Factors Inducing Resurgence in the Diamondback Moth After Application of Methomyl

Hisashi Nemoto
Saitama Horticultural Experiment Station, Rokumanbu, Kuki-shi, Saitama 346, Japan

Abstract

Applications of sublethal concentrations of methomyl to 4th instar larvae and pupae of the diamondback moth resulted in increased fecundity of the adults which emerged. The adult females derived from the treated pupae laid more eggs with a higher rate of fertilization as compared with the untreated check. However, the adult females thus treated had a shorter life span than the untreated ones. These effects of methomyl enhanced the intrinsic rate of natural increase (r) or the finite rate of increase per month (λ). Applications of methomyl decreased lycosid spiders which were important predators of 3rd to 4th instar larvae of the diamondback moth in the cabbage fields. It is suggested that the application of methomyl might cause a resurgence of the moth population through the stimulation of the reproductive potential and differential mortality between predators and prey.

Introduction

The major caterpillar pests of crucifers in Japan are common cabbageworm, *Pieris rapae crucivora* Boisduval (Lepidoptera: Pieridae), diamondback moth (DBM), *Plutella xylostella* (L) (Lepidoptera: Yponomeutidae), and beet semi-looper, *Autographa nigrisigna* (Walker) (Lepidoptera: Noctuidae). Insecticides are the most commonly used control agents against these pests in Japan.

In 1981, at Saitama Horticultural Experiment Station (SHES), DBM became abundant after applications of methomyl against common cabbageworm in the cauliflower field but not in the untreated field (Figure 1). Ripper (1956), who reviewed resurgences of pest populations after insecticide treatment, suggested the following as the causes for insect pest resurgence: (a) reduction of natural enemies along with the pest by pesticides, (b) favorable influence of pesticides on phytophagous arthropods (stimulating influence on the pest directly or via the plant), and (c) the removal of competitive species.

This paper describes results of two experiments conducted to analyze the process of DBM resurgence. In the first experiment direct stimulation of methomyl on the reproductive potential was examined and in the second, predators of DBM were identified and the toxicity of methomyl against on these predators evaluated.

Stimulation of Reproductive Potential

Larval treatment with methomyl

Effects of sublethal concentrations of methomyl applied to 4th instar larvae on the fecundity of DBM are shown in Table 1. The adult females derived from the treated larvae deposited more eggs than the control irrespective of concentrations of methomyl.

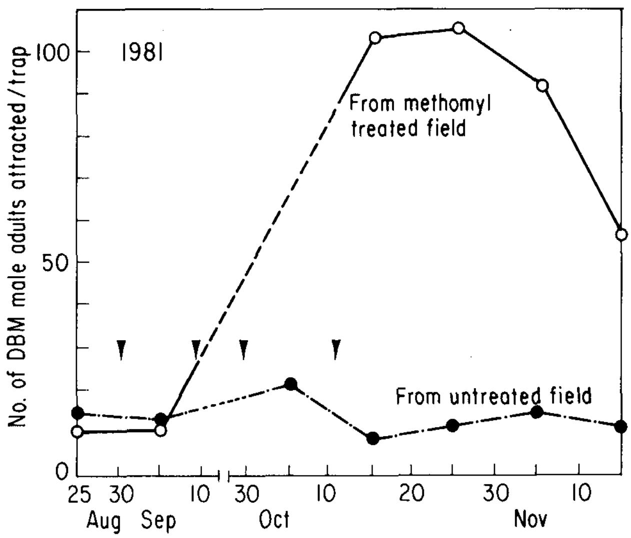

Figure 1.
Effects of methomyl treatments on the diamondback moth populations captured in pheromone traps from cauliflower fields of SHES. Three dry type traps (made by Takeda Chemical Ind Ltd) baited with "Px" (a synthetic sex pheromone for *P. xylostella*, which is a mixture of 0.05 mg of (Z)-11 hexadecenal with 0.05 mg of (Z)-11 hexadecenyl acetate and 0.001 mg of (Z)-11 hexadecenol) were arranged in each field. ▼: date of treatment

Table 1. Effects of the treatment of the fourth instar larvae with sublethal concentrations of methomyl on the fecundity of DBM

