Capture of Male Moths of *Spodoptera litura* F. (Lepidoptera : Noctuidae) in Virgin Female Traps and Influence of Blacklight upon Them. I. Males of Natural Sources

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Spodoptera litura male moths of natural sources were captured in virgin female traps as early as March. They were trapped in greatest abundance during the period from August to October. The total number of captured males per night was hardly influenced by alterations in the number of traps in operation. The outermost traps tended to capture more males on the average than the intermediate ones. In terms of catchability, traps 5 m away from a 20 watt blacklight appeared to be considerably inferior to those placed at distance further away.

INTRODUCTION

In our laboratory, the ecological aspects of sex pheromone problems have been studied as a part of a broad research program concerned with the integrated control of the noctuid, *Spodoptera litura*, which is injurious to soybean, taro, alfalfa and other crops in Japan. In this paper, captures of the males of natural sources in virgin female traps are dealt with and the influence of blacklight upon them are also examined. With regard to the subject of the release of marked males and their retrapping, a separate paper is in preparation.

MATERIALS AND METHODS

Ten stands (1.2 m in height) were arranged in a single row at 10 m intervals along a road at a farm of the Shikoku Agricultural Experiment Station, Zentûzi, Kagawa Prefecture. They were numbered 1 through 10 in a southerly to northerly direction. A virgin female trap was set on all of the stands. Two trap-setting procedures were followed. In the first, all of the stands (Nos. 1 to 10) were used, while in the second, only 6 of the 10 stands (Nos. 1, 3, 5, 6, 8, and 10) were employed. In the following, the respective trap numbers are represented by the corresponding stand numbers (Fig. 1).

Traps were made by boring an opening on all sides of a plastic container used for homework and by attaching a net cage to the inside of the lid of the container (Fig.

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Fig. 1. Virgin female traps (T5 to T10) and blacklight (BL). Their arrangement is shown on the right side.

Fig. 2. A single virgin female trap. Half of the lid is opened to show the net cage (C) in which *S. litura* females are confined.

2). Virgin females, which had emerged in mass culture and been retained indoors one full night for maturation, were confined to the net cage. They were replenished every night of trap operation. Water was poured into the bottom of the container, and a small amount of surfactant was added. Males which entered the trap through the openings and fell into the water were prevented from escaping by pieces of a plastic plate attached to the inside of the openings.

At the very centre of the row of stands (5 m equidistant from stand No. 5 and 6), an electric plug was set for a 6 or 20 watt blacklight of the BLB type. A water pan with a diameter of 60 cm was put beneath the lamp in order to collect moths attracted to the blacklight (Fig. 1).

Capturing of males in the traps was carried out with minimum interruption during the period from June to December, 1971 and March to July, 1972. Blacklight was illuminated continuously or in irregular patterns during the periods. There was no instance, however, in which the collection of moths by blacklight was carried out without the operation of the virgin female traps. In 1972, use of the 6 watt blacklight was terminated.

RESULTS

The number of virgin females kept in the trap

During the first month of research, the number of virgin females per trap was altered daily in order to investigate the effect on male capture. As shown in Fig. 3, the number of captured males was highly variable even when the same number of females was used and no clear-cut correlation was detected between the two parameters. Consequently, the number of females per trap per night was fixed at 10 individuals for all subsequent experiments.

Capture of Male Moths of *S. litura*

Fig. 3. Relationship between the number of females per trap and the total number of males captured in 10 traps.

Fig. 4. Seasonal fluctuations in the number of males captured in the traps. Three-day-moving-average (n) calculated from raw data is transformed into $\log(n+1)$.

Seasonal fluctuation in the number of trapped males

Fig. 4 was drawn without regard to the number of traps operated and the conditions of blacklight. It seems useful, however, in suggesting general seasonal trends in the number of trapped males.

