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Some factors influencing the performance of pheromone traps for codling moth, oriental fruit moth and the two european grape vine moth species in Italy

The most part of the research on various aspects of the biology and population dynamics of Lepidoptera pests in orchards and vineyards of Italy has been done by using commercial traps and pheromone dispensers optimized abroad. Geographical segregation of the species could result in more or less marked differences in their responses to synthetic sex-attractant mixtures.

We designed, constructed and tested many trapping devices during the period 1975-1978 and examined by field trials some of the factors potentially connected with their effectiveness. Parameters such as trap design and colour, dosage and purity of the synthetic attractants have been studied.

These were the objectives of our program, and we report herein the results of a 3-yr study undertaken in orchards and vineyards in the North of Italy on the following pests: codling moth, *Cydia pomonella* (L.), oriental fruit moth, *Cydia molesta* (Busck), and the two European grape vine moth species *Lobesia botrana* (Den. & Schiff.) and *Eupoecilia ambiguella* (Hb.).

MATERIALS AND METHODS

Instrumentation - Chemical structures of the products were confirmed by elemental analysis, i.r. spectroscopy (Perkin Elmer 257 spectrophotometer), ^{1}H and ^{13}C n.m.r. spectroscopy (Bruker WH 90 instrument), and mass spectrometry (Varian MAT 112 S and/or CH 5 spectrometers). High pressure liquid chromatography (Water Ass. pump) was used in the purification of the end products and was done on stainless steel columns packed with 20% $AgNO_3$ coated silica gel (Adsorbosil 2-ADN) using benzene as eluent. Analytical g.l.c. was carried

out in a Carlo Erba 2150 gas chromatograph equipped with high resolution glass capillary columns (Ucon HB 5100, 25m × 0.34mm and Carbowax 20M, 50m × 0.34mm).

Chemicals - (8E,10E)-8,10-dodecadien-1-ol (8E,10E-12:OH) was prepared by a modification of the synthesis of Mori (1974) consisting in the coupling of sorbyl acetate with 6-tetrahydropyran-2-yloxy-hexyl magnesium bromide in the presence of a catalytic amount of Li_2CuCl_4 in THF. This route has been recently published and gave 8E,10E-12:OH practically pure (Henrick 1977, Samain and Descoins 1978).

(Z)-8-Dodecen-l-yl acetate (8Z-12:Ac) was prepared by the reduction of 8-dodecyn-l-yl acetate over Lindlar catalyst in the presence of synthetic quinoline. Pure Z-isomer was obtained by preparative h.p.l.c.

(E)-8-Dodecen-l-yl acetate (8E-12:Ac) was prepared by the reduction of 8-dodecyn-l-yl acetate with lithium aluminium hydride in diglyme at 140°C.

(Z)-9-Dodecen-l-yl acetate (9Z-12:Ac) was synthesized by the reduction of 9-dodecyn-l-yl acetate over Lindlar catalyst in the presence of synthetic quinoline. Pure Z-isomer was obtained by preparative h.p.l.c.

(7E,9Z)-7,9-Dodecadien-l-yl acetate (7E,9Z-12:Ac) was obtained by the coupling of (2E,4Z)-2,4-heptadien-l-yl acetate (Cassani *et al.*, 1979) with 5-tetrahydropyran-2-yloxypentyl magnesium bromide in the presence of a catalytic amount of Li_2CuCl_4 in THF. Partial isomerization (ca. 10%) to the 7E, 9E-isomer occured, this contaminant was easily removed by treatment with tetracyanoethylene in THF. The tetrahydropyranyl ether was converted directly to 7E,9Z-12:Ac with acetyl chloride and glacial acetic acid. The product (=99.5% purity) was obtained by crystallization from pentane at −35°C.

