8:15	PVC	80(100)	SEDQ	1st & 2nd
1994	as in 1990	69:8:8:15	PVC	80(100)	SEDQ	2nd
1995	as in 1990	77:8:10:5	PVC	80(100)	SEDQ	2nd
1996	as in 1990	77:8:10:5	PVC	80(100)	SEDQ	2nd
1997	Z11-16:Ac Z11-16:OH	90:10	Liquid	80(100)	SEDQ/NPP[b]	2nd
1998	as in 1997	90:10	Liquid Liquid	80(100)	SEDQ/NPP[b] SEDQ/TNO[b]	2nd
1999	as in 1997	90:10	Liquid Liquid	80(100)	SEDQ/NPP[b] SEDQ/TNO[b]	2nd

Results

ECB density in fields treated with MCB pheromone (1990, 1993, and 1994). The number of ECB larvae per plant was always lower in fields treated with MCB pheromone than in untreated fields within each year and sampling date (Table 2).

ECB density in fields treated with MCB pheromone (1995 and 1996). As in the previously cited years, ECB populations were lower in fields treated with MCB pheromone, though only the second generation of MCB was targeted in 1995 and 1996 (Table 3).

ECB density in fields treated with MCB pheromone (1997, 1998, and 1999). When liquid formulation with the two major pheromone components was sprayed to disrupt mating of MCB, ECB densities were never significantly (P<0.05) lower in treated than in untreated fields (Table 4).

Table 2. Mean (±s.e.) number of larvae of ECB per plant in fields treated with the MCB pheromone and untreated fields. Within each year and sampling date, means followed by a different letter are significantly different ($P<0.05$).

Year	Sampling date	Larvae/plant	
		Treated	Untreated
1990	September	0.6±0.5 b	1.9±1.0 a
	October	0.6±0.4 b	0.9±0.5 a
1993	September	0.8±0.8 b	2.4±1.9 a
	October	0.9±1.0 b	2.5±1.9 a
1994	September	0.5±0.5 b	1.0±0.6 a
	October	0.5±0.4 b	1.5±0.7 a

Table 3. Mean (±s.e.) number of larvae of ECB per plant in fields treated with the MCB pheromone and untreated fields. Within each year and sampling date, means followed by a different letter are significantly different ($P<0.05$).

Year	Sampling date	Larvae/plant	
		Treated	Untreated
1995	September	0.6±0.5 b	1.9±1.0 a
	October	0.6±0.4 b	0.9±0.5 a
1996	September	0.8±0.8 b	2.4±1.9 a
	October	0.9±1.0 b	2.5±1.9 a

Table 4. Mean (±s.e.) number of larvae of ECB per plant in fields treated with the MCB pheromone and untreated fields. Within each year and sampling date, means followed by a different letter were significantly different ($P<0.05$).

Year	Sampling date	Larvae/plant	
		Treated	Untreated
1997	September	0.5±0.8	0.6±1.0
	October	0.5±0.9	0.5±1.0
1998	September	2.8±2.9	2.4±3.4
	October	2.3±1.9	2.6±2.4
1999	September	1.4±0.9 a	0.6±0.4 b
	October	1.4±0.7 a	0.6±0.6 b

Pheromone trap catches. Catches of MCB and ECB males in traps baited with MCB or ECB or both MCB and ECB pheromone blends are shown in Figures 1 and 2. As expected, the highest number of ECB and MCB males were caught in traps baited with their own pheromone, whereas practically no catches were recorded in traps baited with the pheromone of the other species. The addition in the same trap of the pheromone of the other species caused the number of catches to decrease significantly (P<0.05). For *M. unipuncta* catches, a pattern similar to that of MCB was observed (Fig. 2).

