EAG Responses of the Fruit- and Pinaceae-Feeding Type of Yellow Peach Moth, *Conogethes punctiferalis* (GUENÉE) (Lepidoptera: Pyralidae) to Monoterpene Compounds

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EAG responses to 21 monoterpene compounds were compared between the two types of the yellow peach moth, *Conogethes punctiferalis* (GUENÉE). The fruit-feeding type (FFT) females responded more highly to 17 compounds than males, whereas no sexual difference was found in the Pinaceae-feeding type (PFT). Both sexes of PFT responded to alcohols, aldehydes and ketones significantly higher than did FFT. The cluster analysis of EAG responses of each type showed a definite difference in the antennal olfactory spectra between FFT and PFT. From these facts, it was concluded that FFT and PFT are probably taxonomically different species.

INTRODUCTION

A previous report on electroantennogram (EAG) responses of the fruit-feeding type (FFT) and the Pinaceae-feeding type (PFT) of the yellow peach moth, *Conogethes punctiferalis*, to 90 alkanyl homologous compounds showed that C6 and C9 to C12 compounds evoked high EAG responses from both types of moths. The differences in antennal sensitivity to C6 compounds between the two types also suggested that FFT and PFT are separate species (HONDA et al., 1986).

Additional differences between FFT and PFT in EAG response spectra to terpene compounds including the volatile compounds in their host-plants were reported.

MATERIALS AND METHODS

Moths were prepared under the same conditions and EAG measurement method was essentially the same as that described by HONDA et al. (1986).

Twenty-one monoterpene compounds of extra pure grade (>98.5%) including volatile constituents of host-plants were tested in 1% (v/v) ether solutions with linalool as a standard. The antennae were exposed to the test compounds and the standard compound (linalool) alternatively at 30 sec intervals. The amplitudes of responses to the terpenes were expressed either as an absolute EAG amplitude (mV) or as a relative intensity to the mean amplitude of two adjacent standard responses as used by GUERIN and VISSER (1980).

Squared euclidian distances $(X-Y)^2$ were calculated from the relative intensities of paired compounds (X and Y), and the resulting matrices of the distances were trans-

Table 1. EAG activities of 21 terpene compounds by the fruit-feeding type (FFT) and the Pinaceae-feeding type (PFT) of yellow peach moth

Chemicals tested ^a	Mean EAG amplitudes (mV)					
	F F T			P F T		
	Male	Female		Male	Female	
I (hydrocarbone)						
α -Terpinene	1.06	1.69 ^p	*	0.88	1.10	ns
α -Phellandrene	1.17	1.77 ^p	*	0.88	1.02	ns
α -Pinene	0.63	1.00	*	0.82 ^f	0.82	ns
β -Pinene	0.77	1.25 ^p	*	0.77	0.73	ns
γ -Terpinene	0.68	1.04	ns	0.67	0.75	ns
Limonene	0.42	0.60	ns	0.80 ^f	0.58	ns
Myrcene	0.53	0.40	ns	0.56	0.77 ^f	ns
II (alcohol, aldehyde, ketone)						
α -Terpineol	1.07	1.35	ns	1.46 ^f	1.96 ^f	ns
Terpinene-4-ol	0.48	0.69	*	0.93 ^f	1.32 ^f	ns
Linalool	0.40	0.71	*	0.84 ^f	1.02 ^f	ns
Geraniol	0.21	0.42	*	0.59 ^f	0.86 ^f	ns
Nerol	0.30	0.51	*	0.60 ^f	1.02 ^f	ns
Citronellol	0.26	0.47	*	0.54 ^f	0.73 ^f	ns
Citronellal	0.37	0.81	*	0.66 ^f	1.05 ^f	ns
Carvone	0.28	0.60	*	0.48 ^f	0.74 ^f	ns
III (acetate)						
Terpenyl acetate	0.28	0.92	*	0.72 ^f	0.76	ns
Geranyl acetate	0.36	1.02 ^p	*	0.54	0.70	ns
Neryl acetate	0.29	0.77	*	0.56 ^f	0.66	ns
Citroneryl acetate	0.32	0.81 ^p	*	0.39	0.51	ns
Bornyl acetate	0.26	0.94 ^p	*	0.50 ^f	0.54	ns
Isbornyl acetate	0.28	0.49	*	0.42	0.49	ns

^a All chemicals were tested at 10 μ l of 1% (v/v) ether solution.* : significantly different between sexes of each type at $P < 0.05$.

ns: not significantly different.

^f Significantly different from FFT's response at $P < 0.05$.^p Significantly different from PFT's response at $P < 0.05$.

formed into dendrograms using an agglomerative cluster analysis by a group average method.

