Feeding Suppression and Its Disappearance in Larvae of the Gypsy Moth, *Porthetria dispar* (L.), by *Bacillus thuringiensis* Berliner

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マイマイガの幼虫に対する *Bacillus thuringiensis* の摂食抑制とその消失

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The "B. t. product" which is formulated from toxins and spores of *Bacillus thuringiensis* Berliner as the principal active ingredients, has a highly lethal effect on insects, especially lepidopterous larvae. The lethal effect in general may develop very slowly. It may take several days after ingestion to kill the larvae. On the other hand, the feeding by the larva may be greatly suppressed within a few hours after the ingestion of the B. t. product. In the case of the ingestion of sublethal quantities of the B. t. product, the larva may recover from the loss of appetite when given untreated diet. The writers wish to present the results of a short experiment evaluating quantitatively the feeding suppression by the B. t. product on the larvae of the gypsy moth, *Porthetria dispar* (L.), and the disappearance of this suppression.

Materials and methods

Full grown larvae of the gypsy moth, which were used in the tests, were collected in the field in May, 1973, in Kikugawa, Shizuoka Pref. They were fed the leaves of persimon. A commercial B. t. product, "Thuricide", was used at six levels of concentrations, a 1 : 1 (v/v) serial dilution of a 2000 ppm solution. Persimon leaves of uniform size were dipped into each test solution, and the leaf area was measured with a digital area counter (Hayashi Denko Co., Type AAM-5). The weight of the larva was expressed in mg. Each test larva was confined with a treated leaf in a covered Petri dish, 9 cm in diameter and 2 cm in height. The dishes were kept in a rearing room at 25°C. After 24 hours area of the uneated leaf was measured. The feeding suppression was expressed as the quantity of consumed treated leaf (consumed area in cm^2/weight of larva g). The larvae were subsequently given fresh untreated leaves for 24 hours, and the quantity of leaf consumed was determined. In the control, untreated

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Table 1. Feeding suppression in the last instar larvae of the gypsy moth by Thuricide and the recovery rate of feeding. The effect of suppression is expressed as the consumed leaf area per weight of larva (cm^2/g).

Feeding	Symbol	Concentration (ppm) 2000	1000	500	250	125	62.5	Control
Feeding suppression	y	5.69	16.08	24.01	18.23	29.27	36.35	39.65
		9.45	21.82	26.98	26.93	33.82	47.20	60.23
		14.03	21.86	27.20	29.70	41.40	49.58	66.33
		20.09	23.10	34.80	31.44	43.80	54.93	72.06
		21.15	23.93	36.58	37.15	49.85	55.92	77.15
		22.85	26.04	43.05	45.18	51.67	56.90	81.10
		24.01	33.51	49.90	47.16	54.42	59.50	93.46
		24.08	46.95	50.47	48.59	62.57	61.75	98.85
		26.40	48.16	53.67	54.25	62.88	69.04	99.01
		26.85	48.51	65.94	57.07	72.13	73.01	99.38
		28.05	53.45	66.11	59.08	72.88	73.53	99.74
		29.90	55.02	66.57	61.51	73.29	81.72	106.99
		31.23	55.44	76.69	64.46	74.78	83.33	107.50
		31.89	55.70	79.53	64.56	76.56	83.82	107.95
		32.36	60.21	79.69	64.56	93.94	84.55	108.89
		33.82	61.12	84.97	70.16	96.67	85.60	110.99
		45.88	61.25	85.18	75.81	100.16	93.32	141.45
		52.80	67.49		77.03	101.25	93.60	
		53.91	74.31		77.37		103.31	
		62.55			83.95		135.15	
	Σy	596.99	853.95	951.33	1094.19	1191.34	1482.61	1570.37
	f	20	19	17	20	18	20	17
	$\bar{y}$	29.85	44.94	55.96	54.71	66.19	74.13	92.37
Feeding recovery	y	23.27	6.12	10.42	35.83	18.79	45.98	9.22
		29.62	12.63	12.76	44.71	45.38	54.48	52.67
		43.04	37.09	35.62	52.27	64.56	56.93	76.06
		45.07	38.15	51.51	52.51	67.81	60.97	81.83
		49.16	45.53	57.20	52.51	80.60	72.86	92.43
		50.55	58.80	57.37	56.33	81.00	80.48	89.47
		56.60	60.32	68.04	66.32	83.13	82.07	92.68
		61.05	63.54	72.78	67.74	85.75	82.40	94.46
		62.02	67.68	73.09	68.08	90.99	85.65	107.42
		62.45	70.09	76.44	68.19	95.06	92.06	110.14
		65.81	70.66	77.47	70.04	98.41	92.18	110.71
		79.51	75.32	102.80	80.14	107.39	99.25	118.34
		82.00	79.87	104.33	80.39	108.32	99.85	127.24
		85.47	80.97	104.67	87.79	118.93	119.20	134.18
		92.54	85.40	110.72	89.66		121.50	134.89
			87.43	114.98	96.61		173.54	147.04
			107.54	117.63	110.17			170.94
			111.43					
			126.64					
	Σy	888.16	1285.21	1247.83	1179.29	1146.12	1419.40	1749.72
	f	15	19	17	17	14	16	17
	$\bar{y}$	59.21	67.64	73.40	69.37	81.87	88.71	102.92

leaves were fed to the larvae, and the quantity consumed was determined.

