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EFFECT OF ENVIRONMENTAL FACTORS TO MALE ADULT CATCH BY SYNTHETIC FEMALE SEX PHEROMONE TRAP OF THE DIAMONDBACK MOTH, *PLUTELLA XYLOSTELLA* L. IN TAIWAN[1]

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C. J. W. Maa, Y. H. Chen, Y. J. Ying and Y. S. Chow (1987) Effect of environ mental factors to male adult captured by synthetic female sex pheromone trap of the diamondback moth, *Plutella xylostella* L. in Taiwan. *Bull. Inst. Zool., Academia Sinica* **26**(4): 257-269. In order to understand how the environmental factors; temperature humidity and free water would affect the sexual behavior of male adults to the synthetic female sex pheromone of diamondback moth, *Plutella xylostella* L., male mass trapping by different blends of the pheromone was carried out in the field around this island. The three components; Z-11-hexadecenal, Z-11-hexadecenyl acetate and Z-11-hexadecen-1-ol were blended in ratios of 2:8:0.1 to 6:4:0.1. Fifty micro grams of the blended mixture per bait was used for each trap in the field test. Results showed that a condition of high humidity with mild temperature, i.e. 85% relative humidity and 18±1.5°C, would be favorable for male captured by blends of 2:8:0.1 and 3:7:0.1. When it is getting dry and warm the blends of 4:6:0.1 and 5:5:0.1 would lure more male adults. Nevertheless, pheromone blends with high acetate content were favorable for male mass trapping in Taiwan. Free water and rain fall might impose influence onto the male behavior to the pheromone response in the field.

Geographical diversity of male response to the female sex pheromone (FSP) of diamondback moth (DBM), *Plutella xylostella* L. were found in Taiwan (Chow *et al.*, 1977), Canada (Chisholm *et al.*, 1979), and Japan (Yamada and Koshihara, 1980). In Japan, it was reported that the blend of optimal male catch of the moth was a mixture of (Z)-11-hexadecenyl acetate, (Z)-11-hexadecenal, and (Z)-11-hexadecen-1-ol in a ratio of 5:5:0.1. Same result as that of Japan for the male catch was reported in a summer vegetable cropping area at a mountain village nearby Taipei metropolitian, Taiwan by Chow *et al.* (1977). In Canada, combination of three parts of acetate and seven parts of aldehyde for the optimum male catch was reported.

This variation of male response to the synthetic female sex pheromone of different further blend was evaluated during 1982-1983. According to the result, traps with high content of aldehyde compound fail to catch a satisfactory number of DBM in field herein Taiwan. This result was different from what was found in Canada.

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The survey on male response to the synthetic female sex pheromone (SFSP) of DBM in northern Taiwan revealed that male moth responding to the blend was likely to be population-dependent. Male adults from Nan-Kang, Sheh-Tzu, Sang-Chung and I-Lan showed a preponderant response to a blend ratio of 3:7:0.1 of aldehyde, acetate and alcohol. Male adults from Chu-Pei prefered to 4:6:0.1 combination (Maa *et al.*, 1984).

Laboratory assay showed that the interaction of monthly relative humidity (RH) and male orientation response to the pheromone baitswas linear, with interception at RH 82.6%. Temperature and male response also had a linear interrelationship with an interception at 18.4°C on the axis. Temperature or RH over these critical point would have negative impact. These conditions of 82.6% RH and 18.4°C, however, are not necessarily standard for all blends in respect to optimal male response in the laboratory. Bioassay on two malathion-susceptible strains (Bamboo Lake and Geou-Fang) and one resistant strain (Lu-Chu) did not show any detectable variation of the pheromone response of male DBM adults to the 5:5:0.1 (aldehyde: Acetate: alcohol) blend when the temperature was at 25±2°C, and the RH at 80% (Maa *et al.*, 1985, Maa and Lin, 1985).

In order to find out how the environmental factors and the different blends affect DBM male sexual behaviour, these variables were monitored in relation to the optimal male catch in field. A general survey were carried out during the year of 1982-1987. The major cruciferous cropping areas for summer and winter-early spring were investigated. Other areas of minor important in crop production of summer season were also chosed for this study.

MATERIALS AND METHODS

Insects of bioassay

Diamondback moth, *Plutella xylostella* L., used for bioassay were reared under constant temperature of 25±1°C, and a light-dark cycle of 14-10. Larvae were fed on seedlings of rapeseeds according to Koshihara and Yamada (1976) and adults on 20% honey-water (Chow, Y. S. unpublished data). Stocks of newly emerged adults from the insectarium were synchronized within 12 hr period and were assayed in a Y-type apparatus (Maa *et al.*, 1983) to testify the interaction of RH and the blends of the pherome. Five hundred and fifty pupated diamondback moth harvested from a 24-hr synchronized batch of egg mass, were checked for emergence. The emerged female and male adults were recorded every two hours for seven days In order to find out how long a cohort of DBM would need to emerge.