Reflecting the abundant emergence of adult moths in autumn, the number of captured males was greatest in August and September of 1971, and occasionally

Fig. 5. Relationship between the average temperature during a night and the number of males captured in all the traps operated in that night. In 1971, $\circ$, $\triangle$, $\times$, $\bullet$ and $+$ represent the periods November 1 to 10, 11 to 20, 21 to 30, December 1 to 10, and 11 to 20, respectively. In 1972, $\circ$, $\triangle$, $\times$, $\bullet$ represent the periods March 22 to 31, April 1 to 10, 11 to 20, and 21 to 30, respectively.

surpassed 1,000 individuals during a single night. A decrease was seen as the season advanced, but even in early December, a good number of moths were trapped during warm nights. In 1972, captures were recorded as early as late March. Their number gradually increased from April to June, and reached the same level of abundance as July of the preceding year. Male flight to the traps was seriously restrained under the conditions of low temperatures. As demonstrated in Fig. 5, the lower limits in the average nocturnal temperature under which males hardly trapped were about 9 °C in the early winter of 1971 and about 13 °C in the spring of 1972.

The number of *S. litura* moths collected under the blacklight during a single night never surpassed 20 individuals even during the period from August to October. A large majority of these were males.

Relationship between the number of traps and the total number of captured males

In the autumn of 1971, pairs of double nights, each pair consisting of one night during which all traps, Nos. 1 to 10, were utilized (referred to as the '10-trap operation' in the following) and the second one during which only 6 traps, Nos. 1, 3, 5, 6, 8 and 10 ('6-trap operation') were provided for examining the relationship between the number of traps and the total number of males captured in them. The results show that more males were not always captured in the night of 10-trap operation than in that of 6-trap operation (Table 1), and no significant difference in the number of captures was detected between the two operations.

In June and July of 1972, a series of investigations were carried out under a design similar to the above mentioned 1971 investigations. No significant effect was shown

Table 1. DIFFERENCES IN THE TOTAL NUMBER OF CAPTURED MALES BETWEEN 10-TRAPS OPERATION AND 6-TRAPS OPERATION IN 1971

Pair	Total captures		Difference (A—B)	Date of trap operation	
	A ^a	B ^b		A	B
<i>Blacklight off</i>					
1	882	821	61	Sept. 27	Sept. 28
2	498	188	310	Oct. 4	Oct. 5
3	344	96	248	Oct. 17	Oct. 16
4	200	327	—127	Oct. 24	Oct. 25
5	112	197	—85	Nov. 3	Nov. 4
6	84	20	64	Nov. 10	Nov. 11
7	5	26	—21	Nov. 16	Nov. 17
8	1	0	1	Nov. 22	Nov. 23
9	97	0	97	Nov. 28	Nov. 29
10	0	40	—40	Dec. 4	Dec. 5
<i>Six-W Blacklight on</i>					
1	803	421	382	Oct. 2	Oct. 3
2	352	354	—2	Oct. 22	Oct. 23
3	162	35	127	Nov. 1	Nov. 2
4	0	5	—5	Nov. 8	Nov. 9
5	64	16	48	Nov. 14	Nov. 15
6	2	64	—62	Nov. 20	Nov. 21
7	114	67	47	Nov. 26	Nov. 27
8	23	0	23	Dec. 2	Dec. 3
<i>Twenty-W Blacklight on</i>					
1	951	434	517	Sept. 30	Oct. 1
2	192	170	22	Oct. 7	Oct. 8
3	91	140	—49	Oct. 13	Oct. 14
4	426	202	222	Oct. 19	Oct. 20
5	235	249	—14	Nov. 5	Nov. 6
6	34	113	—79	Nov. 12	Nov. 13
7	10	40	—30	Nov. 18	Nov. 19
8	18	63	—45	Nov. 24	Nov. 25

^a Ten-trap operation^b Six-trap operation

in the reduction of the number of traps on the total number of captures (see Table 3).

Comparison of the number of captured males among trap groups

In the course of our research, we were conscious of the fact that males were often captured in abundance in the outermost traps (Nos. 1 and 10) as compared with the inner ones. As a result, capture data were summarized for the following 5 trap group pairings: (1) Trap No. 1 and 10, (2) 2 and 9, (3) 3 and 8, (4) 4 and 7, and (5) 5 and 6. (In the 6-trap operation, trap groups (2) and (4) were absent). Table 2 shows the monthly totals and the gross totals of captures in the respective trap groups. Concerning the results given in Table 2, χ^2 -test was carried out under the null hypothesis of even distribution in the number of captured males among the trap groups, and in every case, the hypothesis was rejected at the 1% level of significance. Examination

