The use of sex pheromones to control *Ephestia kuehniella* Zeller (Mediterranean flour moth) in flour mills by mass trapping and attracticide (lure and kill) methods

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Abstract

Since the identification of the components of the sex pheromone of *Ephestia kuehniella* Zeller in the 1970s, considerable progress has been made in the use of this pheromone for control. This paper reports the results obtained in flour mills using mass trapping and attracticide (lure and kill) methods. The mass trapping method when applied in two large flour mills, using a multifunnel trap every 260–280 m^3 baited with 2 mg of TDA (Z9, E12-14Ac, with a daily release of 13 μg) removed a large number of males from the mills. This prevented the expected increase in the population of *E. kuehniella* which remained at a constant low level. Subsequently, the number of larvae and damage to products in all departments were reduced. The number of fragments revealed in filth tests was also low. Control of *E. kuehniella* males by the attracticide method, using laminar dispensers (2 × 2 cm), baited with 2 mg of TDA and 5 mg of cypermethrin, showed that the combined action of the pheromone and the insecticide achieved good results. The success using attracticide applications every 220–280 m^3 was encouraging. The sublethal and lethal effects of attracticide formulations were found to be more intense if associated with a silhouette of inverted triangular shaped forms as a 'sign stimulus'. The control achieved with these two methods made the usual second fumigation of the mills unnecessary.

The employment of pheromones for the control of pest populations in mills may come into more widespread use if made price competitive with conventional insecticides. A benefit of the attracticide method is that it allows a broad spectrum of insecticides to be used selectively, thus preventing the death of beneficial insects, which may occur when conventional insecticides are used. The use of synthetic pheromones may lead to a drastic reduction of chemical treatments with subsequent economic and quality advantages. Goods may be protected from possible pesticide residues and thus improve the image of the company's products.

Introduction

In the Mediterranean region *Ephestia kuehniella* Zeller (Lepidoptera: Phycitidae) is a major pest of flour mills. It is generally present in Italian mills all year round with fluctuations that peak in June and also between August and September. The pheromone of *E. kuehniella* was identified in the 1970s as a blend of Z9E12-14Ac (TDA), Z9E12-14OH (TDO) and Z9-14Ac (TA) (Brady et al. 1971a,b; Brady 1973; Kuwahara and Casida 1973; Sower et al. 1974). Since then, the main component, TDA, has been used for monitoring *E. kuehniella* in many parts of the world. To pass from simple monitoring of storage phycitid moths to more sophisticated uses of their pheromone such as mass trapping, attracticide (lure and kill) and even mating disruption, it is often necessary to use the exact doses released of their pheromone components (Bommer and Reichmuth 1980). Taking into consideration the work of Read and Haines (1976), Mankin et al. (1980), Levinson and Buchelos (1981), Süss and Trematerra (1982), Trematerra and Rossi Porzio (1982), Levinson and Hoppe (1983), Hodges et al. (1984), Burkholder and Ma (1985), the activity of TDA and TA was investigated.

Using rubber septa it was found that *E. cautella* (Walker) responded well to a mixture of TDA + TA at doses of 10 ± 5 μg (100 ng released daily); *E. kuehniella* to TDA at doses of 2000 μg (13000 ng released daily) and *Plodia interpunctella* (Hübner) to a mixture of TDA + TA at doses of 1 ± 0.5 μg (10 ng released daily) (Süss and Trematerra 1985, 1986; Trematerra 1986).

Research has been carried out with the aim of reducing or finding alternatives to traditional chemical treatments, which often amount to two fumigations and several other limited insecticide treatments per year (Fig. 1). Direct control of infestations of *E. kuehniella* in flour mills by pheromones has been reported: mass trapping, by Levinson and Buchelos (1981), Trematerra and Battaini (1987), and Trematerra (1988, 1990); the possibility of the attracticide method, or lure and kill (an insecticide–pheromone combination), by Trematerra and Capizzi (1987, 1991); and mating disruption, by Trematerra and Capizzi (1987).

This paper reviews the studies undertaken in Italy from 1986 to 1993 on the possibility of controlling *E. kuehniella* infestations by sex pheromones using mass trapping and attracticide methods.

Studies on Mass Trapping Method

Preliminary observations in two different flour mills

Integrated control of *E. kuehniella* can be achieved in flour mills by mass trapping and the limited use of insecticides (Trematerra and Battaini 1987). Experiments were performed in two different unheated flour mills, one a small traditional kind, the other a large processing plant with modern machinery.

In this preliminary study, funnel traps (mastrap type, produced by G. Donegani Institute, Novara, Italy) (Fig. 2) with rubber dispensers baited with 2 mg of TDA (release rate of 13 μg daily) were used. The traps were placed in the most infested parts of the processing area of the traditional mill, covering an area of 567 m^3, while in the industrial mill covering 1560 m^3. Using the pheromone dispersion model proposed by Mankin et al. (1980) and consideration of the work of Süss and Trematerra (1985), two traps were placed in the former and six traps in the latter (in both areas one trap per 260–280m^3 was used). The traps were placed 2–2.5 m from the floor and 3.5–4 m from the walls.