Chemicals and Field test

The pheromone components Z-11-16: Ald, Z-11-16: OAc and Z-11-16: OH, used for field test were synthesized and were of 98% purity as evidenced by GC (Lin and Chow 1983b). Preliminary tests were carried out in Bamboo-lake (Chow *et al.*, 1977). Five favorable blends were chosed for this study. All the blends each in ratios of 2:8:0.1, 3:7:0.1, 4:6:0.1, 5:5:0.1 and 6:4:0.1 (Ald:OAc:OH) were prepared as baits for male trapping Fifty μg of each pheromone blend with addition of 200 μg butylated hydroxytoluene was then injected into a four cm long polyethylene microtubes with one end sealed. The microtubes were fastened under the top of the sticky paper pheromone trap. The trap and the pheromone bait were replaced weekly.

If a vegetable plot covered an area of 10×10 m² was available in the field, all the five blends the pheromone mentioned above were used for a test of 5×5 Latin Square Design. A plot which was with an area bigger than 100 m² but was not in a square form, a Complete Ramdom Design would be used for the test. In case this was not valiable in the spot, a 4×4 LSD with four blends; 3:7:0.1, 4:6:0.1, 5:5:0.1 and 6:4:0.1 was be

used. The traps for the protective plots, using a pheromone blends of 8:2:0.1, were hung around the experimental plots. The test was cheched at least twice within 2 weeks. Daily weather records were transcribed from the daily report of the Central Weather Bureau, ROC. Daily temperatures and mean RH were as the major physical parameters to evaluate the impact of climate on the response of the male adults to the pheromone. For indoor bioassay pheromone blends of 3:7:0.1, 5:5:0.1 and 7:3:0.1 were used. Laboratory conditions were adjusted to the requirement of the test. Assays was following to Maa *et al.* (1983).

Daily field test

This test was carried out in Yeongjing district, Changhua County of western Taiwan. This area is famous for vegetable production, especially the cruciferous vegetables. Male catch in trap by the pheromone bait was counted eight times each day. The trap was replaced at least twice during a 24 hr period.

The climate conditions of the cropping area and the micro-climate conditions of the insect habitats were recorded by a hair-hygrometer with a mercury thermometer. This test was mostly worked out during winter and early spring. The status of male catch was also continuously investigated every 2 hrs for 24 hr. The climate conditions were also recorded accordingly.

Site for field test

Sheh-Tzu (ST) DBM were mostly heavily

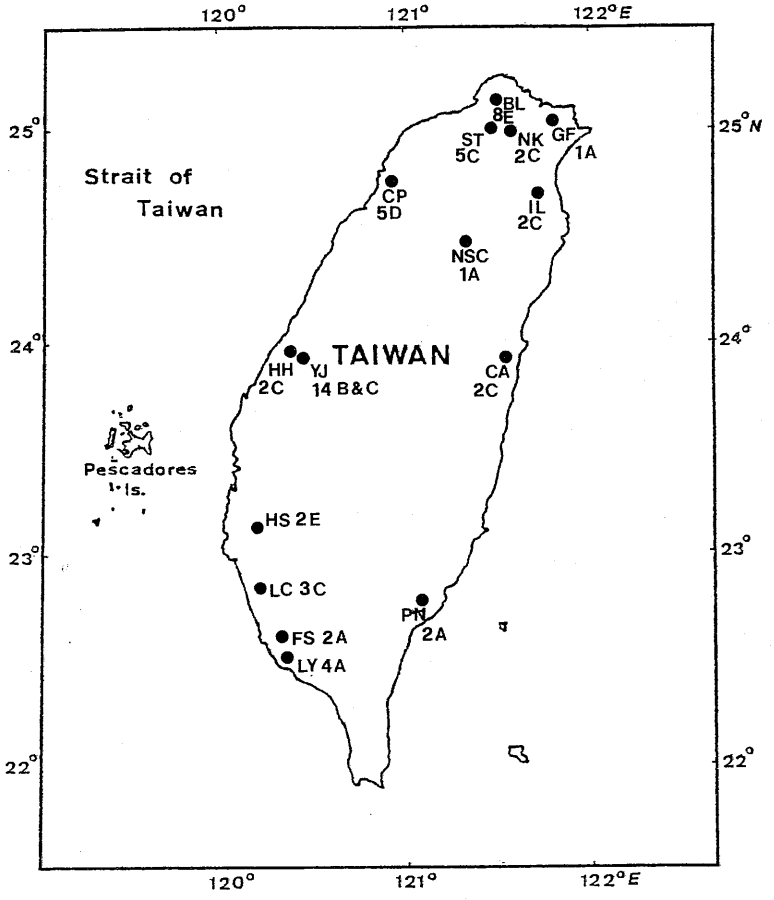

Fig. 1. The location of the field test site and the number of the test with pheromone blend preference showing on the study of male mass trapping by synthetic female sex pheromone of diamondback moth in Taiwan; A is for no perference, B for 2:8:0.1 blend, C for 3:7:0.1, D for 4:6:0.1, and E for 5:5:0.1 in pheromone perference.

selected by pesticide application. Nan-Kang (NK) is a suburban area of Taipei City. Bamboo-Lake (BL) is a mountain village for summer vegetable cropping near Taipei. Geou-Fang (GF) is also a mountain area where no pesticide was used for pest control. I-Lan (IL) is a farm area. Nan-San Village is also a mountain area for summer cropping in I-Lan county. Chu-Pei (CP), Pi-Nan (PN), Chi-An (CA), Hsishih (HS), Feng-Shan (FS), and Lin-Yuan (LY) are country areas with vegetable production for local market. Lu-Chu (LC), Hsi-Hu (HH), and Yieong-Jing (YJ) are the major areas for vegetable production for whole island as well as for export (Fig. 1).