Trapping devices - Several trapping devices were tested. However, we report herein the results obtained with traps of the type shown in Fig. 1. The advantages of these traps are their ease to produce, compactness for storage and transport, durability and versatility for routine monitoring of key pests. They are made of plastic material (polionda), lined with an adhesive substance, 21,5 cm long × 23 cm wide × ca. 11 cm high. Different coloured traps were used and they were charged with test chemicals placed on rubber septa (5 × 9 mm rubber-stoppers, sleeve type, Angelo Ascenso Milano) molded with 0.1% wt. of 2,6-di-*tert*-butyl-4-hidroxy-toluene.

Field testing on codling moth - Separate sets of rubber septa were charged with 10,1, and 0.1 mg of 8E,10E-12:OH dispensed in 100 μl of hexane. Relative attractiveness of the various cap charges was evaluated in 1975 in a non-insecticide-sprayed apple orchard

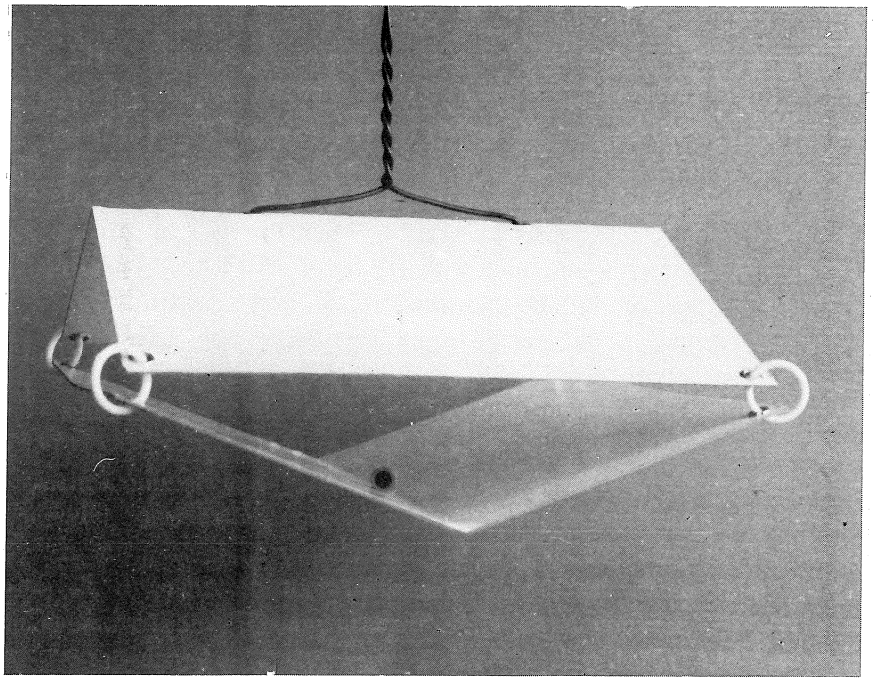

Fig. 1 - Trap design developed by Montedison S.p.A.

(Azienda Campiglia, Nebbiuno, NO) using a randomized complete-block design with 4 replicates positioned on 1 white tap/tree at a height of 1.5 m and a 50 m tree spacing. Traps were cleared of moths and randomized every fourth day. The effect of varying the trap colour was investigated in 1976 in the previously described orchard. Different coloured traps were baited with 1 mg of 8E,10E-12:OH and randomized every fourth day. The seasonal distribution pattern of moth emergence was monitored during 1977 and 1978 by weekly counts of males captured in white (1977) and yellow (1978) traps baited with 1 mg of the at-

tractant in a commercial apple orchard (Azienda Aghina, Corciago, NO) at a rate of 2 traps per hectare. Pheromone dispensers were replaced every 6 weeks.

Field testing on oriental fruit moth - A series of 8Z-12:Ac, 8E-12:Ac and dodecyl alcohol (12:OH) mixtures were dispensed in 100 μl of hexane to rubber septa, which were applied to white traps in a commercial peach orchard (Azienda Piacentini, Volpedo, AL). Field test was conducted during June 3 - October 10, 1976 using a randomized complete-block design with 4 replications in each comparison and 1 trap/tree at a height of 1.5 m and a 50 m tree spacing. Traps were randomized every fourth day and caps replaced every 6 weeks.