The pipe unions were opened in each mill during temporary stoppages in the processing, to enable the pheromone to attract

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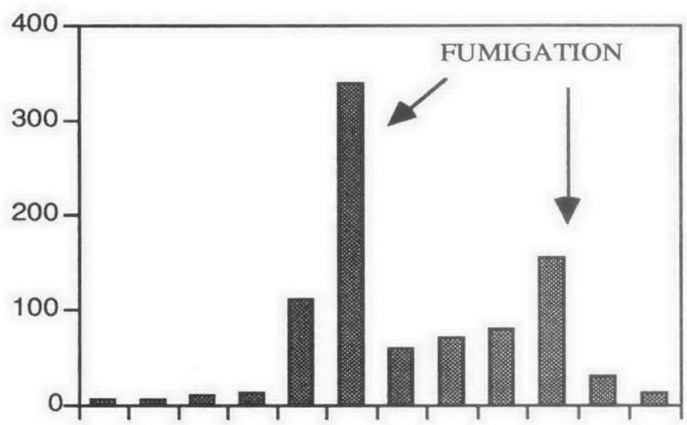

Fig. 1. Dynamic population of *Ephestia kuehniella* males in a fumigated flour mill.

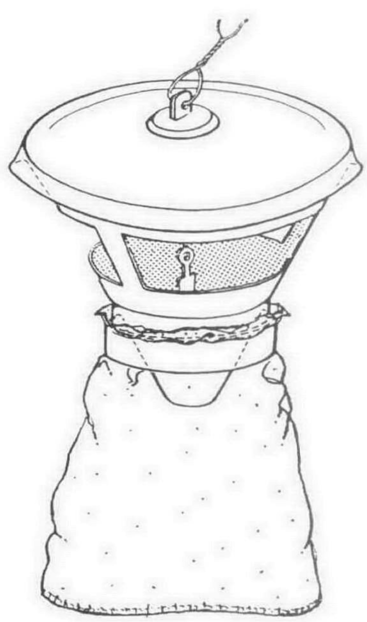

Fig. 2. The funnel trap used in the experiments.

moths hiding in the machinery. Trap captures and residual infestation of adults on the walls and machinery were recorded every week. Experiments were performed from April to October, when the moths were most numerous. As a control, observations were made in a different mill using pheromone traps for simple monitoring. The rubber dispensers used in the experiments were replaced at three-month intervals, when they became ineffective. The population fluctuations of *E. kuehniella* in the untreated flour mill are shown in Figure 3.

The results from the traditional mill (Fig. 4) show a marked increase in *E. kuehniella* during the first two weeks of June, until it was fumigated. This fumigation had a limited effect on the population. The 3402 captures in the traps prevented any further increase in the population, which remained limited and constant during the following months.

The results from the experiments in the industrial mill are reported in Figure 5. They show that the pheromone traps attracted a large number of *E. kuehniella* (8825 males), higher on average than trapped in the traditional mill.

A comparison of the percentage of males trapped to those free in the environments showed the mass trapping method to have a capture effectiveness over 94%. During the trial, monitoring traps trapped fewer *E. kuehniella* than normally found during months when moth development was unfavourable.

Of interest was the small number of females present in the residual infestation (14 specimens in the traditional mill and 388 in the industrial mill). This suggests their possible migration to adjacent rooms not permeated with pheromone. With regard to this, observations in other areas of the mills showed an abnormal abundance of females (over 75% of all moths present) compared with the control mill, where female presence was 50–55%.

Application of the method in a large flour mill

These experiments were performed in an unheated flour mill situated near Parma, in northern Italy. The mill was large (about 15000 m^3) and produced approximately 100 t/day of flour from spring wheat, *Triticum aestivum* L. (Trematerra 1988).

Following the findings of Trematerra and Battaini (1987), 56 funnel traps baited with 2 mg of TDA were placed in the mill, with a further four traps outside the mill. These outside traps were placed near loading equipment which was frequently flour covered. Trap capture and residual infestation of adults on the walls and machinery were recorded between 9 and 10.00 am every two weeks from May to November.

The monthly mean temperatures of the mill varied between 18 and 30°C from May to November, which allowed the continuous development of *E. kuehniella* for seven to eight months of the year.

The total fumigation with methyl bromide carried out in the last week of April in the flour mill led to a rapid decrease of the number of moths caught in the pheromone traps. Suppression of the number of moths caught in traps lasted only two to three weeks. The treatment was only partially successful, and rapid recolonisation of the mill occurred by insects present on the outside wall of the building, as evident from the peak catches of *E. kuehniella* in outdoor traps.

Trap captures in the mill are reported in Figure 6, and residual infestations of adults on the walls and machinery in Figure 7. Pheromone traps generally attracted a high number of male moths (about 15600). A total of 13777 *E. kuehniella* males was trapped in the mill, whereas 1813 were trapped in the four traps situated outside the mill (Fig. 8).

The continuous presence of the traps in the mill resulted in a population reduction of 95–97%. The use of this method led to a reduction in chemical use within the mill, with a few limited treatments needed, plus one rather than the usual two fumigations required.

The catches of males varied according to the weather, being relatively high at the end of May, gradually decreasing during June and early July but increasing between July and August, and then abruptly declining from September to November. This confirmed the results observed in the preliminary tests in the smaller mills.