RESULTS

Status of adult emergence and indoor assay

Fig. 2 shows that a batch of eggs laid by the female DBM within 24 hr period completed the emergence within six days. The major peaks of emergence were found during day two, three, and found after the first newly emerged adult eclosed. This suggested us that at least seven days period is needed for the male mass trapping in the field survey. Fig. 3 shows that the female adult emerged approximately 12 hours ahead of the male. The emergence rate of the two sexes would become with same pace during the end of the 2nd and the 4th day. Since at this point the sex ratio of these two sexes is approximately equal to one at three o'clock in the morning. The maximum difference of emergence rate between the two sexes was found around three o'clock in the afternoon. The ratio is 1.00 over 1.24 at day three and 1.00 over 1.17 at day five favoring to the female individuals. It is interesting to know that the sex ratio would approach to one. It is two days after the initiation of adult emergence when it is a time for sexually matured adults to couple and mate.

Indoor assay on preference of male DBM to pheromone blend revealed that in a range of 75-85% RH there is no difference among the three blends at room temperature (data not shown). This result suggested that possibly only an extreme RH or temperature condition might impose a detectable influence onto the male responding to the blend.

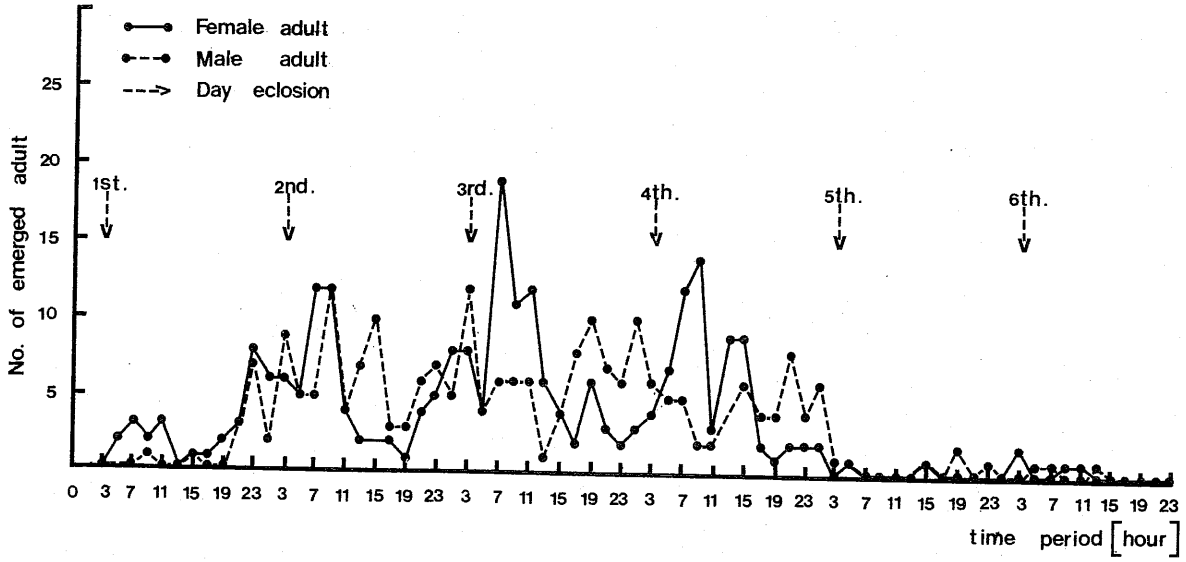

Fig. 2. Time distribution of adult emerging from a population of pupated diamondback moth harvested from a 24-hr. synchronized batch of egg mass; five hundred and fifty pupae were used for this study.