Methomyl concentrations (ppm)	No. eggs laid[ab]		No. examined
	per female	per mg of pupal weight[c]	
100	180.0 ± 44.8[d] (1.49)*	42.8 ± 8.0 (1.40)**	4
50	139.5 ± 16.7 (1.15)*	36.3 ± 2.1 (1.19)**	6
10	157.2 ± 18.4 (1.30)*	38.0 ± 3.3 (1.25)**	6
Control	121.2 ± 25.2	30.5 ± 6.4	6

[a] Figures in parentheses indicate the rate of relative increase as compared with control. [b] Figures with asterisks differ significantly from control at 5% level (*) and 1% level (**) by t-test. [c] No. eggs deposited per mg of fresh body weight of pupa. [d] Mean ± standard deviation.

In particular, at concentrations of 10 and 100 ppm, methomyl significantly increased reproduction. A 49% increase in the number of eggs per female was observed at 100 ppm followed by 30% at 10 ppm and 15% at 50 ppm. Based on pupal weight differences were highly significant.

Pupal treatment with methomyl

Dipping pupae (5.5 to 6.5 mg/each) in sublethal concentrations of methomyl resulted in increased fecundity of the adults. The adult females derived from these treated pupae laid more eggs with higher rates of fertilization, as compared with the untreated ones, irrespective of the concentrations of methomyl (Table 2). At 10 ppm, there was a 17% increase in number of eggs per female followed by a 12% increase at 100 ppm, a 10% increase at 500 ppm, and an 8% increase at 50 ppm. The number of fertilized eggs per female increased 1.3 times at 10 ppm and 1.15 times at 500 ppm compared to the untreated ones. The number of fertilized eggs per female per day increased 1.68 times at 10 ppm and 1.33 times at 500 ppm. The percentage of fertilized eggs also increased by methomyl treatment as compared to the untreated check. However, the adult females thus treated had a shorter life span than the untreated ones (Table 2).

Table 2. Longevity and fecundity of female DBM adults treated with methomyl in pupal stage

	Control	Methomyl concentrations (ppm)			
		10	50	100	500
No. of pairs examined	10	7	13	13	11
Adult emergence (%)	98.3	100	95.5	98.5	97.0
Longevity of female adults (days)	7.7±1.1[a]	6.1±0.7	6.5±0.7	6.7±1.2	7.1±2.0
Oviposition period (days)	5.1±0.9	4.4±1.0	4.6±0.7	4.6±1.0	5.6±2.0
Fecundity (eggs/female)	164.2±37.9	191.9±44.4 (1.17)[b]	176.9±28.4 (1.08)	183.2±40.2 (1.12)	180.6±41.4 (1.10)
No. of eggs/female/day	24.9±6.6	37.5±8.3	32.3±6.1	33.0±8.1	31.9±11.7
No. of fertilized eggs/female	139.3±37.0	182.0±43.3 (1.31)	170.1±28.2 (1.22)	175.1±35.3 (1.26)	160.6±37.2 (1.15)
No. of fertilized eggs/female/day	21.2±6.5	35.7±8.4 (1.68)	31.1±6.1 (1.47)	31.6±7.4 (1.49)	28.3±9.9 (1.33)
Fertilized eggs (%)	84.4	94.7	96.2	95.6	88.9

[a] Mean ± standard deviation. [b] Figures in the parentheses indicate the rate of relative increase as compared to the control.

Figure 2 shows survivorship and oviposition curves of female adults treated with methomyl in the pupal stage. The adults derived from the treated pupae deposited greater numbers of eggs for the first two days than the untreated ones. Figure 3 shows a typical comparison of cumulative oviposition curves between control and treated individuals at 10 ppm of methomyl in the pupal stage. The treated females laid not only more eggs but also a greater proportion of fertilized eggs as compared with the check.