The prolonged presence of the traps in the flour mill, particularly during periods when climatic conditions were favourable for moth development led to a drastic reduction of infestation to the level of 'insectistasis' as defined by Levinson (1983). As observed above, the number of females present in the mills indicated an extremely low percentage which was repeatedly found throughout the tests. The pheromone present in the treated environment may have induced female moths to leave the mill for other areas more suitable for reproduction, or the absence of males may have stimulated dispersal. High concentrations of synthetic sex pheromone caused an

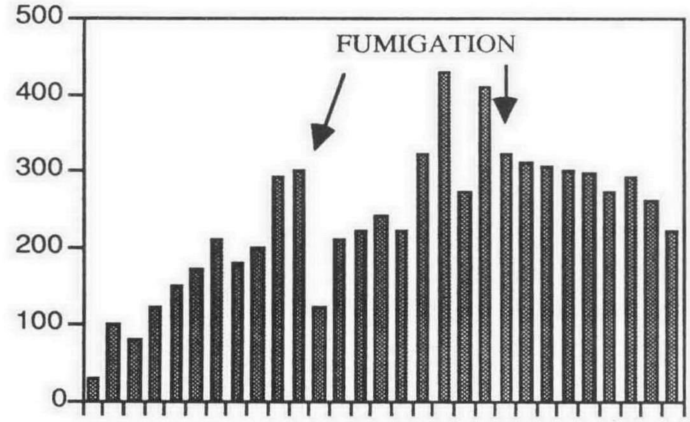

Fig. 3 Dynamic population of *Ephestia kuehniella* in the untreated flour mill.

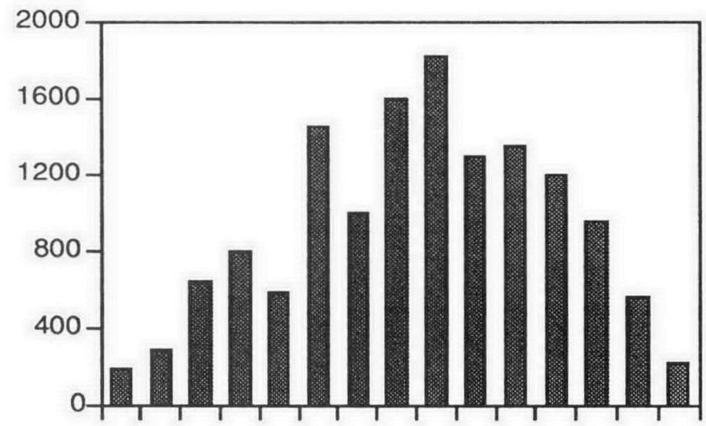

Fig. 6. Catches of *Ephestia kuehniella* males in the flour mill.

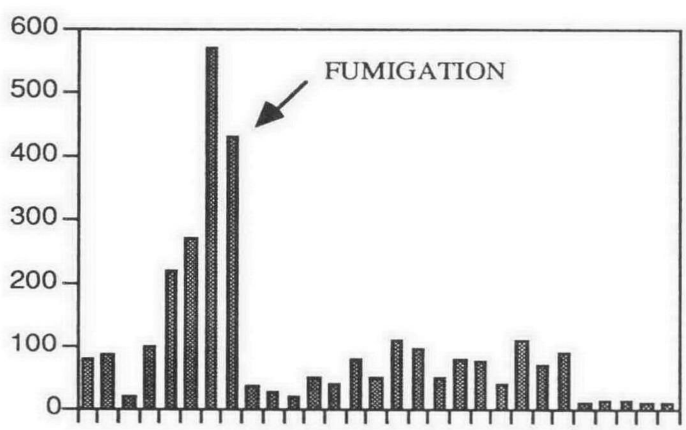

Fig. 4. Weekly catches of male *Ephestia kuehniella* in the environment of the traditional flour mill.

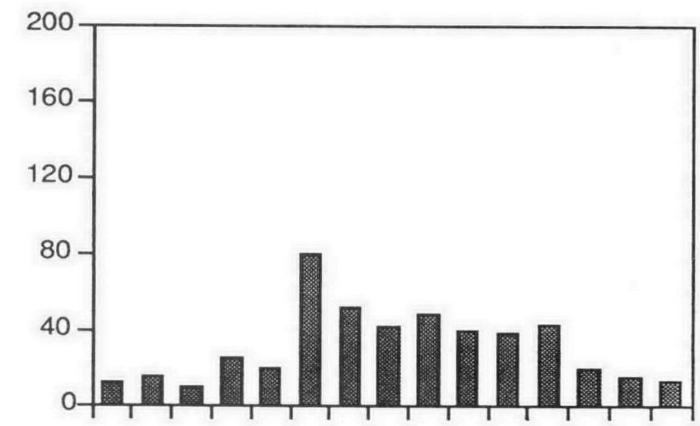

Fig. 7. Residual infestation of adults of *Ephestia kuehniella* in the flour mill.

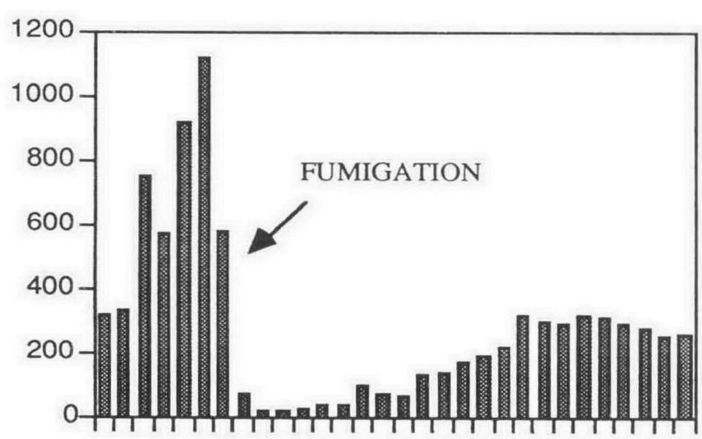

Fig. 5. Weekly catches of male *Ephestia kuehniella* in the environment of the industrial flour mill.