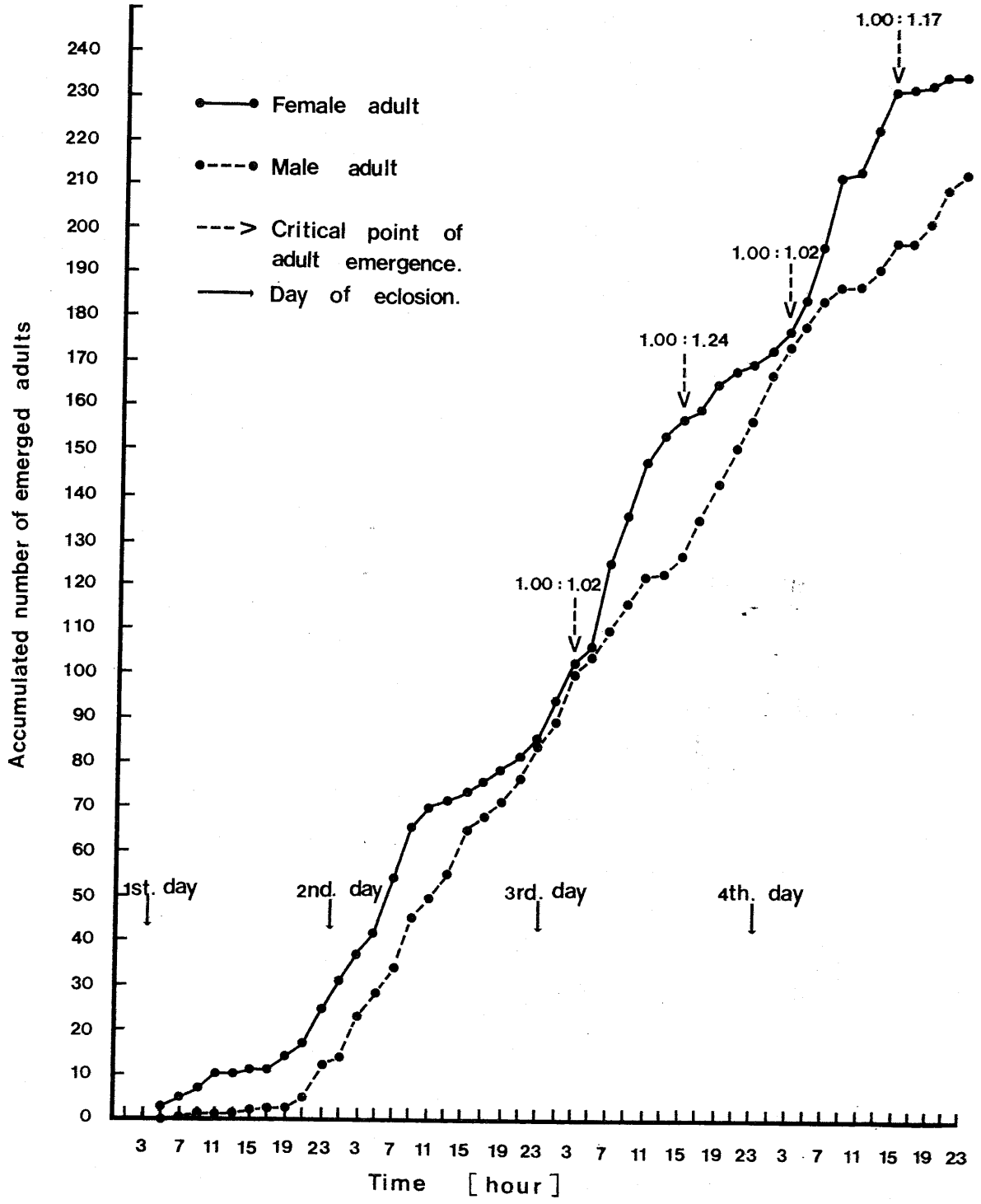

Fig. 3. Sex ratios of male to female adults emerged during each period of time of adult eclosion; five hundred and fifty pupae were used for this study.

TABLE 1

Weekly field test of male response to the female sex pheromone with different ratios of hexadecenal and hexadecenyl acetate

Location	Date	RH%	Temp. °C	Total DBM trapped	Best ratio Ald/OAC and significance	Experimental design with total df
In northern Taiwan						
Shan-Chung	1983 10/14-10/25	81.8±6.2	26.6±3.3	2145	3:7(SS)	LSD 5×5(99)
Nan-Kang	12/22-1/5	82.7±4.3	12.3±2.1	720	3:7(SS)	LSD 5×5(49)
Sheh-Tzu	4/29-5/11	80.6±5.3	24.6±2.3	1879	3:7(S)	LSD 4×4(47)
Chu-Pei	1983 3/21-4/15	86.0±5.1	22.8±3.3	1912	4:6(SS)	LSD 4×4(79)
Nan-Shang	1983 6/10-6/22	75.5±8.9	18.6±1.7	1396	—(NS)	LSD 4×4(31)
I-Lan	1984 2/25-3/10	88.3±4.5	14.2±2.3	1422	3:7(S)	LSD 5×5(49)
I-Lan	1983 6/12-6/22	75.5±8.9	18.6±1.9	761	—(NS)	LSD 5×5(49)
In southern Taiwan						
Hsin-Shin	1983 2/8-3/2	88.5±4.3	17.3±2.1	2362	5:5(S)	LSD 4×4(31)
Feng-Shan	1983 12/13-12/18	68.1±6.5	17.7±1.5	1737	—(NS)	LSD 4×4(31)
Lu-Chu	1983 12/9-12/18	76.5±2.7	19.0±1.2	3298	3:7(SS)	LSD 4×4(47)
Lin-Yuan	1983 12/25-1984 1/11	70.6±5.3	21.2±2.2	9633	—(NS)	LSD 4×4(63)
In eastern Taiwan						
Pi-Nan	1983 1/28-3/3	69.7±3.6	17.6±2.1	3740	4:6(S)	LSD 5×5(49)
Chi-An	1983 12/21-1984 1/7	76.5±6.4	13.2±2.7	1082	5:5(SS)	CR $\frac{n=4}{t=4}^{a}$ (31)
Chi-An	1983 12/21-1984 2/7	76.9±4.4	15.6±1.8	331	3:7(S)	CR $\frac{n=4}{t=4}$ (31)
Chi-An	1983 1/18-1/27	75.2±3.1	15.7±1.8	577	6:4(S)	CR $\frac{n=3}{t=8}$ (23)
In western Taiwan						
Hsih-Hu	1982 11/23-11/26	80.7±1.7	21.6±0.8	2749	3:7(S)	CR $\frac{n=16}{t=5}$(79)
Hsih-Hu	1982 12/8-12/13	82.3±4.2	19.3±3.8	1634	3:7(S)	CR 4×4 (15)
Hsih-Hu	1982 12/24-1/4	82.3±3.8	17.1±2.6	2041	3:7(S)	CR 4×4 (15)
Hsih-Hu	1983 2/18-3/1	87.3±5.2	15.4±1.4	1321	—(NS)	LSD 4×4(31)
Hsih-Hu	1983 12/16-12/26	79.4±2.3	17.2±1.2	167	3:7(S)	LSD 4×4(15)
Hsih-Hu	1984 1/2-1/10	77.5±3.5	14.5±1.2	245	3:7(S)	LSD 4×4(15)
Hsin-Hu	1984 1/10-1/20	82.5±3.1	16.6±1.3	439	3:7(S)	LSD 4×4(15)
Yieong-Jing	1982 12/2-12/4	82.3±3.3	20.2±0.5	749	3:7(S)	LSD 4×4(15)
Yieong-Jing	1982 12/4-12/8	77.8±2.3	18.5±1.7	486	—(NS)	LSD 4×4(15)
Yieong-Jing	1982 12/14-12/18	80.3±7.8	15.8±1.9	259	24:6(SS)	LSD 4×4(15)
Yieong-Jing	1982 12/18-12/24	81.8±2.2	16.2±2.7	1507	4:6(S)	LSD 4×4(15)