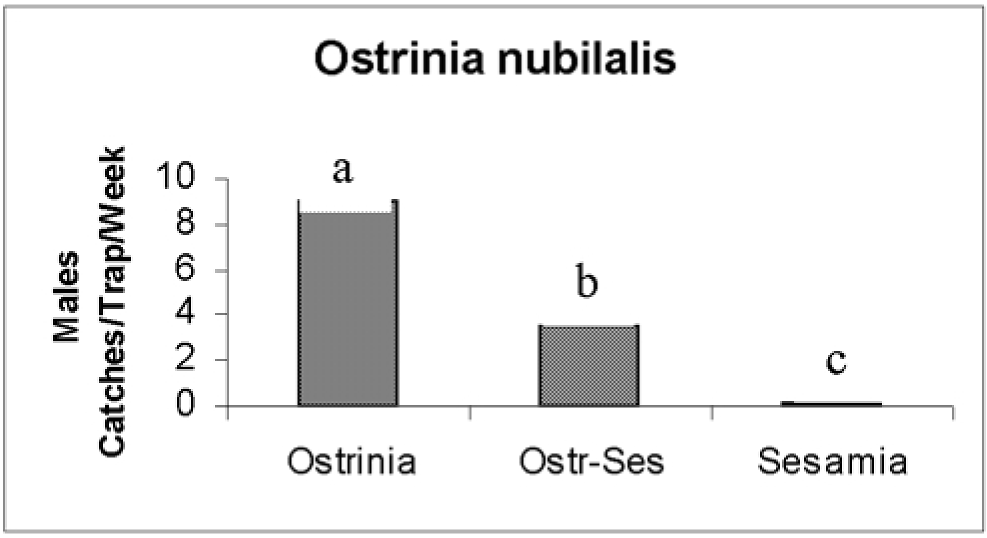

Figure 1. Mean number of *O. nubilalis* males caught in traps baited with; the pheromone of *O. nubilalis*, the pheromone of *S. nonagrioides* or with the two pheromone blends. Traps were placed in maize fields from June 5 to October 15. The three means shown were significantly different (P<0.05) from each other.

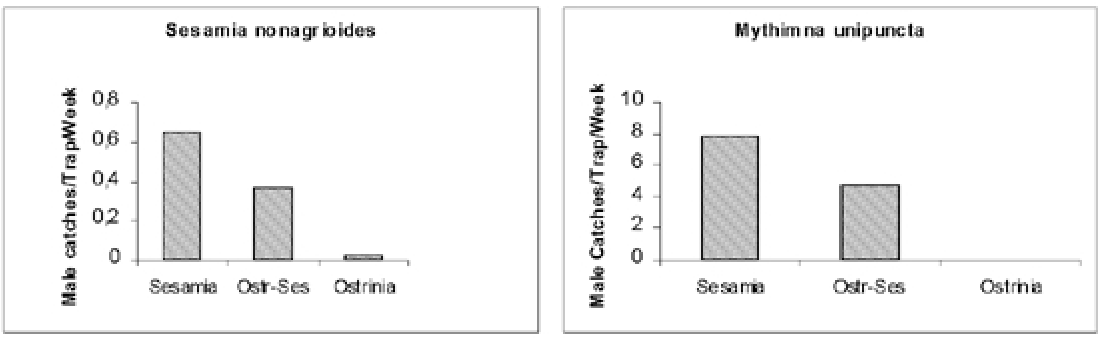

Figure 2. Mean number of *S. nonagrioides* and *M. unipuncta* males caught in traps baited with; the pheromone of *O. nubilalis,* the pheromone of *S. nonagrioides* or with the two pheromones blends. Traps were placed in maize fields from June 5 to October 15. The three means shown in each figure were significantly different (P<0.05) from each other.