The effect of varying the trap colour was investigated in a commercial peach orchard (Azienda Franco, Volpedo, AL) in 1977. Different coloured traps were baited with 186 μg of 8Z-12:Ac, 14 μg of 8E-12:Ac and 8 mg of 12:OH and randomized every fourth day. The seasonal distribution pattern of moth emergence was monitored by weekly counts of males captured in yellow traps baited with the above attractant mixture. Orchard received traps at a rate of 2/ha and pheromone dispensers were replaced every 6 weeks.

Field testing on *Eupoecilia ambiguella* - The studies to determine the optimum amount of 9Z-12:Ac in the rubber septa were conducted in three commercial vineyards separated by about 50 km. All treatments were replicated 4 times and randomized at least once. White traps were used and they were in the field from April 21 to July 21, 1977. Moths were counted and removed from the traps twice a week. The effect of varying the trap colour was conducted along the general patterns previously described for codling moth and oriental fruit moth. Seasonal trends in the daily flight activity were obtained during 1977 and 1978 by weekly counts of males captured in white (1977) and Hawana-brown (1978) traps baited with 1 mg of 9Z-12:Ac and distributed in the vineyards (Azienda Valbissera, S. Colombano, MI) at a rate of 3/ha. Pheromone dispensers were replaced every 6 weeks.

Field testing on *Lobesia botrana* - The effect on attraction of different isomer contents was studied in a commercial vineyard during the 1977 using 1 mg of chemicals per septum in white traps. All treatments were replicated 4 times and randomized at least once. Moths were counted and removed from the traps twice a week. The seasonal

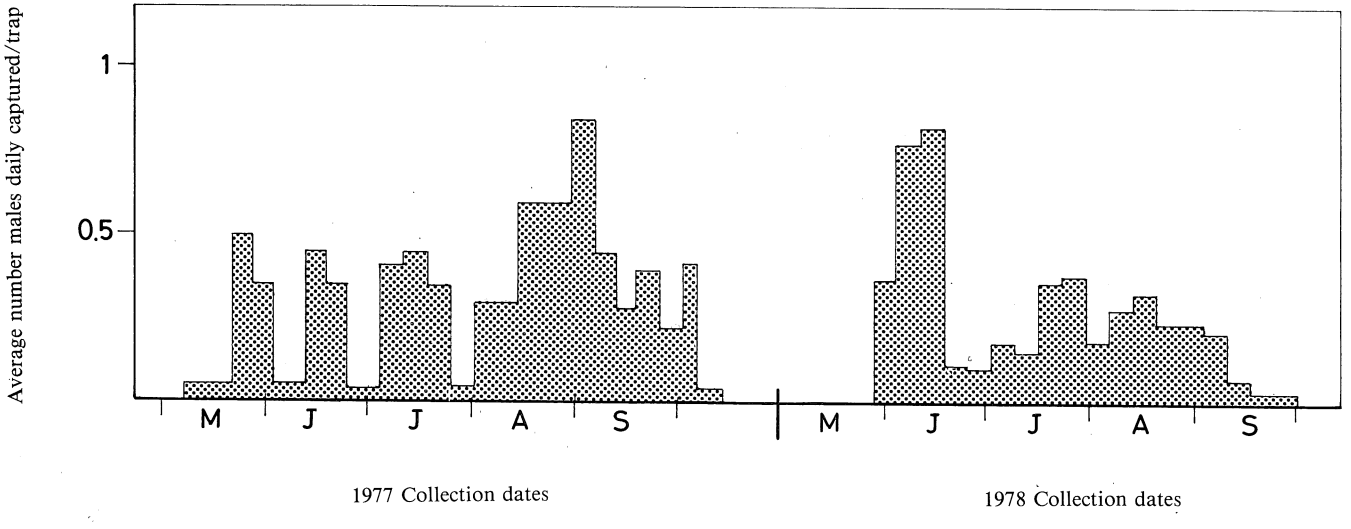

Fig. 2 - Seasonal abundance of *Cydia pomonella* as indicated by daily average number males captured per trap during 1977 and 1978.

distribution pattern of moth emergence was monitored during 1977 and 1978 by weekly counts of males captured in Hawana-brown traps baited with 1 mg of 7E,9Z-12:Ac and distributed in the vineyard (Azienda Valbissera, S. Colombano, MI) at a rate of 3/ha.