Results and Discussion

The consumed quantities of leaves by the larvae are given in Table 1. The analysis of variance (Table 2) shows highly significant mean squares among the 6 B. t. concentrations in both feeding suppression and its rate of disappearance. Probit diagrams of the cumulative distribution of the consumed quantities of leaves do not suggest their transformation to some other units (Fig. 1). The simple averages of consumed quantities can be used for examining the relationship between the consumed leaf quantities and the concentrations of Thuricide. The relationship between the two variables was analysed by the maximum likelihood estimation method of parameters for quantitative response data[4] using $H = 92.40$ for feeding suppression and 103.38 for its disappearance (Table 3). The mean squares D^2 for feeding suppression and the disappearance of the suppression are less than the error mean squares in Table 2. Therefore, there is no indication of significant deviation from the fitted sigmoid curves. Higher feeding suppressions are obtained with higher concentrations of Thuricide, and the recovery from the loss of appetite is slower in individuals whose feeding has been most severely suppressed. The difference between the regression coefficient of concentration-feeding suppression line and that of the concentration-recovery line means that the suppression and its disappearance do not proceed in parallel. The recovery from the loss of appetite in individuals whose feeding is greatly suppressed is much slower than in the individuals whose feeding is lightly suppressed.

Table 2. Analysis of variance of the data in Table 1.

Term	Feeding suppression				Feeding recovery			
	DF	SS	MS	F	DF	SS	MS	F
Treatment	6	45716.4732	7619.4122	18.33	6	21540.1843	3590.0307	4.15
Error	124	51548.7575	415.7158		108	93338.7661	864.2478	
Total	130	97265.2307			114	114878.9524		

Angus[1] and Angus and Norris[2] used the onset of paralysis in the silkworm, *Bombyx mori* (L.), for evaluating the effectiveness of B. t. product. The present study indicates that the recovery from the loss of appetite is important in evaluating the effectiveness of B. t. products. Burgerjon[3] devised a photoelectric apparatus for measuring the quantity of food consumption by phytophagus insects. He reported that the dosage-mortality of larvae of the European cabbage butterfly, *Pieris brassicae* (L.), caused by *B. thuringiensis* could be expressed by the dosage-food consumption reduction curves determined by his apparatus. Several investigators have gravimetrically determined the per cent utilization and food consumption by phytophagus insects. In 1964, McGinnis and Kasting[5,6] developed a sensitive indirect method using chronic oxide. Recently a digital area counter has become available and it would save much time and

Table 3. The maximum likelihood estimation of the data in Table 1.

Term	Feeding suppression	Feeding recovery
H	92.40	103.38
H'	92.14	103.65
a	6.4610	6.3309
b	−0.7883	−0.4983
$m\times10^5$	1.8598	2.6710
ED_{50}(ppm)	720	4695
Dilution	1389	213
D^2	327.28	291.81

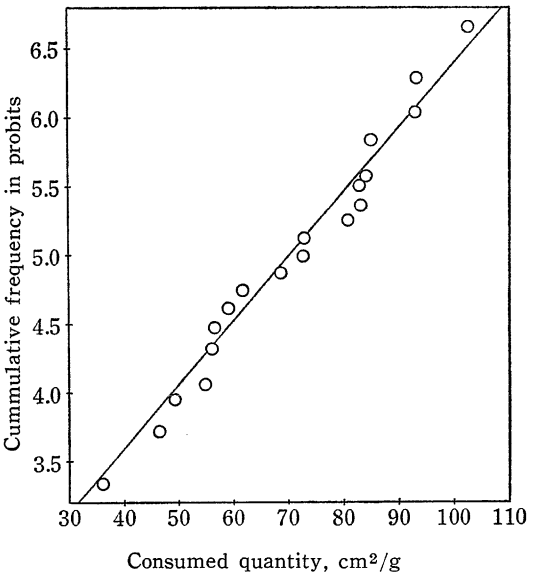

Fig. 1. Cumulative distribution of the consumed quantities of persimon leaves treated with Thuricide at a concentration of 62.5 ppm.

labour when used with the method that the writers have used in this study.

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摘　　要

Bacillus thuringiensis Berliner の生産する毒素が，鱗翅目幼虫に対して，非永続的な可逆性の摂食阻害作用を有することはしられている．マイマイガの幼虫が，毒素を処理したカキの葉を摂食する量を，自記面積計によって測定し，この作用性を数量的に解析証明した．