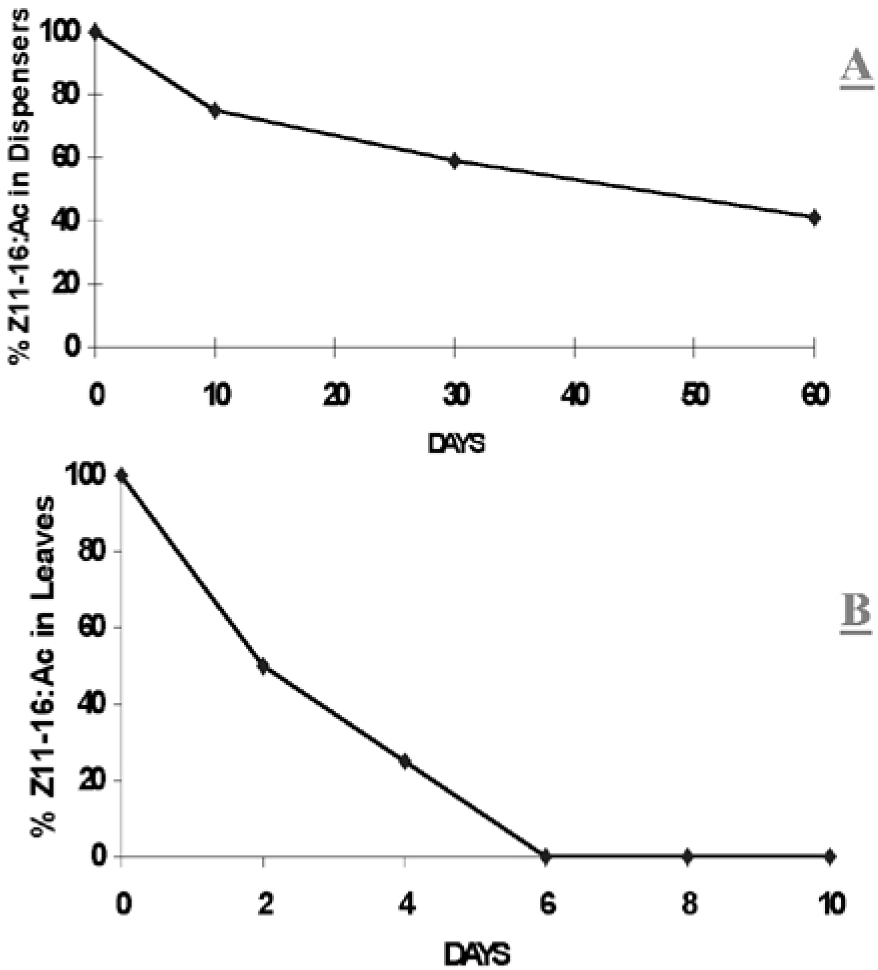

Figure 3. Percentage of Z11-16:Ac, major component of *S. nonagrioides* pheromone blend, that remained in PVC dispensers in 1994 (A) or in leaves in 1998 (B) in the days following the establishment of dispensers in the field or leaf spraying respectively.

Pheromone release rate. Release rate of the major pheromone component Z11-16:Ac was far lower when the pheromone was applied in a solid dispenser than when it was sprayed with a liquid formulation. Figure 3 shows values of the release rate for two years. In the first case, 40 % of the pheromone component remained in the dispensers 60 days after they were placed in the field, whereas in the case of liquid formulation practically 100% of the component sprayed had been released only six days after spraying.

Discussion

The application of pheromone to disrupt MCB mating decreased ECB population densities in the first 5 years of the experimental period when solid PVC dispensers were used, whereas it had no effect in the last three years in which the pheromone blend was sprayed as a liquid formulation. These results are similar to those obtained when the efficacy of mating disruption against MCB was evaluated in the same field trials (author's unpublished results). The liquid formulations showed a lower pheromone persistence than the solid dispensers, which could explain the lower effectiveness in the control of MCB and also the lower effect of MCB pheromone on ECB populations. Also, the liquid formulations were composed of only the two major components of MCB pheromone and this could also contribute to their lack of effects on ECB density. The results of trap catches confirm the mutual interference of MCB and ECB when the complete sex pheromone of the other species is added to their own pheromone. The decrease in the number of catches of *M. unipuncta* when ECB pheromone is added to MCB pheromone in traps would further confirm such a hypothesis. It should be noted that *M. unipuncta* shares the major component with MCB and that it is usually caught in traps baited with MCB virgin females (Albajes et al., 1985).

Allomonal effects of aggregative and epideictic pheromones on competing species have been observed in bark beetles (Prokopy, 1981; Birch, 1984; Blum, 1996). Observations on interspecific interactions of sex pheromones have been restricted to species that share one or more pheromone components. The results reported here suggest that sex pheromones can also play a role in the competition of herbivores even if they do not share components in their pheromones, as is the case of *S. nonagrioides* and *O. nubilalis*. Research should be done to determine whether only males are sensitive to the pheromone of the competing species, as shown in the trap experiment, or the females may also respond to the allomonal effects of the pheromone of competitors. Note that Palanaswamy & Seabrook (1978) showed that, at a high concentration in the environment, the sex pheromone of *Choristoneura fumiferana* may act as an epideictic pheromone that enhances the dispersal of mated females in overcrowded areas.

In summary, the results of this work suggest that the sex pheromone of a stem borer may have allomonal effects on concurrent stem borer species. Further research is needed to determine which mechanisms and pheromone components are involved in this interaction; this is currently being investigated in our laboratory. This knowledge may be useful for controlling the maize pest complex by mating disruption techniques and also for predicting the potential impact of mass use of pheromones in maize fields.

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References

Albajes, R.; Canela; R., Eizaguirre; M., Riba, M. & Guerrero, A. 1985: (Z)-9-Tetradecen-1-ol, an attractant for *Athetis hospes* Freyer. Colloq. INRA 46: 55-58.