Table 2. MONTHLY TOTALS AND THE GROSS TOTALS OF CAPTURED MALES IN EVERY TRAP GROUP^a

Year and month	10-trap operation								6-trap operation					
	No. of night	Trap group					Total	χ^2_0	No. of night	Trap group			Total	χ^2_0
		1+10 (1)	2+9 (2)	3+8 (3)	4+7 (4)	5+6 (5)				1+10 (1)	3+8 (3)	5+6 (5)		
Blacklight off														
1971														
July	6	159	155	107	161	144	726	13.75	0				—	—
Aug.	10	1110	661	550	467	623	3411	367.57	0				—	—
Sept.	10	1407	1068	890	795	833	4993	252.63	1	333	255	233	821	20.22
Oct.	4	349	256	276	196	209	1286	57.74	4	327	295	373	995	92.94
Nov.	5	108	65	44	44	38	299	55.60	3	117	56	70	243	25.21
Total	35	3133	2205	1867	1663	1847	10715	643.09	8	777	606	676	2059	21.51
1972														
May	4	21	9	12	9	4	55	—	15	72	49	40	161	10.21
June	6	76	76	52	51	47	302	13.62	15	330	216	191	737	44.76
July	5	139	139	110	126	89	603	15.07	10	415	349	270	1034	30.62
Total	15	236	224	174	186	140	960	31.38	40	817	614	501	1932	79.62
Six-W blacklight on														
1971														
July	4	100	77	72	80	49	378	17.69	0				—	—
Aug.	9	628	439	421	276	243	2007	23.41	0				—	—
Sept.	8	891	744	668	441	505	3249	203.06	0				—	—
Oct.	5	594	446	343	328	229	1940	197.70	3	459	305	280	1044	54.01
Nov.	5	137	86	103	71	36	433	64.82	5	83	64	40	187	14.98
Total	31	2350	1790	1607	1196	1062	8007	656.96	8	542	369	320	1231	66.24
Twenty-W blacklight on														
1971														
July	4	165	156	106	91	44	562	87.59	0				—	—
Aug.	11	1455	1080	888	699	296	4418	842.51	0				—	—
Sept.	11	1705	1344	1284	958	522	5813	683.25	0				—	—
Oct.	4	291	184	207	137	83	902	134.83	4	424	341	183	948	94.87
Nov.	4	84	62	58	55	38	297	18.37	4	215	134	116	465	35.88
Total	34	3700	2826	2543	1940	983	11992	1714.23	8	639	475	299	1413	122.77
1972														
May	5	25	18	21	8	6	78	17.51	4	25	20	6	51	11.41
June	5	91	57	55	33	43	279	34.49	4	111	59	28	198	53.30
July	3	193	109	116	106	43	567	100.29	4	189	163	104	456	24.96
Total	13	309	184	192	147	92	924	138.09	12	325	242	138	705	74.71

^a The whole χ^2_0 values are significant at the 1% level.

of Table 2 shows that in most of the 1971 10-trap operations with the exception of those in the '20W BL on' category, the cause of the statistical significance can mainly be attributed to the abundant capture of males in the trap group (1) (the outermost traps). Furthermore, in September of 1971, when males were trapped in greatest abundance, data in the respective nights of 10-trap operation without blacklight were

Influence of blacklight upon the attraction of males to the virgin female traps

Table 3. RESULTS OF OBSERVATIONS FOR BL OFF-6W BL ON-20W BL ON
REPETITION (1971) AND FOR BL OFF/10-TR OP-BL OFF/6-TR OP-20W
BL ON/10-TR OP-20W BL ON/6-TR OP REPETITION (1972)

Year		1971			1972			
Blacklight and trap operation		BL ^a off	6W BL on	20W BL on	BL off		20W BL on	
					10-TR OP ^b	6-TR OP	10-TR OP	6-TR OP
Total no. of males captured in:	all the traps (A)	6,415	5,401	6,734	683	653	814	622
	trap group Nos. 5 and 6 (B)	1,088	762	583	95	155	83	129
B/A × 100 (%)		17.0	14.1	8.7	13.9	23.7	10.2	20.7
Order of trapping intensity								
		1971			1972			
Combination		Frequency distribution concerning:		Combination		Frequency distribution concerning:		
No.	BL off							6W BL on
(1)	3 — 2 — 1 ^e	7} 13	1	(1)	4 — 2 — 1 — 3	1} 3	0	
(2)	2 — 3 — 1	6}	1	(2)	2 — 3 — 1 — 4	2}	1	
(3)	3 — 1 — 2	0	2	(3)	4 — 1 — 2 — 3	0	1	
(4)	1 — 3 — 2	2	3	(4)	3 — 4 — 2 — 1	1	0	
(5)	2 — 1 — 3	1} 5	5} 13	(5)	1 — 4 — 2 — 3	1	0	
(6)	1 — 2 — 3	4}	8}	(6)	4 — 2 — 3 — 1	0	1	
				(7)	1 — 2 — 3 — 4	1	0	
				(8)	3 — 2 — 4 — 1	0	2}	
				(9)	2 — 1 — 4 — 3	0	2}	
				(10)	1 — 2 — 4 — 3	1	0}	
Total		20	20	Total		7	7	