a. Latin Square Design or complete Random Design with no of total drgree of freedom.

b. SS: significant at $p=0.01$; S: significant at $p=0.05$; NS: not significant; tested through Dancun's multiple range test.

Status of male catch in field

This study is consisted of three parts of field work. Fig. 1 shows the site chosen for the field tests, the number of the test carried out in each site, and the blends that with optimal male catch in the site. The result of weekly checked test was tabulated in Table 2. Results that were checked every day was listed in Table 3 and those checked every 2 hrs or so, in Table 4.

For the weekly or daily survey, counting the number of the trapped male adult should be started at 3 pm. in the afternoon according to what we were informed from the data of

TABLE 2
Daily field test of male response to the female sex pheromone with different ratios of hexadecenal and hexadecenyl acetate

Date	RH% at 21 hr	Temp. °C at 21 hr	Precipitation (0.1 mm/hr)	Average no. of DBM per trap per day	Best ratio Ald/OAc and significance	Experimental design with total df
1982 12/2-3	92	19	0	23.4	3:7(S)	LSD 4×4(15)
1984 11/23-24	82	18	0	20.8	—(NS)	CR 5×6(29)
11/24-25	70	18.4	0	89.6	—(NS)	CR 5×6(29)
11/25-26	67	17.5	0	5.7	—(NS)	CR 5×6(29)
1985 1/31-2/1	81	14	0	48.2	—(NS)	CR 5×6(29)
2/7-8	97	18	57.0	58.0	2:8(SS)	CR 5×6(29)
2/8-9	93	19	15.5	137.2	2:8 and 3:7 (SS)	CR 5×6(29)
2/14-15	85	16.5	0.9	21.5	2:8 and 3:7 (SS)	LSD 5×5(24)
2/15-16	85	19.3	0	87.0	4:6(SS)	LSD 5×5(24)
2/16-17	85	19.7	0	85.7	—(NS)	LSD 5×5(24)
1987 3/4-5	69	19	0	33.8	—(NS)	LSD 5×5(24)
3/5-6	72	21	0	16.3	—(NS)	LSD 5×5(24)
3/6-7	70	21	0	31.3	—(NS)	LSD 5×5(24)

a. Latin Square Design or Complete Random Design with no. of total degree of freedom.
b. S: Significant at $p=0.05$., SS: significant at $p=0.01$., by Duncan's multiple test. NS: not significant.

adult-emergence study (Fig. 3). However, for convenience, we adjusted the counting time one hour late to the normal schedule. This adjustment would not interrupte the result of counting since we would not miss the optimal activity of the coupling and mating of the adult DBM (Yamada and Koshihara, 1980).

In general, most of the field test showed that male adults were lured by the blends with high acetate content. In fact, 24 out of 42 tests showed that the majority of the snared male adults were attracted by a pheromone blend of 3 aldehyde: 7 acetate: 0.1 alcohol, or blend of 2 aldehyde: 8 acetate: 0.1 alcohol mixture (Table 2 and 3). This was occurred in the areas of northern and western Taiwan (see Fig. 1). The rest of the total test showed that the male individuals prefered to blends with 4:6:0.1 or 5:5:0.1 mixture. These cases were found in the test site located on southern or west-southern part of Taiwan. This phenomenan is likely to be dependent on the geographical distribution of the chosen site for the field test. However, we should not neglect the impose of climate factors to the habitats of insects under investigation. The climate conditions, of the chosen site, within a span of a whole week were somehow variable. Nevertheless, Table 2 shows that relative humidity over RH 75%, found in most cases, would be favorable for the blend of 3 aldehyde: 7 acetate or of 4 aldehyde: 6 acetate to lure the male adults. Relative humidity below 75% or so would make the male moths not able to discrimate between one another of the blend in test. This is the case being found in YL, FS, TE, IL and YJ. There are two cases, in HL and HS, that the male adults responded to the lure of 5 aldehyde: 5 acetate. Similar status of male adults responding to the lure was also found in the daily test of the following content.