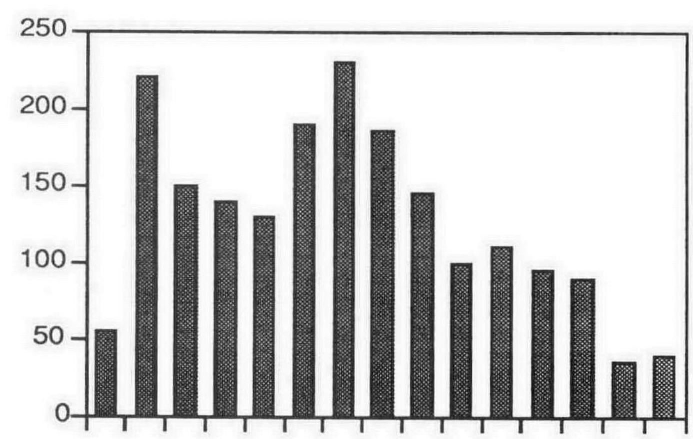

Fig. 8. Catches of *Ephestia kuehniella* males outside of the flour mill.

increased flight activity amongst females, which may have increased dispersal.

Three years of mass trapping

The experiment was performed over three years in an unheated flour mill situated in Pianura Padana, northern Italy. The mill consisted of a large building of 20000 m^3 in which about 125 t/day of flour were produced from spring wheat. Funnel traps with 2 mg of TDA (daily release of 13 μg) were used in the test. The dispensers remained effective for about 2.5–3 months and were then replaced. Following the work of Trematerra and Battaini (1987) and Trematerra (1988), 67 traps were placed inside the mill and five outside. Trap capture and residual infestation of adults on the walls and machinery were recorded every two weeks. The success of the trial was noted by observing the fluctuations of larval presence in machinery and insect fragments in the flour produced by the mill, and determined by filth tests.

Control observations were made in a different mill, situated in the same area, using pheromone funnel traps for simple monitoring. Mean trap catches reflecting the moth population in the control mill are reported in Figure 9.

In 1987 the mill was fumigated with methyl bromide in the last week of April and again between August–September. This resulted in a rapid decrease of the number of moths trapped in the pheromone treated mill, but for only two to three weeks. The fumigations were only partially successful, with rapid recolonisation of the mill, possibly from insects present on the outside walls of the building or from insects surviving the fumigation. This was seen in the peak catches of *E. kuehniella* in traps, and similar observations were made in 1988 and 1989. Total trap captures in the mill during the three years of the trials are reported in Figure 10, with the trap captures from traps situated outside the mill shown in Figure 11.

The traps removed males from *E. kuehniella* populations preventing an increase in the residual population. The effectiveness of mass trapping, gauged by the percentage of males trapped as compared with those free in the environment in the course of the experiments, was about 90–95%. The prolonged presence of the traps in the flour mill, particularly during periods when the moths were able to breed, led to a reduction throughout the mill, including areas where no processing occurs, such as the stock yards and sales office.

the investigation showed that moths that are harmful to food supplies are found outdoors. The well-founded assumption that they might re-infest appropriate goods should be taken into consideration with regard to storage, especially since it has hitherto been taken for granted that an infestation can arise only from infested products.

The control program considered here made a second fumigation (in August–September) of the mill unnecessary in both 1988 and 1989. The use of the pheromone was accompanied by careful cleaning, particularly of the machinery, which further reduced the possibility of moth reproduction.

There was also a consequent economic and qualitative advantage arising from the protection of the products from pesticide residues and an enhanced reputation for the company.

The impressive reduction in the population density of the moth raises the question of whether insectistasis can be achieved in flour mills by mass trapping alone. Extrapolation of the data suggests that using pheromone traps for longer periods should result in a further reduction of the population density of *E. kuehniella*. However, it was not possible to eliminate the infestation, or even to reduce the level to insectistasis, if trapping was not accompanied by careful cleaning, particularly in corners and inside the machinery where moths were able to reproduce undisturbed.

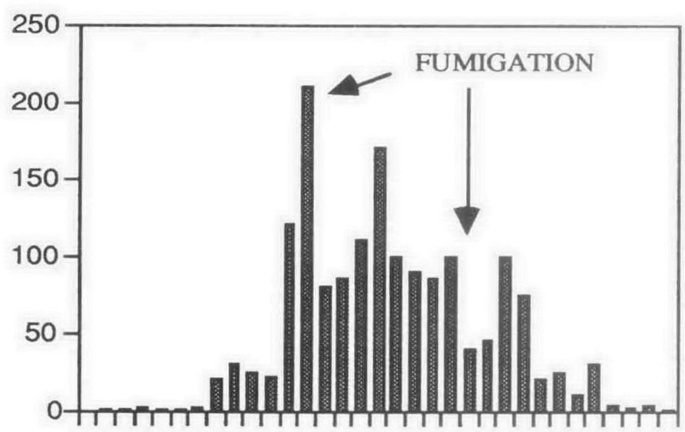

Fig. 9. Dynamic population of *Ephestia kuehniella* males in the control flour mill.