RESULTS AND DISCUSSION

EAG responses of both types to 21 terpenes including linalool are shown in Table 1. FFT females responded higher to 17 compounds, excluding γ -terpinene, limonene, myrcene and α -terpineol, than the males, whereas no sexual difference was found in PFT to all compounds tested. Males and females of PFT responded to all compounds of the second group, α -terpineol, terpinen-4-ol, linalool, geraniol, nerol, citronellol, citronellal and carvone significantly higher than did FFT, respectively. To the compounds of the other groups, hydrocarbons and acetates, no clear-cut difference was observed between FFT and PFT.

Fig. 1. Dendrograms showing the results of agglomerative cluster analysis of EAG activities of 20 terpenes by the fruit feeding type (FFT). Horizontal scale indicates increasing dissimilarity from right to left.

In order to determine whether any grouping of EAG spectra occurred, a cluster analysis was made. The dendrograms (Fig. 1) visualize the degree of dissimilarity in EAG activities among 20 compounds in both sexes of FFT. The horizontal scale of each dendrogram indicates increasing dissimilarity from right to left. On a higher level three large clusters could be distinguished: (I), α -terpinene, α -phellandrene and α -terpineol, (II) α -pinene, β -pinene and γ -terpinene, (III), the remaining compounds containing most terpene acetates. It can be noted that the compounds of group I do not cluster with the other two (II and III) until the final step of clustering, and also that the dissimilarity in EAG activity of individual compounds of group III is least among the three grouped members of compounds.

On the other hand, the cluster analysis for PFT gave remarkably different dendrograms from those of FFT (Fig. 2). α -Terpineol of 20 compounds exclusively made a

Fig. 2. Dendrograms showing the results of agglomerative cluster analysis of EAG activities of 20 terpenes by the Pinaceae-feeding type (PFT). Horizontal scale indicates increasing dissimilarity from right to left.

characteristic cluster, showing the largest dissimilarity in EAG activity, but other members of the compounds were incorporated into two other large clusters at the lower level of dissimilarity.

Since the degree of dissimilarity in EAG activity of the above 20 terpenes reflects the inter-chemical differences in their relative EAG activities, these two series of dendrograms indicate that FFT and PFT have different antennal sensitivity: FFT is most sensitive to α -terpinene, α -phellandrene, and α -terpineol, and more to α -pinene, β -pinene and γ -terpinene, whereas PFT is sensitive to α -terpineol only.

GUERIN and VISSER (1980) reported that six compounds, terpinolene, α -, and β -terpinene, α -phellandrene, α -terpineol, carvone among 24 terpenes evoke high EAG responses in the carrot fly, *Psila rosae*.

With the wood wasp, *Sirex noctilio*, on the other hand, a correlation between EAG

Fig. 3. Dendrogram showing the results of agglomerative cluster analysis of EAG responses of FFT and PFT to 20 terpenes. M and F: male and female.

activity of terpene compounds and their chemical structure was reported by SIMPSON (1976); within each class of compounds, the ones having a pinane skeleton and unsaturation gained the highest EAG response from the wasp compared with linalool as a standard.

This is in contrast to our result that the higher EAG activities were observed in most of the compounds having a terpinene skeleton, although with terpenyl acetate this was not so. This is also in contrast to the results on EAG response of FFT and PFT to straight-chain alkanyl homologues, because the total number of carbons in the molecules of all chemicals tested had a correlation with induction of prominent EAG (HONDA et al., 1986).

If a correlation is found between EAG responses to certain odor compounds and actual behavioral responses to them for host-plant selection by the moth, FFT could perceive more compounds as sign stimuli from host-plant odor complex than PFT. If so, our data will be partly supported by the fact that FFT is typically polyphagous while PFT is rather oligophagous (SHINKAJI, 1969; SEKIGUCHI, 1974), and also that the FFT gravid females respond for oviposition to not only the odors of their host-plant but also those of Pinaceae plants which are the host-plant of PFT (HONDA and MATSUMOTO, 1984). Actual behavioral responses of adults to these EAG active compounds, however, remain to be studied.

The cluster analyses of responses of 20 moths (10 FFTs and 10 PFTs) were made in order to draw conclusions about the taxonomic relationships between FFT and PFT (Fig. 3). The members of PFT yielded one large cluster at the lower level of dissimilarity of EAG response, and this could be completely distinguished from the other cluster composed of FFT members.

VAN der PERS (1981) applied a cluster analysis to EAG response spectra from 7 *Yponomeuta* species and from *Adoxophyes orana* to get taxonomic information. However, no clear conclusion on taxonomic relationships was drawn from the analysis because of the relatively close similarity between the response spectra.

EAG profiles are very useful in comparing the responses of different insect species to stimulation by the same substances at the same concentrations, because differences in such responses may indicate physiological differences in the insect olfactory systems. Therefore, the variations in EAG profiles to terpenes between FFT and PFT lead us to the conclusion that the two types of yellow peach moth are probably taxonomically different in this species. This conclusion is also supported by the differences in morphology of the adult and the larvae, the larval olfactory and gustatory responses to each host-plant constituents and, also, by the EAG response of adults to *n*-alkanyl compounds of the two types (HONDA, 1985; HONDA et al., 1986).

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