Alfaro, A. 1972: Notas sobre *Ostrinia nubilalis* (Hub.) y *Sesamia nonagrioides* (Lef.) A. INIA, Serie: Prot. Veg. 2: 145-170.

Birch, M.C. 1984: Aggregation in bark beetles. In: Chemical ecology of insects. Bell, W.J.; Cardé, R.T. (Ed.): 331-353. Chapman and Hall. Ltd.

Blum, M.S. 1996: Semiochemical parsimony in the Arthropoda. Annu. Rev. Entomol. 41: 353-374.

Deland, J.P.; Judd, G.J.R. & Roither, B.D. 1994: Disruption of pheromone communication in three sympatric leafroller (Lepidoptera: Tortricidae) pests of apple in British Columbia. Environ. Entomol. 23: 1084-1090.

Ferrao, P.; Gries, G.; Wimalaratne, P.D.C.; Maier, C.T.; Gries, R.; Slessor, K.N. & Li, J. 1998: Sex pheromone of apple blotch leafminer, *Phyllonorycter crataegella*, and its effect on *P. mespilella* pheromone communication. J. Chem. Ecol. 24: 2059-2078.

Johnson, D.T.; Lewis, B.A. & Snow, J.W. 1991: Control of grape root borer (Lepidoptera Sesiidae) by mating disruption with two synthetic sex pheromone compounds. Environ. Entomol. 20: 930-934.

Klun, J.A.; Chapman, O.L.; Mattes, K.C.; Wojtkowski, P.W.; Beroza, M. & Sonnet, P.E. 1973: Insect sex pheromones: Minor amount of opposite geometrical isomer critical to attraction. Science 181: 661-663.

Klun, J.A. & Cooperators 1975: Insect sex pheromones: intraspecific pheromonal variability of *Ostrinia nubilalis* in North America and Europe. Environ. Entomol. 4: 891-894.

López, C.; Sans, A. & Eizaguirre, M. 1999: Influencia de la planta de maíz en el apareamiento de *Sesamia nonagrioides* Léfèbvre (Lepidoptera: Noctuidae). Inv. Agr. Prod. Prot. Veg. A . 14(3): 415-422.

Mazomenos, B.E. 1989: Sex pheromone components of corn stalk borer, *Sesamia nonagrioides* (Lef.). Isolation, identification and field tests. J. Chem. Ecol. 11: 1241-1247.

Niwa, C.G. & Daterman, G.E. 1989: Pheromone mating disruption of *Rhyacionia zozana* (Lepidoptera: Tortricidae): Influence on the associated parasite complex. Environ. Entomol. 18: 570-574.

Palanaswamy, P. & Seabrook, W.D. 1978: Behavioral responses of the female Eastern spruce budworm, *Choristoneura fumiferana*, to the sex pheromone of her own species. J. Chem. Ecol. 4: 649-655.

Prokopy, R.J. 1981: Epideictic pheromones that influences spacing patterns of phytophagous insects. In: Semiochemicals. Their role in pest control. Nordlund, D.A.; Jones, R.L.; Lewis, W.J. (Ed.): 181-213. John Wiley and Sons, New York.

Riba, M; Sans, A.; Eizaguirre, M.; Perdiguer, A.; Gimeno, F. & Aguilar, L. 1992: Optimización de la composición del atrayente sexual de *Sesamia nonagrioides* Lef.. Bol. San. Veg. Plagas 18: 193-200.

Sans, A.; Riba, M. & Blasi, R. 1993: Caracterización de las poblaciones de las razas de *Ostrinia nubilalis* (Hbn.)(Lepidoptera: Pyralidae) en el Nordeste peninsular basada en estudios de la feromona sexual. EFCE Publication Series 101 (2): 3-10.

Sans, A.; Riba, M.; Eizaguirre, M. & Lopez, C. 1997: Electroantennogram, wind tunnel and field responses of male Mediterranean corn borer, *Sesamia nonagrioides*, to several blends of its sex pheromone components. Entomol. Exp. Appl. 82: 121-127.

Sreng, I.; Maume, B. & Frerot, B. 1985: Analyse de la sécrétion phéromonale produite par les femelles vierges de *Sesamia nonagrioides* (Lef.) (Lepidoptére, Noctuidae). C.R. Acad. Sc. Paris, t. 301, Série III, nº9: 439-442.