◊ Arrangement in order of decreasing trapping intensity: 1. 20W BL on, 2. 6W BL on, and 3. BL off.

contrast to results on those nights when a blacklight was not employed. In 1971 and 1972, these phenomena were reexamined on a larger scale.

From late July to late September, 1971, the following 3 lighting schedules were examined: blacklight off, 6 watt blacklight on, and 20 watt blacklight on. They were repeated 20 times. All 10 traps were in operating during this experimental period. In June and July, 1972, the following 4 lighting schedules were repeated 7 times: 10 and 6 traps operations, with and without 20 watt blacklight. In the upper half of Table 3, the totals of trapped males throughout the observation period are shown. With regard to the total number of males captured in all operated traps, there was no distinct difference among the different lighting schedules in each year. However, the total numbers of males in trap group (5) and their percentage of the total number captured in all traps showed considerable variability. In 1971, the values for nights following the '20 W BL on' schedule were low compared with those nights of the different schedules, while the situation in 1972 was more complicated, with the difference between '10 TR OP' and '6 TR OP' being larger than that between 'BL off' and '20 W BL on'.

In each repetition, the nights of respective kinds were arranged in descending order of trapping intensity. The concept "trapping intensity" described here is used to express either of the following 2 considerations: the total amount of males captured in all operated traps, and the ratio of the number of captures by trap group (5) to the total catch by all the traps. The results of the arrangement are given in the lower half of Table 3 as frequency distributions of 2 kinds in the occurrence of combinations of the orders. The frequency distributions in 1971 demonstrated that with regard to the total number of males captured in all the traps, the nights with 20 watt blacklight schedule were top in 13 (the cases of combination Nos. (1) and (2)) of the total 20 repetitions. Concerning the ratios of capture of trap group (5) in terms of the number of captures, these were last in 13 repetitions (the cases of combination Nos. (5) and (6)). It was noted, however, that in the former, there were 5 repetitions in which the nights with 20 watt blacklight were last (the cases of combination Nos. (5) and (6)), so that no significant orderliness was detected through FRIEDMAN's test in this kind of arrangement. As for the arrangement concerning the ratio of the trap group (5), on the contrary, orderliness was significant at the 1% level. In both kinds of arrangement in 1972, orderliness was insignificant.

The results given in Table 2 also show a strong tendency that 20 watt blacklight brought about a decrease in the number of males captured in the traps nearset to the light.

Conclusively, it can be said that 20 watt blacklight had an adverse effect on the capture of males in the traps 5 m away from the light, but its effect on increasing the total number of males captured in all the traps operated was rather doubtful. The 6 watt blacklight seemed to be ineffective.

DISCUSSION

It is noteworthy that males were captured in the virgin female traps as early in season as March-April. They are regarded as from a natural population, although the possibility exists that a number of males which happened to escape from mass culture in the laboratory were also included. In Zentûzi and its neighbourhood, it is nearly

impossible to collect *S. litura* moths by light in spring, probably because under a low density of the moth at that time, the chance which they happen to be trapped by light is extremely low due to their comparatively low sensitivity to light. Virgin female traps are therefore said to be useful for forecasting the early-season occurrence of the moth and also for studying its overwintering status. Our information on the overwintering of this species is still imperfect. In Kôti Prefecture, heated vinylhouses and glasshouses for vegetable cultivation have been seen to be important overwintering sites of the species. In Kagawa Prefecture including Zentûzi, however, such facilities are scarce, and so the species is believed to overwinter mainly in unheated places. Surmizing from the evidence that in March, males were already captured in the virgin female traps, there is a fair possibility that the species overwinters in its pupal and adult stages as well as in its larval stage.