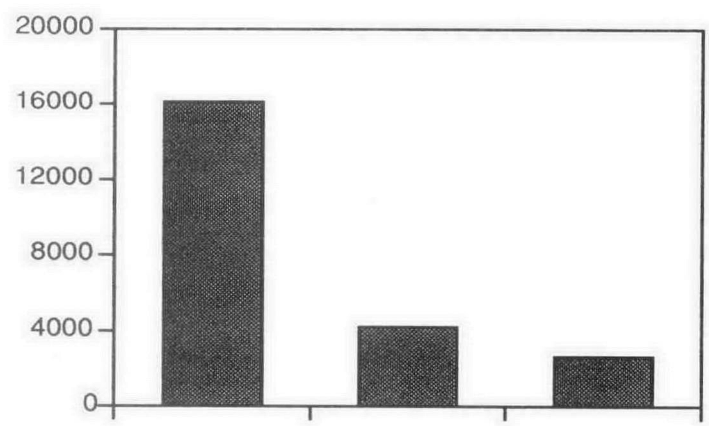

Fig. 10. Total captures inside the flour mill during three years of mass trapping.

The pheromone traps attracted a high number of male moths, with a total of 16108 trapped in the mill during 1987, 4158 in 1988, and 2639 in 1989. It is interesting that 1813 males were also trapped in the five traps situated outside the mill during 1987, 871 in 1988, and 670 in 1989. The continuous presence of traps both inside and outside the mill caused a marked decrease in the *E. kuehniella* population during the second and the third year, resulting in levels 26% and 16%, respectively, of those recorded during the first year.

In the same trial, high levels of the infestation occurred in rooms where flour or bran silos were present. In these areas the moths were able to find considerable residues of flour and other goods. During the three years of experiments, moths were observed to be more abundant on floors where it was easier for the gravid female to enter from outside the mill and colonise the environment (Fig. 12).

Investigations on the appearance of moths of the genera *Ephestia* and *Plodia* outside warehouses and food processing factories were reported by Trematerra (1988). The results of

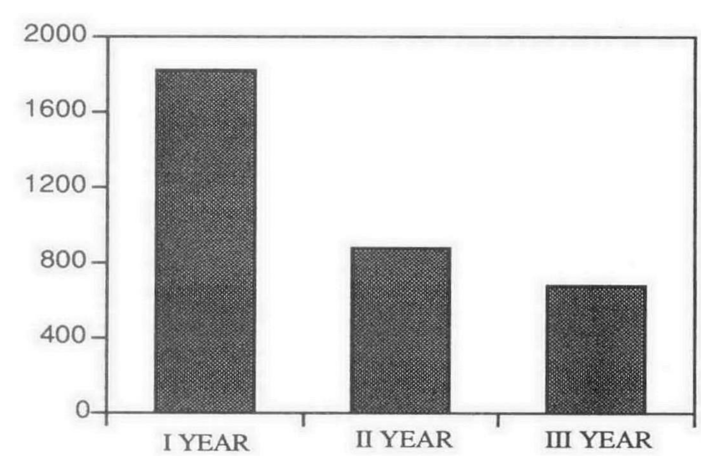

Fig. 11. Total captures outside the flour mill during three years of mass trapping.

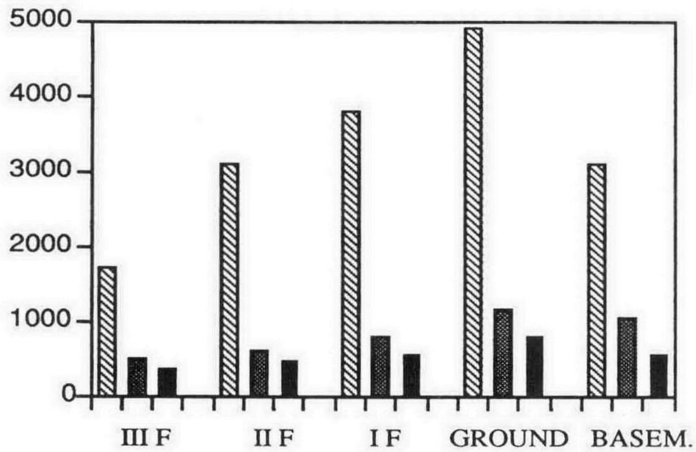

Fig. 12. Dynamic population of *Ephestia kuehniella* males in different floors of the flour mill during three years of mass trapping.

Assuming a highly efficient trapping system and trapping regime have been established, the problem still remains of accurately assessing the effects of the treatment. With regard to the experiments reported above, the residual infestation of adults throughout the three years of the trial was determined as well as larval presence in machinery. Fragments of moths in the flour were determined by monthly filth tests.

Regular inspection of catches in pheromone traps and in rooms revealed the periodic appearance of a summer generation of *P. interpunctella* and *Sitotroga cerealella* (Olivier), but their population density was low. The presence of *Tribolium castaneum* (Herbst) and other Coleoptera in the mill in August was controlled by localised insecticide treatments.

As observed before in the other mills controlled by mass trapping, the small number of *E. kuehniella* females present in the residual infestation was of special interest. This number, compared with that found in the environment, indicated an extremely low percentage which was repeatedly found throughout the tests.

Furthermore, electroantennogram tests on virgin females and on mated females revealed a positive response of mated females to the TDA. This response maybe explained as a disturbed response to the presence of the pheromone (Trematerra and Capizzi 1991), although the biological significance is not fully understood.

Studies on the Attracticide Method

Preliminary applications

The method involves combining insecticide on one side of the laminar dispenser with the attractant effect of the pheromone.

The preliminary study was carried out in a large mill by Trematerra and Capizzi (1987). The technique of the mass-trapping trials (Trematerra and Battaini 1987) was applied, but instead of funnel traps, laminar dispensers (2 × 2 cm) were used baited with 2 mg of TDA and treated with 10 mg of cypermethrin. The dispensers were placed on the walls and machinery 1.8–2.0 m from the floor, with one dispenser for every 220–280 m^3.