Status of male catch in Yieong Jing District: A daily test survey

Table 3 shows that there is no significant preference of the male adults to any blend of the female sex pheromone in Yieong-Jing

TABLE 3
Percentage distribution of DBM trapped during each interval in field[a]

Duration	1730-2000	2000-2200	2200-0000	0000-0230	0230-0400	0400-0700	0700-1600	1600-1730	No. of DBM
Ratio of Ald/OAc									
2:8	39.9±7.2[b]	1.5±0.6	11.5±4.0	17.4±2.6	4.2±1.7	2.9±2.9	14.7±2.2	8.1±2.2	801
3:7	37.7±5.1	1.9±0.5	8.6±1.4	15.7±6.6	2.2±2.6	5.2±5.3	19.3±2.1	9.5±5.4	238
4:6	33.6±5.8	2.8±1.7	23.2±8.0	13.2±4.1	3.6±3.6	5.3±4.5	13.6±3.4	4.8±4.1	186
5:5	36.9±4.6	4.1±4.1	15.0±3.1	7.7±4.8	3.6±3.7	5.6±1.6	17.9±3.7	9.2±4.1	183
7:3	27.5±6.6	3.5±3.8	24.6±8.8	9.5±9.2	2.8±2.8	0.05±02	2.5±6.5	4.7±4.8	122
Temp.	18°C	17°C	16.5°C	16.3°C	17.5°C	18°C	22°C	20°C	
RH %	92	90	92	94	96	96	92	93	
Precipitation	No	No	No	Drizzle	Rain	Heavily rain	Rain	No	

a. Location Yieong Jing District, Chang-Hua County. Feb. 7-8, 1985.
b. Average of four replicates; mean±S. E.
c. The blend of 2:8 is statistically different from other blends; with significance at $p=0.01$ by Duncan's multiple range test.

District when it was dry and relative humidity lower than 80% or so. These cases were dated 1981, Dec. 4 to 8; 1984, Nov. 14 to 24; 24 to 25; 25 to 26; 1985, Jan. 31 to Feb. 1; Feb. 16 to 17; 1987, March 4 to 5; 6 to 7. The later two tests were closely investigated. When it was with RH 80% or more with no rainfall the blend of 3 aldehyde: 7 acetate, would lure more adult moths by the bait. When the air was saturated with moisture and with rain, no matter whether the rain was heavily or drizzling, the catch of the 2 aldehyde: 8 acetate combination would predominate the field. These were dated 1985, Feb. 1 to 7; 7 to 8; 8 to 9; 14 to 15. These results were further justified by daily test checked every 2 hrs. Table 4 revealed that a saturated RH in the air definitely make the blend of 2 aldehyde: 8 acetate most favorable for male catch whether it is without or with rain. Table 5 also shows, in the left column, that rain fall of 51 mm/cm² from 16:00 to 17:30

TABLE 4
Humidity and temperature effect to field attractance of male DBM by pheromone trapping

Duration		Number of DBM trapped during each interval			
		1985. Jan. 31-Feb. 1		1985. Feb. 8-Feb. 9	
		16:00-17:30	17:30-06:00	16:00-17:30	17:30-06:00
Ratio of Ald/OAc	2:8	61.5[c]	0.8	24.0	304.5
	3:7	34.0	0.0	12.0	242.3
	4:6	34.7	0.3	9.8	156.2
	5:5	58.5	0.3	4.6	81.4
	7:3	60.5	1.4	5.4	84.8
Temp. °C[a]		22.4	11.2	22.2	18.0
RH%		65	88	92	92
Precipitation[b] 0.1 mm/hr		No	No	51.0	14.2

a. Temperature and RH recorded in field. b. Precipitation recored from CWB local station.
c. Average of four replicates.

pm. would not minimize the male catch rate to any extend. The catching rate was estimated to be 6% of a total 24 hr interval. This rate is as much as that of 17:30–06:00 interval of Table 4. A rain fall of 14 mm/cm^2 was with little effect to the lure in attracting the male adults in the field. On the other hand, a drastical change of temperature would decrease the response of the male to the bait. The right column of Table 5 shows that when the temperature dropped from 22.4°C to 11.2°C by 17:30 pm, the rate of male catch also dropped to its minimum with less than one male, in average, being trapped by the pheromone trap during a 13 hr. interval. It is likely that the male adult activity was terminated by the cold temperature. This rate of male catch is very low comparing with those of the counterpart listed in Table 4. Wind speed over ten meter per sec would also terminate the male activity (data not shown).