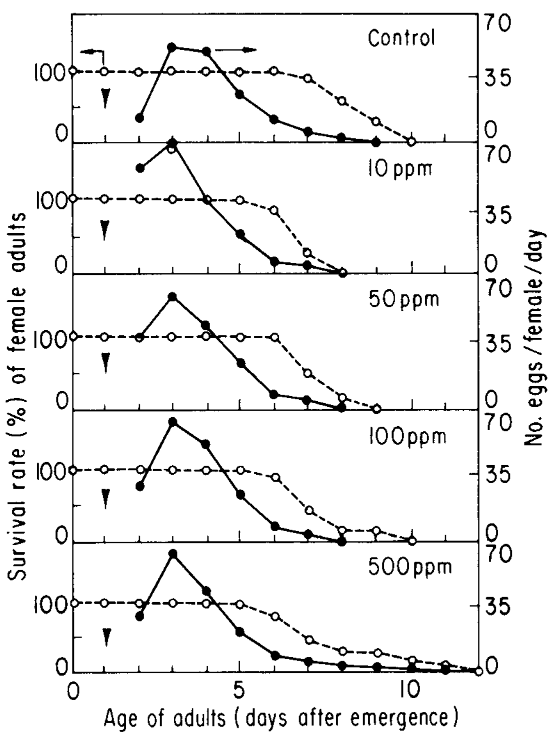

Figure 2.
Survival and oviposition curves of female adults treated with different concentrations of methomyl in the pupal stage. ▼: pairing

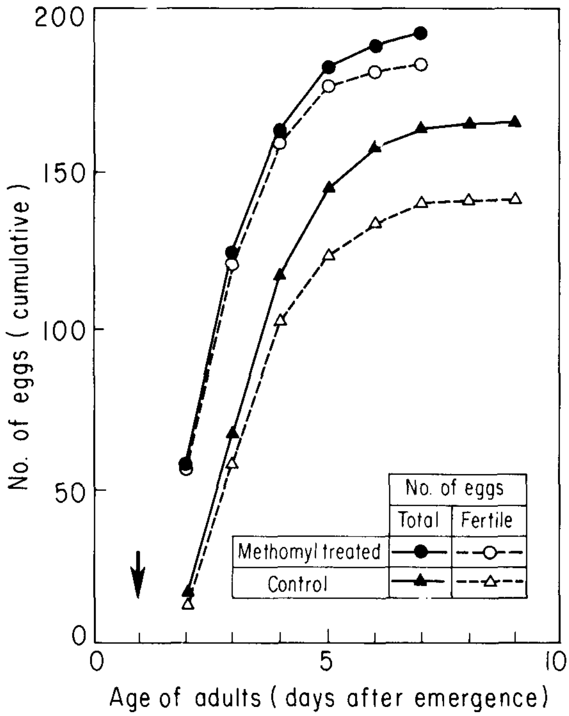

Figure 3.
Comparison of cumulative oviposition curves between untreated and methomyl treated individuals. ▼: pairing

Rate of population increase

We obtained a survival rate (*lx* (E-L)) value of 0.45 from egg to pupa by rearing the insects on radish *Raphanus sativus* (L) seedlings in the laboratory. Substituting the values of 0.5 for sex ratio, age-specific survival rate (*lx*) is expressed by the following equation (Nemoto et al 1984):

$$lx = lx(\text{E-L}) \times (\text{sex ratio}) \times lx(\text{P}) \times lx(\text{A})$$
$$= 0.225 \times lx(\text{P}) \times lx(\text{A})$$

where *lx*(P) is the rate of adult emergence and *lx*(A) is the age-specific survival rate of female adults.

The value of *r* (intrinsic rate of natural increase) was estimated by using the age-specific survival rate and fecundity tables based on the equation given by Birch (1948):

$$R_0 \simeq \Sigma(l_x\ m_x)$$
$$T \simeq \frac{\Sigma x\ l_x\ m_x}{\Sigma l_x\ m_x}$$
$$r \simeq \mathrm{Ln}\ R_0 / T$$
$$\lambda = e^{30r}$$

where R_0 is net reproductive rate, m_x is age-specific fecundity, x is age (days), T is mean generation time and λ is finite rate of natural increase after 30 days.

The population doubling time under given conditions can be calculated as:

$$\text{doubling time} = \frac{\log_e 2}{r}$$

The population parameters of DBM treated with methomyl in the pupal stage were calculated by using the number of fertilized eggs shown in Table 2. The values of T for the treated ones were smaller than in the untreated check (Table 3). Also, the values of R_o increased as compared with the untreated check. As a result there was an increase in the value of r by 6% to 13% in the treated one. Consequently the values of λ (after 30 days) increased 2.03, 1.59, 1.63, and 1.37 times for 10, 50, 100, and 500 ppm methomyl, respectively.