The effectiveness of this method was compared with mass trapping which was used to protect another area of the same mill (Fig. 13).

The residual infestation of adults on the walls, machinery and in traps was recorded weekly. Experiments were performed from April to May of the following year (Fig. 14). The laminar dispensers and the natural rubber dispensers in the traps were replaced every 2.5–3 months.

The attracticide method eliminated over 90% of the males, with a stabilised residual infestation at acceptable levels. The success of this method may be ascribed to the males touching the attraction source again and again (Fig. 15). The prelimi-

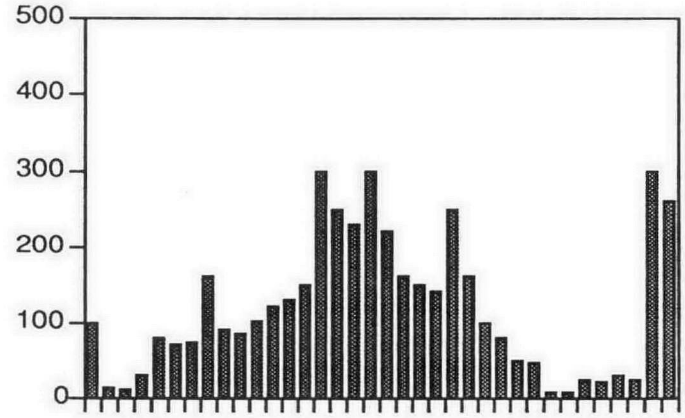

Fig. 13 Dynamic population of *Ephestia kuehniella* during a year of mass trapping.

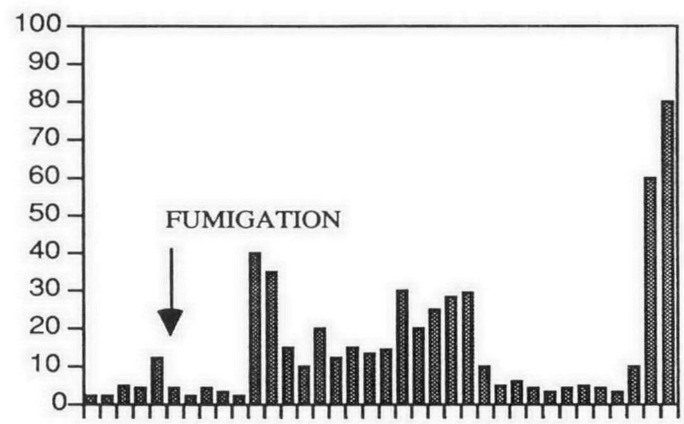

Fig. 14. Residual infestation in the environment treated by mass trapping.

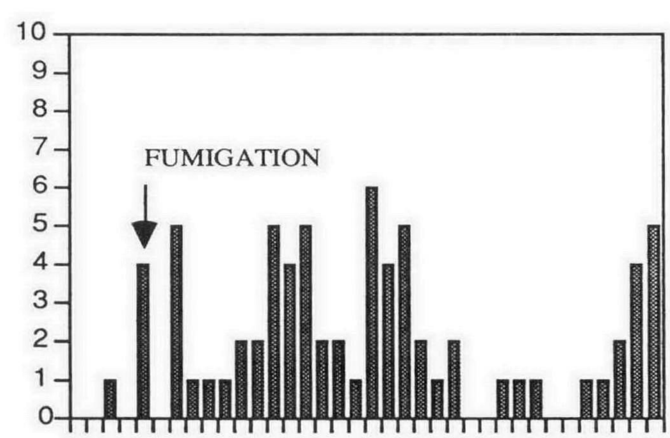

Fig. 15. Residual infestation in the environment treated by the attracticide method.

nary data showed that this method and mass trapping have the same degree of control of *E. kuehniella*.

Control of *E. kuehniella* in an entire mill is currently in progress. In this case the sublethal and lethal effects of attracticide formulations were combined with a silhouette of inverted triangular forms as a 'sign stimulus'. These forms were used in conjunction with the pheromone and cypermethrin (5 mg) applied on the surface of the laminar dispenser. Using the experimental plan reported above, a long-term program was undertaken in central Italy in a large mill that produced flour from *T. aestivum* and from *T. durum* L. After two years the attracticide method removed a high percentage of males from the mill and prevented an increase in the population of *E. kuehniella*, which remained limited and constant during every month of the year. The numbers of larvae and damage to products in all departments were diminished and the fragments revealed in the filth test were also negligible.

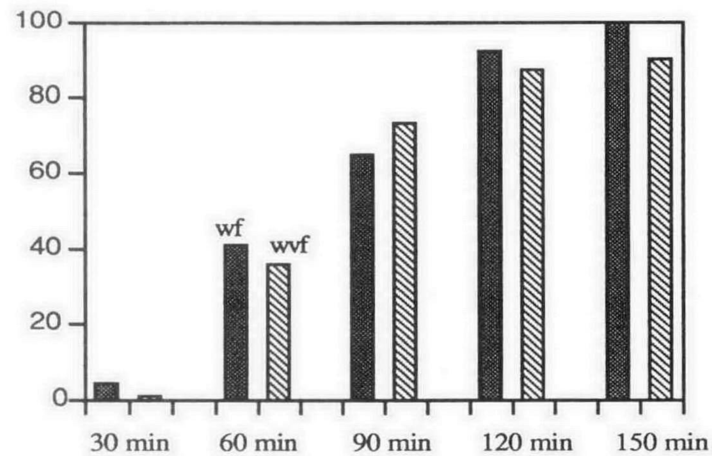

Fig. 16. Percentage mortality of males during the tests performed in big cages; without females (wf), with virgin females (wvf).