Results and discussion

Codling moth *(Cydia pomonella)* - Since preliminary trapping data indicated that isomeric impurities were strongly detrimental to the effectiveness of the synthetic 8E,10E-12:OH, we decided to operate with the purest attractant preparation. This conclusion was in complete accord with results of Roelofs *et al.* (1972). Table 1 summarizes dosage response to three different cap charges. The 10 mg amount of attractant per dispenser did not appear to be as efficient as the other doses. A test of longevity of caps charged with 0.1 mg of the attractant showed that the septa were attractive for at least 3 weeks in the field, then rapidly lost their effectiveness after few days of additional exposure. Traps baited with 1 mg were slightly less attractive than traps baited with freshly made dispensers after 4 weeks of field aging. We concluded that an initial cap charge of 1 mg of 8E,10E-12:OH would maintain an optimal attractiveness for a period of at least 15 days. Although codling moth captures were not greatley influenced by trap colour (Table 2), the Hawana-brown traps caught significantly more males. Fig. 2 shows the seasonal distribution pattern of moth emergence.

Oriental fruit moth *(Cydia molesta)* - The ethological function of individual components of the attractant mixtures used in our trapping trials has been described by Cardé *et al.* (1975). Table 3 clearly shows that the pure Z-isomer was considerably less attractive than any of the other mixtures containing the opposite isomer; the highest catches were observed with 3% to 10% of E-isomer. There is strong evidence that captures were also enhanced when dodecyl alcohol was present in the attractant mixtures. Evaluation of colour preference (Table 2) showed that the most effective trapping was achieved with yellow traps.

Relative attractancy of septa of ages ranging from fresh-4 wk fresh to 4 weeks was determined by placing them in the orchard simultaneously. 3-Week old rubber septa containing the chemical mixture VIII of Table 3 were as attractive as fresh septa. Fig. 3 shows the seasonal distribution pattern of moth emergence.

TABLE 1. Effect of varied initial charge on the attractancy to males of *Cydia pomonella* (codling moth)[a].

8E,10E-12:OH charge of rubber septum (mg)	Mean no. of males per trap[b]			
	1st wk	2d wk	3d wk	Total
10	0	0	2	2a
1	9	24	22	55b
0.1	12	21	16	49b

a The test was conducted in 1975 from August 4-25.

b Numbers followed by the same letter are not significantly different (P = 0.05, *t* test).

TABLE 2. Effect of trap colour on male response of codling moth *(Cydia pomonella)*, oriental fruit moth *(Cydia molesta)* and the two European grape vine moth species *(Eupoecilia ambiguella* and *Lobesia botrana)*.

Trap colour	Mean number males per trap[a]			
	C. pomonella[b]	*C. molesta*[c]	*E. ambiguella*[d]	*L. botrana*[e]
White	17a	291a	67a	—
Blue	12b	331a	28b	181a
Yellow	37c	450b	14b	580b
Red	13b	256c	81a	926c
Bright green	35c	194d	—	592b
Yellowish green	35c	—	36b	—
Dark green	12b	—	178c	376b
Hawana-brown	52d	340a	63a	443b

a Numbers followed by the same letter are not significantly different (P = 0.05, *t* test).

b The test was conducted in 1976 from Jul. 15 - Aug. 15.

c The test was conducted in 1977 from Jul. 15 - Aug. 31.

d The test was conducted in 1977 from May 7 - Aug. 5.

e The test was conducted in 1977 from May 14 - Aug. 24; traps were baited with 0.1 mg of 7E,9Z-12:Ac.