Table 4 also reveals that the male adult were active through the whole night. Although, there were fluctuation of the activity to the pheromone source. It is shown that there are two peaks of up level activity of the male adult. The first one could be found between 17:30 and 20:00 pm., i. e. a interval between one hour before and after the sunset, and the other peak appeared between 22:00 pm. and 2:30 am. of the following day. The down level activity of the DBM during night was around 20:00 to 22:00 pm. Another low trough was found during 16:00 to 17:30 pm. of the day time. An additional quite time for the male adult was found during 2:30 to 7:00 am. In general, the insect is not active at day time if they were not disturbed.

Status of the habitat: a micro-climate condition survey

It has been found that there is chronicle change of the environmental conditions within the habitat of the insect during a day. There is not much change in temperature within the space of the habitat 50 cm above the ground. It was estimated that during 8 to 10 o'clock in the morning the difference between the top of the canopy and the bottom of the canopy, 2 cm above the ground, is only two and half units of centigrade. In fact, the conditions do not change much between the top of the canopy and the space above the canopy. Same situation was found in that space during 4 to 7 pm. Variation of relative humidity in the canopy is, somehow, with a wider spectrum. It is of RH 81% in the bottom, 78% in the middle of canopy and 76% on the top in the morning during 8 to 10 am., and is of 85%, 87% and 91% in the afternoon by 5 pm. The humidity increased rapidly on the cropping plots after sunset. The air was almostly saturated with moisture within the canopy after 7:30 pm., one hour later after sunset. The moth fly around the plant and mate within the canopy or hop over 10 cm above the plants during the mating time. Usually, Yieong-Jing cropping area is humid during night because the irrigated water was continuously supplied to the plot in routine management.

DISCUSSION

Climate conditions were considered to be important factors that would influence the male adult response to the female sex pheromone of insect species (Roelofs, 1978). Mating behavior of the male adult of most lepidopterous species to virgin female sex pheromone was found temperature-dependent (Baker and Roelofs, 1981). Kanno and Sato (1979) indicated that in rice stem borer moth, *Chilo suppressalis* Walker, adult mating was scarcely affected by humidity variation at 20°C. On the other hand, European corn borer, *Ostrinia nubilalis* Hubner, showed another trend in sexual behavior which was affected by the free water in the air. De Rozari *et al.* (1977) suggested that the free water is required to initiate the sexual activity. Whether this potential would be expressed was almostly depending on the availability of both sexes combined with temperature, relative humidity and illumination of

light in the circumstance. Obviously, either of these factors may play some roles on stimulating the sexual activity of both male and female adults of a specific insect species. Whether the stimulation is triggered by either factor is depending on how the adult were constrined by the factor.

The diamondback moth, as small as mosquito, is always active day and night. During the growing season of the cruciferous vegetable this insect has inhabited the crop plot. They migrated away from the plot when the season is over. The climate of Taiwan is subtropical with hot summer and brief but nippy winter with average temperature of 21°C in the north and 24°C in the south. Northern Taiwan has a rainy season in winter and is wetter than the south. The cruciferous growing seasons was initiated from late fall to mid-spring. There are some mountain areas for summer crops. These areas are located in northern Taiwan with frequent thunder showers in summer. The field test was completed during winter and spring. There are only two tests were carried out during summer.

Humidity and Pheromone preference of male adult

The microclimate of the insect habitat, was actually very humid especially in Yieong-Jing District. The humidity was found fluctuated from time to time during the period of sunrise and sunset. In fact, the relative humidity around the habitat is about 75% during day time and was saturated with moisture at night. The difference of RH between the space of the habitat and that above the habitat was estimated 25 units in percentage of RH in a shinning with cloud day, and was 40 units in a cloudy with rain day in general. Drastical change of the temperature in the habitat during a day is rare. The difference of temperature between the habitat space and the circumstance is also at a very narrow range, say, about 5 degree. This stable daily temperature with a relative unstable RH in the habitat usually was not able to be reflected from the daily report from the local weather station. It would be imagined the difficult to interpret how the male adult response to the pheromone blends were affected by the climate conditions, in aspect of maximum male catch by different blend, since we know that the DBM adult was only active around the canopy of its niche. However, we should not neglect the potential influence of the climate conditions which would impose its effect on the microclimate of the insect inhabitation. The weekly test with the contemporary daily test were, therefore, both needed for understanding the influence of the climate factors to the sexual behavior of the male DBM to different blends of the pheromone. It is interesting to find that the pattern of maximum male catch lured by various pheromone blends was somehow interrelated with different climate conditions reported by the local weather station. As a matter of fact, a rainy day during winter season or a wet day during early spring would make pheromone blends of 2 aldehyde/8 acetate or 3 aldehyde/7 acetate dominate the male catch in the field. It seems that any kind of free water; rainfall, dew, fog, or mist during a cool night would affect to the male response to the pheromone blend. This is the case found in most test sites in the west and north of Taiwan during winter-spring season. When it is with humidity above RH 75% but without rain blends of 3 aldehyde/7 acetate or 4 aldehyde/6 acetate would lure more male adult moth than the blend of other combinations. These were the cases occurred in the field of western Taiwan. When the weather is dry with humidity less than RH 75% the male moth lost their preference to any of the pheromone blend. These are found in the field located in the south and east of Taiwan during winter-spring season or in the north during summer, or in the west during fall. It is interesting to note that temperature in respect of blend

preference for male eatch played an important role with a low RH during warm season. There are cases with 5 aldehyde/5 acetate blend with higher male catch in southern part of Taiwan. However, this preference was never found with majority male catch during winter-spring season. It is still not sure whether the female adult would release a pheromone blend with high acetate content when it is wet, or it just because of the moisture that might play a functional role as a carrier to disperse the acetate molecule more efficient to the male adult to stimulate the sexual activity during the most reproductive season of the insect in the island.