Table 3. Population parameters of DBM treated with different concentrations of methomyl in the pupal stage

	Control	Methomyl concentrations (ppm)[a]			
		10	50	100	500
Mean length of one generation (T) (days)	18.42	17.71	17.85	17.95	18.10
Net reproductive rate (R_o)/female	30.81	40.95 (1.33)	36.55 (1.19)	37.78 (1.23)	35.06 (1.14)
Intrinsic rate of natural increase (r)/female/day	0.186	0.210 (1.13)	0.202 (1.08)	0.202 (1.09)	0.197 (1.06)
Finite rate of increase (λ)/month	265.75	538.46 (2.03)	423.39 (1.59)	432.38 (1.63)	364.02 (1.37)
Doubling time (days)	3.73	3.31	3.44	3.43	3.53

[a] Figures in the parentheses indicate the rate of relative increase as compared with control.

Effectiveness of Predators as Biotic Mortality Agents

Identification of DBM predators

Many species of predatory arthropods are collected by pitfall traps in the cabbage field in SHES (Table 4). In order to identify the predators of DBM, we used an immunological test. This method was sensitive enough to detect the whole-body extracts of 3rd to 4th instar larvae, pupae, and adults of DBM (Nemoto et al 1985). Field-collected lycosid spiders exhibited a positive reaction in the test, as did some *Misumenops tricuspidatus* (Feb) (Aranea: Thomisidae) (Figure 4). But few of *Labidura riparia japonica* (de Hann) (Dermaptera: Labiduridae) reacted positively and neither did any other suspected predators.

Around 10% of the lycosids collected in July showed a positive reaction. No individuals showed a positive reaction in August when the density of DBM larvae was low (Table 5).

Effect of methomyl on predator population

The effect of methomyl on predator populations was studied in the cabbage field. The numbers of lycosid spiders, particularly *Pardosa astrigera* L Koch and *Lycosa pseudannulata* (Bos et Str), were reduced by the applications of methomyl but certain predatory insects were not affected (Figure 5).

Table 4. Predatory arthropods captured from the cabbage fields at SHES

Family	Species
ARANEA	
Atypidae	*Atypus karschi* Donitz
Micryphantidae	*Gnathnarium deutatum* (Wider)
Tetragnathidae	*Dyschiriognatha quadrimaculata* Bos et Str
Hahniidae	*Hahnia corticicola* Bos et Str
Lycosidae	*Arctosa subamylacea* (Bos et Str)
	Lycosa pseudoannulata (Bos et Str)
	Pardosa laura Karsch
	Pardosa astrigera L Koch
Thomisidae	*Misumenops tricuspidatus* (Feb)
Salticidae	Gen et sp
Gnaphosidae	*Gnaphosa kompirensis* (Bos et Str)
Ctenidae	*Anahita fauna* Karsch
DERMAPTERA	
Labiduridae	*Labidura riparia japonica* (de Hann)
COLEOPTERA	
Harpalidae	*Epomis nigricans* Wiedemann
	Chlaenius sp Gen et sp
Cicindelidae	*Cicindela japana* Thunberg

Table 5. Record of lycosid spiders captured in pitfall traps in the cabbage field at SHES and level of their predation[a]

Date of collection	July 1983		Aug. 1983	
	8 to 12	22 to 26	5 to 9	19 to 23
No. of individuals tested[b, c]	25	27	28	6
Positive reaction (%)	8.0	11.1	0	0

[a] Micro-Ouchterlony precipitation test. [b] No. of spiders/30 pitfall traps. [c] Traped spiders were collected every day.

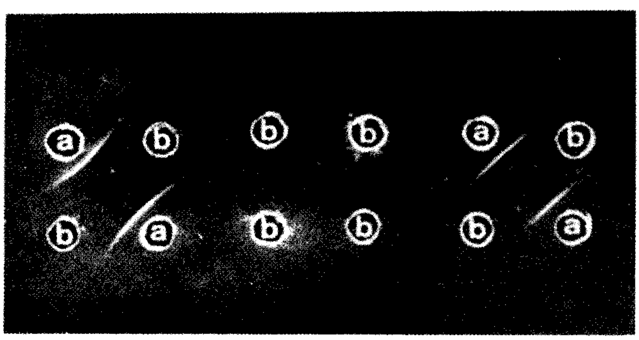

Figure 4. Precipitation test (Micro-Ouchterlony method) with anti-DBM serum against extract of *Pardosa astrigera* L Koch. The anti-DBM serum was placed in the central well and the extracts of *P. astrigera* diluted with saline was placed in the wells around the center. a: feeding on DBM, b: control