Studies on effectiveness

The effectiveness of the attracticide formulations depends initially upon the interaction between the pheromone call and the visual effect of the location of the laminar dispenser. Then, after contact with the treated layer, effectiveness is dependent upon the insecticide effects which modify (at the sublethal level) the behaviour or induce mortality.

With regard to this, Trematerra and Capizzi (1991) performed behavioural tests involving olfactometer, electroantennograms and insecticide activity in order to clearly determine the importance of these factors in the attracticide method. In field tests they checked the measure of control of *E. kuehniella* in practice.

In the olfactometer tests the percentage of *E. kuehniella* males responding to pheromone–insecticide dispenser was 80–90%, confirming that cypermethrin had little influence on their sexual behaviour, as reported for *Pectiniphora gossypiella* (Saunders) by Haynes et al. (1986). These tests also showed no difference in the distribution of virgin females in the presence or absence of TDA. Importantly, gravid females significantly increased their mobility and distribution in the presence of the pheromone. This suggests that gravid *E. kuehniella* can perceive their own pheromone, as reported for other Lepidoptera by Mitchell et al. (1972), Birch (1977), Palaniswamy and Seabrook (1978). This may result in a repellent effect, thus inducing dispersion.

In the electroantennogram tests, males, mated females and virgin females revealed different responses to control and pheromone tests. The average response of males to the stimuli was quantified at 0.42 mV, while the control was 0.17 mV. In mated females the response was 0.24 mV and 0.12 mV, whilst in virgin females it was 0.10 mV and 0.21 mV, respectively. In *E. kuehniella* males, the positive response to the pheromone is expected but in the mated female it may be explained as a disturbed response to the presence of pheromone substance.

Gould (1984) reported certain pyrethroid insecticides to be repellent to some insects, but Trematerra and Capizzi (1991) found no evidence that cypermethrin was responsible for any statistically significant reduction in source contact when comparing control using the dispenser with pheromone alone or when in competition with virgin females. Cypermethrin showed a slight reduction in source contact, but this did not result in any significant change in the behavioural sequence. Males that contacted attracticide dispensers showed symptoms of sublethal poisoning that was only manifested in their ability to perform the behavioural sequence involved in locating the source of pheromone. Percentage mortality during the experiments is reported in Figure 16. It can be seen that the level of mortality of males in the cages was not significantly affected by the simultaneous presence of females. In this case the females survived for a long time. We observed that 56% of males were killed in 30 minutes without mating; 12% in 50 minutes after a behavioural sequence, 18% in 50 minutes after a courtship sequence and only 14% were able to mate with the female. These effects in the field may be more intense than in our experiments because of the high population density.

The possible interaction between optical and pheromone stimuli was studied by recording choices of *E. kuehniella*, males and females of nine different figures varying in shape and position. The experiments were carried out in two unheated mills: one was small, traditional, and wooden; the other a large processing plant, recently built, with advanced machinery. Light brown cardboard figures of approximately 25 cm^2 were placed on a rectangular sticky panel (85 cm x 70 cm) divided into nine sectors. The insects which landed around the sides of these figures were counted and sexed every three days. Experiments were repeated six times, randomising the position of the figures.

The preferential flight of *E. kuehniella* towards the light-brown cardboard figures resulted in the attraction of a significantly higher number of males to inverted triangular forms resembling the female than to any of the others. The mean catch of 106.25 and 103.375, was higher than the catches on the other figures (Table 1).

Control of *E. kuehniella* males in mills by the attracticide method showed that the combined action of TDA and cypermethrin spread on the surface of a laminar dispenser positioned on the inverted triangular figure achieved good results (Figs 17–18).

According to Traynier (1968), male *E. kuehniella* in the presence of the sex pheromone attempt to mate with objects resembling females. In our case the orientation preferences for the silhouette of inverted triangular forms can thus be regarded as a sign stimulus attracting *E. kuehniella* males to a configuration which resembles females.

Levinson and Buchelos (1981) found that male *Ephestia* spp. do not fly to a source of TDA in complete darkness, whereas they readily flew towards the pheromone at dim light. This suggests that in *E. kuehniella* optical stimulation of the retina is important for taking off. Previously, Kennedy and Marsh (1974) described the optomotor reaction in *P. interpunctella*, *E. cautella* and *E. kuehniella* males to a striped pattern on the ground as an anemotactic guide to the appropriate pheromone stimulus. Interaction between optical and

Table 1 Interaction between optical and pheromone stimuli, comparative responses of *Ephestia kuehniella* to various figures. Means followed by the same letter do not differ significantly. Duncan's multiple range test: $P<0.05$, capital letters; $P>0.01$, small letters.