Evidence showed that light rainfall would enhance the reproductive potential of DBM population during winter season. As Lee (1986) indicated that the DBM population would fluctuate to a high level during the winter day at 18°C and light rainfall in the south of Taiwan. Lee's observation has lasted for three year since 1982. Lee (1986) suggested that heavily rainfall during summer would depress the population growth. As very little work has been done during winter/spring season, therfore, it is unable to draw a clear cut between the potential of population growth and the pheromone preference of the male adult moth in the winter field. Nevertheless, it might reflect that it is a well coincidence between a pheromone blend of 2 aldehyde/8 acetate, rainfall, mild temperature and mild temperature and maximum male catch in the open field.

Temperature and Male Response to the Pheromone

According to Chow *et al.* (1978), the male adult of DBM initiated their response to the virgin female around sunset at 18:30 pm in March. The temperature at that time was mild. It was estimated that 36% of the male adult was trapped during a two hour interval after sunset. The response has lasted for several hours. Another peak of the response was found during mid-night. This study carried out in Yieong-Jing District (Table 3) confirmed Chow's study. Besides, it is also found that this situation would change when an deterrent factor was imposed into the habitat of this insect. For example, a decreased temperature in the field would end up a disruption of the normal male catch pattern through the trapping processes. In Japan, temperature at 10-15-11°C around midday of winter season would be favorable for mating. The mating time would shift to mid-night at 19-20°C during summer (Yamada and Koshihara, 1980). In fact, both indoor bioassay (Maa and Lin, 1985) and field test evidently showed that temperature around 18.6°C would be the optimal condition for male responding to the pheromone lure. In Taiwan a temperature below 10°C during winter is rare. Nevertheless, the low temperature around 11°C would constrain the activity of the male adult in field. This is somewhat different from what was found in Japan. It is therefore to be understandable that geographical variation of male response to the pheromone blend are bestowed between the DBM of Taiwan and Japan. This variation in male sexual behaviour of DBM was associated with the adaptitive capability of male DBM to the weather of Japan and Taiwan respectively.

Roelof (1978) indicated that perception of a male adult insect to a specific blend is related to the various threshold levels for behavioral responses. The threshold, as we stated above, undergo large daily changes as affected by various exo- and endogenous input. Therefore, it is expectable that the males are captured by a broad range of ratios of pheromone mixture. We would expected that the ratio of Z-11-hexadecenal, Z-11-hexadecenyl acetate and Z-11-hexadecenol, of DBM would also affected by various exogenous input to the insect. Although no routine check is made on the component ratios for female-released pheromones for each season, the authors suspect there are any changes in the pheromone secretion of the female adults. Therefore, we will expect that under a condition

with optimal temperature, say, 18-20°C, relative humidity would play a major role to elicite the male DBM response to the synthetic female sex pheromone. It is our conclusion that in Taiwan the male DBM adults respond to a blend of comparatively high acetate content since the weather of this island is comparatively humid and warm. When the humidity is high or when it is with free water in the air, a blend of 2:8:0.1 (Ald: OAc: OH) lure the majority of the males in the field. A blend of 3:7:0.1 of the insect pheromone would also snare more DBM males in the field during spring season. The ratios of the three components would change to 4:6:0.1 or to 5:5:0.1 for maximum male catch in the field when it is getting warm during summer in Taiwan. Therefore, for mass trapping or for sexual disorientating the male of the DBM in field a blend with high acetate content should be used for control during winter-spring season. For the DBM managemnt on summer vegetable cropping the blend with comparatively low acetate content pheromone would be a better choice.

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以合成之小菜蛾雌性費洛蒙來偵測氣象因子對田間誘雄之影響

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爲了要瞭解氣象因子，如：溫度、濕度、游離水與小菜蛾（*Plutella xylostella* L.）雄蛾對雌性小菜蛾性費洛蒙不同配方所表現的偏好性，田間誘雄試驗在全省十四個地區展開。小菜蛾雌性費洛蒙之三個主要成份卽：順-11-十六烯醛，順-11-十六乙烯酯及順-11-十六烯醇以 2：8：0.1 到 6：4：0.1 共五種配方各以每餌 50 μg 之用量爲一餌在田間進行了誘雄試驗。結果顯示，在適溫之狀況下；18 ± 1.5℃，濕度高時，雄蛾偏好 2：8：0.1 及 3：7：0.1 之配方，當濕度下降、溫度昇高時，雄蛾偏好，4：6：0.1 及 5：5：0.1 之配方。在二十六個每週調查一次的試驗中，有半數結果顯示高乙酸烯酯含量者效果較好，在十三個每天調查者，有九個結果與每週者雷同，這說明了高含量乙酸烯酯之雌性費洛蒙配方適合於本省使用。文中也談論到雨及自由水對誘雄之影響。