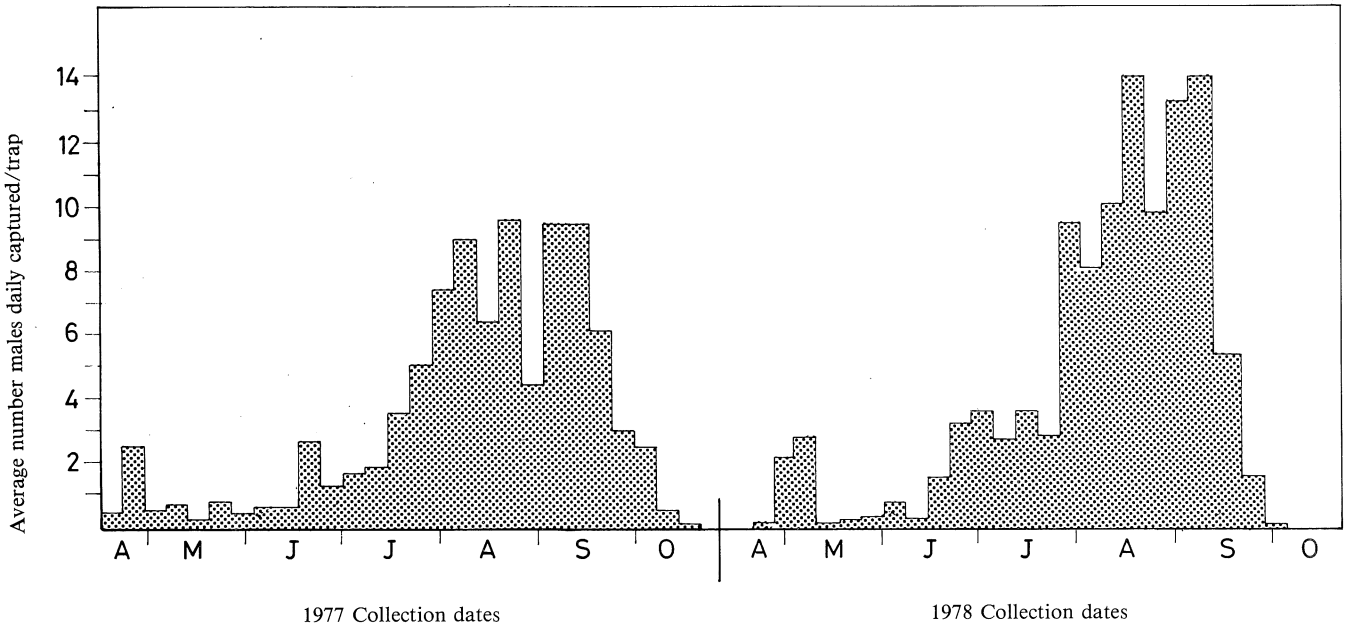

Fig. 3 - Seasonal abundance of *Cydia molesta* as indicated by daily average number males captured per trap during 1977 and 1978.

TABLE 3. Comparisons of attractiveness of (Z)-8-, (E)-8-dodecen-1-yl acetate and dodecyl alcohol mixtures on oriental fruit moth *(Cydia molesta)*.

Test series[a]	8Z-12:Ac (μg)	8E-12:Ac (μg)	12:OH (mg)	Mean no. males per trap[b]
I	200	—	2	125a
II	192	8	—	287a
III	192	8	2	452b
IV	768	32	—	309c
V	768	32	8	951d
VI	186	14	—	260a
VII	186	14	2	595d
VIII	186	14	8	772d
IX	744	56	—	359c
X	744	56	8	923d
XI	180	20	2	579d

a Tests were conducted in 1976 from June 3 - October 10.

b Numbers followed by the same letter are not significantly different (P = 0.05, *t* test).

European grape vine moth *(Eupoecilia ambiguella)* - Preliminary trapping indicated that isomeric impurities were detrimental to the effectiveness of 9Z-12:Ac. Increasing the amount of 9Z-12:Ac over 1 mg in rubber septa did not increase attractiveness. Although a 20 μg charge was not statistically less attractive than those listed in Table 4, for at least 2 weeks, it gradually lost its effectiveness.