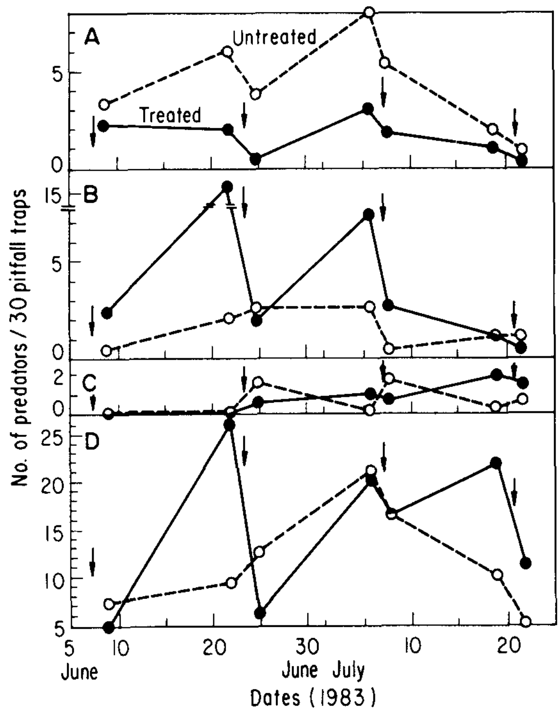

Figure 5.
Effect of methomyl treatments on predatory arthropod populations captured in pitfall traps from cabbage field in SHES. ▼: date of treatment, A: lycosid spiders, B: *Cicindela japana*, C: Harpalidae, D: *Labidura riparia japonics.*

Susceptibility of DBM and *Pardosa astrigera* to methomyl

P. astrigera is the most common lycosid in the cabbage field. The LC_{50} value of methomyl was greater to DBM larvae than to *P. astrigera* (Figure 6). The LC_{50} to lycosids was around 10 ppm as against about 7500 ppm for 4th instar DBM larvae using the dipping method and about 20,000 ppm for 3rd instar larvae by feeding methomyl-contaminated cabbage leaves. Methomyl is generally sprayed at 450 ppm to control crucifer pests.

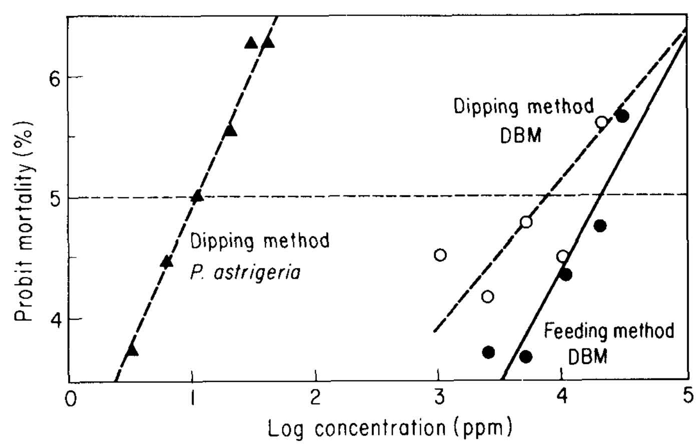

Figure 6. Concentration-mortality curve of methomyl for the spider, *Pardosa astrigera* and DBM.

Discussion

One of Ripper's hypotheses (1956) that insecticide treatment directly stimulates reproductive potential of insects was supported by our data with DBM. It is apparent that several factors such as larval and pupal survival rate, adult longevity, oviposition period, and fecundity affected the intrinsic rate of natural increase (r). Results of our precipitation test showed that lycosid spiders played an important role as a biotic mortality agent of 3rd to 4th instar larvae of DBM. These predators were also more susceptible to methomyl than the DBM larvae.

Resurgense of DBM is indeed induced by application of methomyl in the cabbage fields. This is due in part to stimulation of reproductive potential of DBM and also to differential mortality between predators and DBM larvae. The involvement of additional factors contributing to resurgence and the relative importance of these factors in the induction of resurgence of DBM needs to be investigated.

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