U	73.5 (A,a)
+	79.625 (AB,a)
I	80.0 (AB,a)
●	80.125 (AB,a)
—	88.625 (ABC,ab)
⊥	90.5 (ABCD,ab)
T	93.125 (BCD,ab)
▼	103.375 (CD,b)
▲	106,25 (D,b)

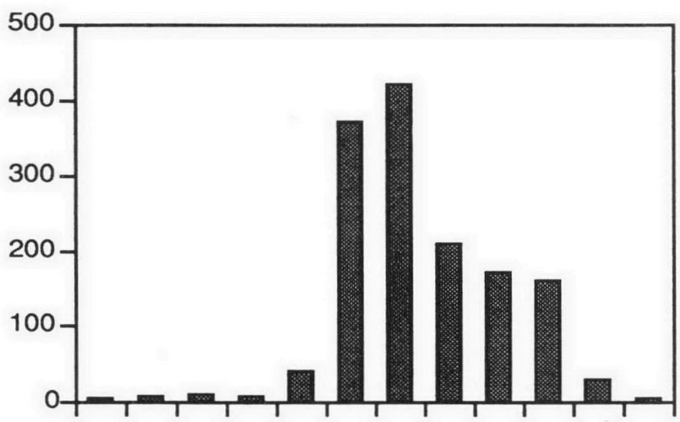

Fig. 17. Dynamic population of *Ephestia kuehniella* in untreated flour mill.

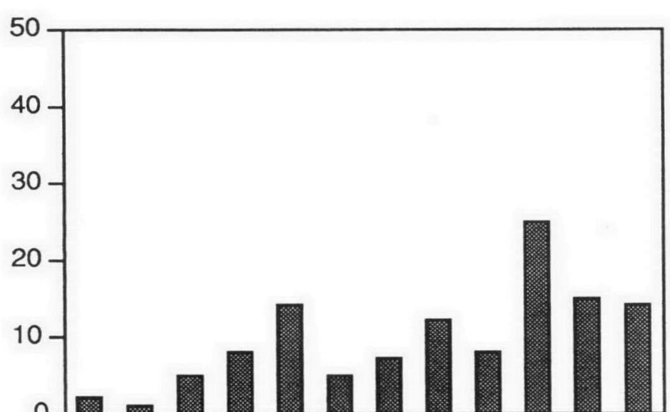

Fig. 18. Dynamic population of *Ephestia kuehniella* in flour mill protected by the attracticide method.

pheromone stimuli in other insects of stored products, such as *E. cautella* and *P. interpunctella*, was also reported by Levinson and Hoppe (1983).

Leos-Martinez (1989) used Lindgren funnel traps without any attractant to determine the daily flight periodicity of *Ahasverus advena* (Waltl), *Cryptolestes ferrugineus* (Stephens) *Oryzaephilus surinamensis* (L.), *Rhyzopertha dominica* (F.), *T. castaneum*, *E. cautella*, *P. interpunctella* and *S. cerealella*. Trematerra and Daolio (1990), using unbaited multifunnel traps, caught *C. ferrugineus*, *R. dominica*, *S. oryzae* and *T. castaneum*. With the same trap more species of Coleoptera and Lepidoptera were collected in a flour mill (Trematerra et al., these proceedings). Quartey and Coaker (1992) undertook studies to improve trap design and found that *E. cautella* responded visually to shapes of different colour and size. They showed that *E. cautella* were attracted to darker coloured vertical rectangles on a white background and to brown and white stripes.

The success of the laminated pheromone dispensers for *E. kuehniella* control in field applications is most encouraging. The sublethal and lethal effects of attracticide formulations was found to be more intense if associated with a silhouette of inverted triangular form. In this case, the combined action of TDA and cypermethrin applied on the surface of the laminar dispenser achieved results similar to those obtained by mass trapping.

The use of pheromones to control pest populations through the attracticide method may become more popular and successful if it is made price competitive with conventional insecticide treatments and lower doses of pheromones are used than those applied in mass trapping or in mating disruption methods. Another benefit is that the attracticide technique allows a broad spectrum of insecticides to be used selectively, preventing the deaths of beneficial insects which may occur with conventional applications of insecticides.

Conclusions

Considerable progress has been made in recent years in controlling *E. kuehniella* with pheromones by mass trapping and by using the attracticide method. Mating disruption trials have been also carried out for species of *Ephestia* in warehouses by permeation with TDA. The isolated environment within such large stores certainly provides a situation where immigration is virtually excluded. The relatively high population densities that occur with such enclosures do not, however, suggest this approach to be promising (Barrer 1976; Haines and Read 1977). However, with *E. kuehniella* few studies have been undertaken. In Italy, mating disruption using laminar dispensers distributing 0.2 mg of TDA/m^3, has resulted in a considerable reduction of an infestation in a traditional flour mill over a three-year period. The number of insects in the funnel traps fell from thousands trapped during the first year to a few males during the third year of mating disruption (Trematerra and Capizzi 1987). Further data are necessary to optimise this control method especially in order to reduce the quantity of pheromones used and thus the risk of residues in food.

Better control of *E. kuehniella* in flour mills can be obtained by the use of mass trapping, attracticide or mating disruption methods, together with careful cleaning of the rooms, particularly in the corners and, above all, inside machinery. This procedure eliminates the possibility of insect reproduction in areas where food is present.

In the case of complex infestations where more than one species of moth or beetle is involved, treatments which use only pheromones become complex and are not effective. Integrated treatments which use different means, including chemicals, achieve better results. An important role should be assigned to all prevention techniques which effectively keep infested goods out of food-processing plants, mills, storehouses, etc.

Insectistasis can be readily achieved by continuous supervision of environments by pheromone traps, in combination with a limited number of curative measures appropriately timed.

The use of pheromones is therefore one of several modern techniques that show promise in controlling stored-product insects. Their use may lead to a drastic reduction of chemical treatments with consequent economic and qualitative advantages. Goods may be protected from possible pesticide residues and hence make a company's products more attractive to consumers.

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