Through our research, it was demonstrated that neither increase in the number of virgin females per trap nor in the number of traps per night consistently increased the total number of males captured during the night. In a trap devised by MRYASHITA et al. (1972), there was also no significant difference in the number of captures between the internment of 10 females and that of 20 ones, within the trap. In our research, the decrease in the number of traps resulted in an increase in the space between traps. Concerning synthetic sex pheromone traps of the cabbage looper moth, *Trichoplusia ni*, TOBA et al. (1970) detected no meaningful difference in the total number of trapped males through the alteration in the space between the traps. They also demonstrated that the number of males per trap was significantly smaller when several traps were operated than at the time of the operation of a single trap. It seems to be a general principle that the increase of the absolute volume of female sex pheromonal substances does not always bring about an appreciable increase of their attractiveness to the males.

It is possible to consider the evidence that in the 10-trap operation, the intermediate traps, No. 2 to 9, often attracted less males in average than the outermost ones, No. 1 and 10, in relation to the description in the above paragraph. Citing the "effective sphere" proposed by HIDAOKA (1972) concerning the fall webworm moth, *Hyphantria cunea*, let us assume here that such a sphere might exist around each trap and be characterized by a male entering this sphere getting oriented to the sex pheromone source. Then, the relatively low intensity of capture in the intermediate traps may be explained as a relative decline of their catchability due to a high degree of overlapping of their spheres. (It is perhaps admissible from the description in the preceding paragraph that probable increase in pheromonal concentration through the postulated overlapping of the spheres brought about no favourable effect on male catchability.) In each of the outermost traps, the portion of its sphere in which it overlapped with that of the neighbouring trap must have been small, accordingly the function of the trap being retained nearly unsuffered. In the 6-trap operation, too, the superiority of the group of the outermost traps in trapping intensity was prevalent phenomenon, in spite of the further expansion of the trap interval by discarding Trap Nos. 2, 4, 7, and 9. Since the trap interval in this case was 20 m excepting that between Trap Nos. 5 and 6, we cannot help but to suppose a considerably large diameter of the sphere if we again assume here the high extent overlapping of the spheres. This would seem to differ considerably from the image which HIDAOKA's "effective sphere" gives us.

Experimental attempts of baiting blacklight with virgin females have been carried

out against several species of moths in the USA and other countries. In many cases, blacklight baited with virgin females was reported to gather more males than blacklight alone (for example, HOFFMAN et al., 1966; HENEBERRY et al., 1967), although there is a report in which no significant difference in male catchability was detected between a synthetic sex pheromone trap and a blacklight trap accompanied by the synthetic pheromone (TOBA et al., 1970). As for *S. litura*, it was revealed by OYAMA and KONO (1971) and also by us that a 20 watt blacklight seems to have a repellent effect on male moths in close proximity, even though it is believed to be somewhat powerful in drawing moths from remote places to its neighbourhood. This suggests that in its practical application, the combination of blacklight with sex pheromones of *S. litura* should be carefully examined in further detail for their mutual antagonistic relation.

REFERENCES

- HENEBERRY, T. J., A. F. HOWLAND and W. W. WOLF (1967) Combination of blacklight and virgin females as attractants to cabbage looper moths. *J. Econ. Ent.* **60**: 152-156.
- HIDAKA, T. (1972) Biology of *Hyphantria cunea* DRURY (Lepidoptera: Arctiidae) in Japan. XIV. Mating behavior. *Appl. Ent. Zool.* **7**: 116-132.
- HOFFMAN, J.D., F.R. LAWSON and B. PEACE (1966) Attraction of blacklight traps baited with virgin female tobacco hornworm moths. *J. Econ. Ent.* **59**: 809-811.
- MIYASHITA, K., K. NAKAMURA and Y. ITÔ (1972) The rate of catch of the male of *Spodoptera litura* F. (Lepidoptera: Noctuidae) by virgin female traps. *Appl. Ent. Zool.* **7**: 109-115.
- OYAMA, M. and T. KONO (1971) Influence of blacklight upon the efficiency of *Spodoptera litura* virgin female traps. *Abst. Papers. Ann. Meet. Jap. Soc. Appl. Ent. Zool.* Tokyo: 52. (In Japanese.)