This indicated that a further reduction in the initial charge level might have resulted in a less attractive pheromone dispenser. Table 2 shows the possible influence of the trap colour in attracting the *E. ambiguella* males; the data suggest that dark green traps were the best. Fig. 4 shows the seasonal distribution pattern of moth emergence.

European grape vine moth *(Lobesia botrana)* - *L. botrana* pheromone was identified as 7E,9Z-12:Ac (Roelofs *et al.*, 1973) and this compound was subsequently used in population monitoring and control studies (Roehrich *et al.*, 1976). These field tests have shown that *L.*

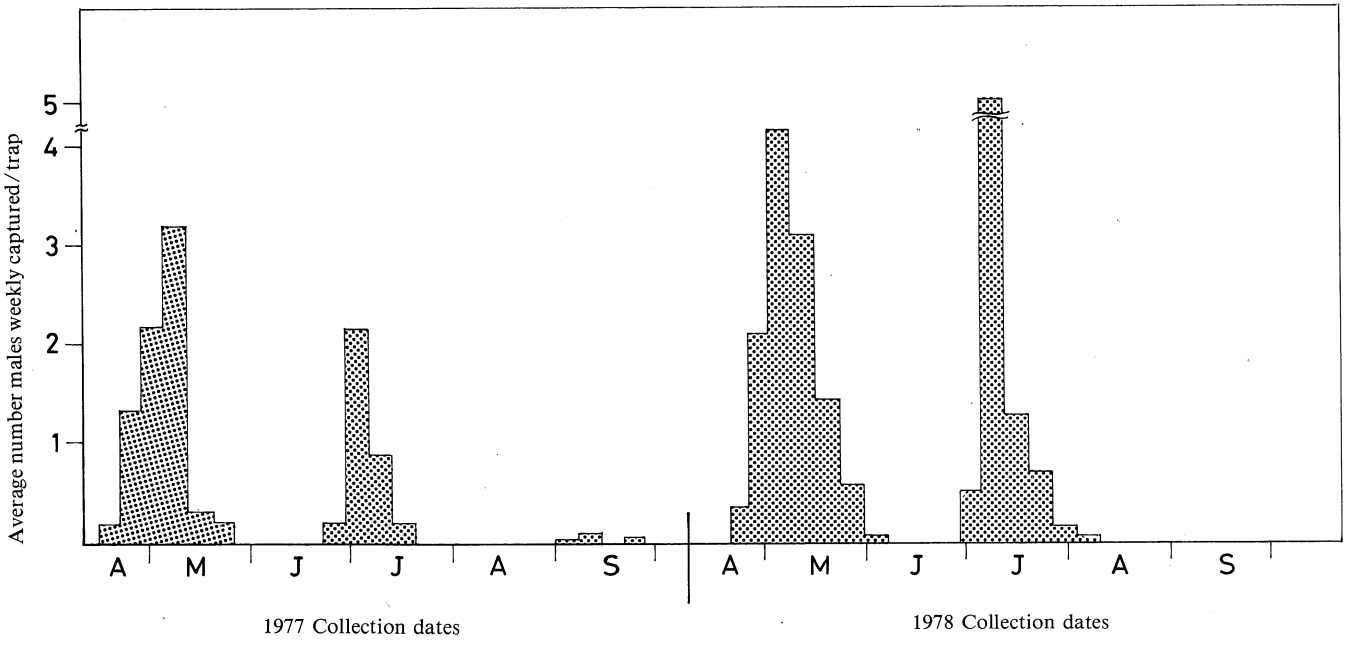

Fig. 4 - Seasonal abundance of *Eupoecilia ambiguella* as indicated by daily average number males captured per trap during 1977 and 1978.

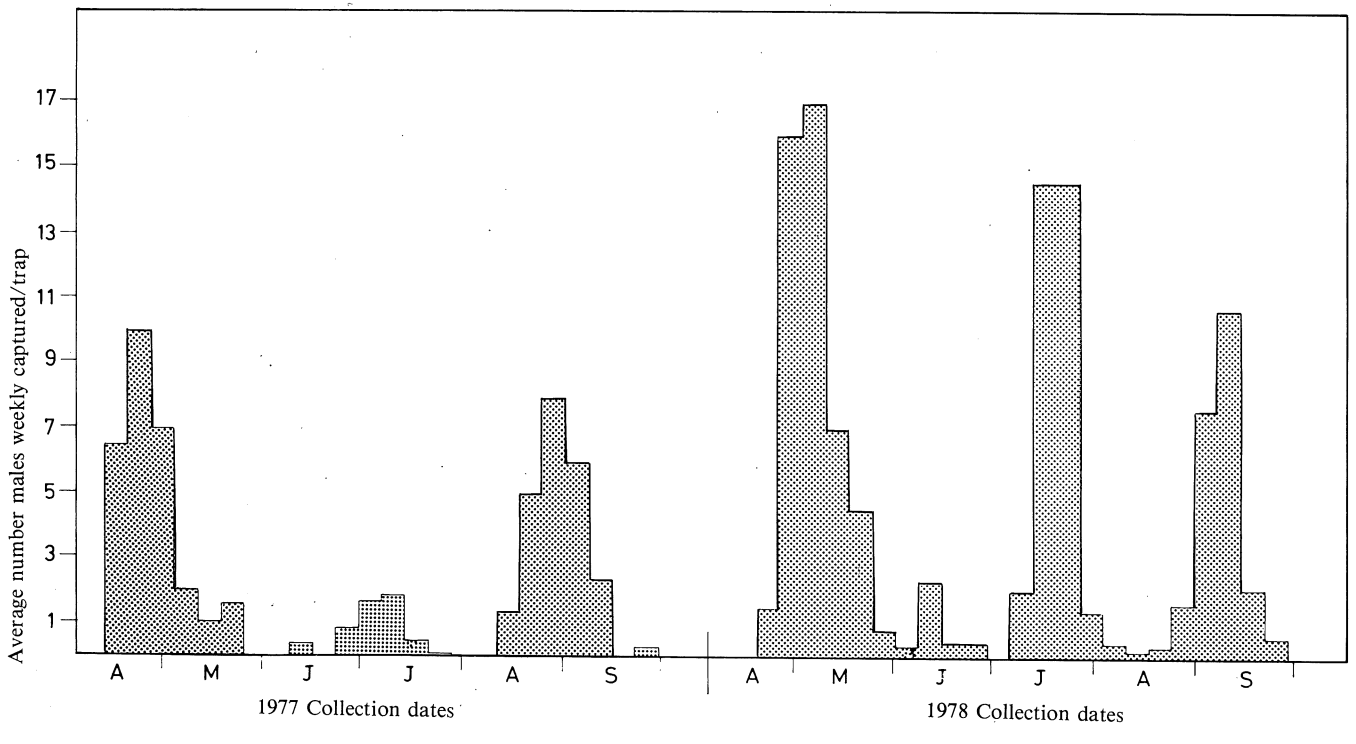

Fig. 5 - Seasonal abundance of *Lohesia botrana* as indicated by daily average number males captured per trap during 1977 and 1978.

botrana males also respond to 7E,9E-isomer, suggesting a genetic heterogenicity of the wild population to the pheromone attraction. In 1977 we had available the 7Z,9Z-12:Ac and we decided to compare in the field the attractancy of this compound, alone and in mixture with 7E,9Z-isomer, with the attractancy of pure 7E,9Z-isomer. The results (Table 5) show that the cap charge with 7E,9Z-12:Ac was more attractive than the two other charges. The 7Z,9Z-isomer seems to possess some biological significance towards wild population. However, a

TABLE 4. Effect of varied initial charge (Z-9-dodecen-1-yl acetate) on the attractancy to males of European grape vine moth *(Eupoecilia ambiguella)*.

Vineyard	Mean no. of males per trap[a, b] captured with two doses of 9Z-12:Ac	
	1000 μg	200 μg
A	121a	95b
B	100a	78b
C	53a	20b

a Means followed by the same letter are not significantly different at 5% level.
b Comparison was conducted in 1977, from Apr. 21 - Jul. 21. Pheromone dispensers were replaced every 5 weeks.

TABLE 5. Field trapping of male *Lobesia botrana* utilizing (7E,9Z)- and (7Z,9Z)-dodecadien-1-yl acetate, conducted August 18 - September 18, 1977.

Amount of attractant on rubber septum	Mean no. males per trap[a]
1 mg 7Z,9E-12:Ac	196a
0.6 mg 7Z,9Z-12:Ac + 0.4 mg 7Z,9E-12:AC	68b
1 mg 7Z,9Z-12:Ac	43b

a Means followed by the same letter are not significantly different at the 5% level. Treatments were replicated and sampled 4 times. Traps were re-randomized after each sampling.

possible isomerization of the product during field exposure could not be ruled out. One trend noted in the trials (Table 6) was that no significant difference in attractancy was observed during three weeks among septa charged with 1,0.1 and 0.01 mg charges of 7E,9Z-12:Ac. As shown in Table 2, red traps were the best for *L. botrana* trapping. Fig. 5 shows the seasonal distribution pattern of moth emergence.

TABLE 6. Comparisons of rubber septa with 3 different initial charges of synthetic *Lobesia botrana* pheromone[a].

Synthetic pheromone charge of rubber septum (mg)	Mean no. of male moths trapped comparison[b]			
	1st wk	2d wk	3d wk	Total
1.00	8a	18a	14a	40
0.10	37b	42a	2a	81
0.01	22b	24a	8a	54

a White traps were used for the comparison. Treatments were replicated 4 times in a randomized block design, and were conducted in 1977 from April 25 - May 16.

b Means followed by different letters are significantly different at the 5% level.

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RIASSUNTO

Alcuni fattori influenzanti l'efficienza delle trappole a ferormone per *Cydia pomonella* (L.), *Cydia molesta* (Busk), *Eupoecilia ambiguella* (Hb.) e *Lobesia botrana* (Den. & Schiff.).

Sono stati studiati alcuni fattori capaci di influire sulle catture di *Cydia pomonella, Cydia molesta, Eupoecilia ambiguella* e *Lobesia botrana* entro trappole a ferormone sessuale sintetico. La trappola più efficiente per il monitoraggio di *C. pomonella* era di colore avana e aveva come innesco 1 mg di 8E,10E-12:OH esente da altri isomeri e formulato in un supporto di gomma. Erogatori di ferormone contenenti la dose di 10 mg risultavano debolmente attrattivi solo dopo 3 settimane di permanenza in campo, al contrario quelli con la dose di 0.1 mg perdevano rapidamente in attività dopo tale periodo. Le maggiori catture di

C. molesta sono state ottenute con trappole colorate in giallo e innescate con 8Z-12:Ac contenente dal 3 al 10% dell'isomero opposto. L'addizione di alcol dodecilico alla miscela attraente ne potenzia l'attività.

I migliori erogatori, formulati con 0.8 mg di 8Z-12:Ac (93% di purezza isomerica) e 8 mg di dodecanolo, conservavano la loro iniziale attrattività per almeno 3 settimane di esposizione in campo. Le catture di *E. ambiguella* non erano dipendenti dalla quantità di attraente nell'intervallo 0.02-1 mg, mentre erano fortemente depresse dalla presenza di impurezze isomeriche nel 9Z-12:Ac. Le trappole verde scuro catturavano meglio di quelle d'altro colore. Il numero più alto di maschi catturati di *L. botrana* era ottenuto con 7E,9Z-12:Ac d'alta purezza. Erogatori contenenti il composto nelle dosi di 1,0.1 e 0.01 mg erano egualmente attrattivi durante 3 settimane di permanenza in campo. Le migliori catture erano ottenute con trappole colorate in rosso.

In campo il 7Z,9Z-12:Ac mostrava una significativa attività; quantunque non si possa escludere un suo riassestamento all'isomero 7E,9Z-12:Ac, il composto sembra avere un suo ruolo nella comunicazione sessuale della popolazione selvaggia di *L. botrana*.

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