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Mechanism of Resurgence of the Diamondback Moth, Plutella xylostella (L.) (Lepidoptera: Yponomeutidae)

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Abstract
The role of predators and parasites was evaluated by artificially excluding them for the estimation of the DBM mortality. The results showed the importance of ground-dwelling predators such as the lycosid spider which was a major biotic mortality agent of DBM at immature stages based on an immunological test; the incidence of this spider decreased by the application of methomyl. The LC_{50} of the lycosid *Pardosa astrigera* was around 10 ppm against about 7,500 ppm for the fourth instar DBM larvae using the dipping method and about 20,000 ppm for third instar larvae by feeding methomylcontaminated cabbage leaves. Applications of sublethal concentrations of methomyl to fourth instar larvae and pupae of DBM resulted in the increase of the fecundity of the adults which emerged. The adult females derived from the treated pupae laid a larger number of eggs with a higher rate of fertilization than the untreated check. The application of methomyl thus may actually cause a resurgence of the insect population through the following mechanisms: (1) insecticide resistance, (2) differential mortality levels between DBM and its predator which is a major factor in the control , and (3) stimulation of the reproductive potential.

Discipline: Insect pest
Additional key words: Brassica, lycosid spiders, natural enemy, predator, resistance

Introduction

The main drawbacks in the insecticidal control of the diamondback moth (DBM) on *Brassica* spp. are as follows : (1) development of insecticide resistance ; (2) resurgence of the insect after applications of insecticide ; and (3) killing of natural enemies.

In 1981, the incidence of DBM increased after applications of methomyl against the common cabbageworm in a cauliflower field compared with the untreated control at Saitama Horticultural Experiment Station (SHES), Saitama Prefecture, Japan. Muckenfuss et al.[1] have also reported that pyrethroid treatment resulted in the resurgence of the diamondback moth due to the reduction in the natural enemy densities. Ripper[7] suggested that the insect pest resurgence could be attributed to the following factors : (a) reduction of the populations of natural enemies along with the pest due to pesticide application, (b) favorable influence of pesticides on phytophagous arthropods directly or via the plant, and (c) removal of competitive species.

This paper attempts to review the results of studies on the resurgence of the DBM and to discuss the mechanism(s) involved.

Evaluation of role of natural enemies

The role of predators and parasites was evaluated by artificially excluding them for the estimation of the DBM mortality. *Brassica* greens on which DBM eggs were laid in the laboratory in a 24 hr period were planted in the cabbage field at SHES during 1989-1990. Cages (90×90×90 cm) were covered with a mesh netting (0.2, 1.0, 1.4, 6.0 and 13.0 mm). Another cage (90×90×30 cm) was covered with a vinyl film except for the top and treated with a sticky substance on the upper edges of the vinyl film to exclude ground-dwelling predators but to allow flying predators to invade the cage. The 0.2-mm-mesh cage excluded all the predators and parasites. The 1.0- and 1.4-mm-mesh cages excluded the pred-ators but not the parasites. The 6- and 13-mm-mesh cages excluded birds and/or predator wasps but not ground-dwelling predators. The number of larvae within the cages covered with 6 and 13 mm mesh and in the control plots decreased more rapidly than in the other cages (Fig. 1), indicating the importance of natural enemies in the reduction of the DBM population[4]. Parasitoids and path-ogens, however, did not always appear to be a key factor.

Identification of DBM predators

Many species of predatory arthropods were collected by pitfall traps in the cabbage field at SHES (Table 1)[2]. To identify the predators of DBM, we used an immunological test. This method was sensitive enough to detect the whole-body extracts of third to fourth instar larvae, pupae, and adults of DBM[5]. Field-collected lycosid spiders exhibited a positive reaction in the test, while few *Labidura riparia japonica* (de Hann) (Dermaptera: Labiduridae) and other suspected predators reacted positively. Approximately 10% of the lycosids collected in July showed a positive reaction; no individuals showed a positive reaction in August when the density of the DBM larvae was low (Table 2)[2].

Effect of methomyl on predator populations

The effect of methomyl on the predator populations was studied in the cabbage field. The numbers

Table 1. Predatory arthropods captured from the cabbage fields at SHES[2]

Family	Species
Aranea	
Atypidae	*Atypus Karschi* Dönitz
Micryphantidae	*Gnathonarium dentatum* (Wider)
Tetragnathidae	*Dyschiriognatha quadrimaculata* Bös. et Str.
Hahniidae	*Hahnia corticicola* Bös. et Str.
Lycosidae	*Arctosa subamylacea* (Bös. et Str.)
	Lycosa pseudoannulata (Bös. et Str.)
	Pardosa laura Karsch
	Pardosa astrigera L. Koch
Thomisidae	*Misumenops tricuspidatus* (Fabricius)
Salticidae	Gen et sp
Gnaphosidae	*Gnaphosa kompirensis* Bös. et Str.
Ctenidae	*Anahita fauna* Karsch
Dermaptera	
Labiduridae	*Labidura riparia japonica* (de Hann)
Coleoptera	
Harpalidae	*Epomis nigricans* Wiedemann
	Chlaenins sp
Cicindelidae	*Cicindela japana* Thunberg

Table 2. Record of lycosid spiders captured in pitfall traps in the cabbage field at SHES[2] 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): Trapped spiders were collected every day.

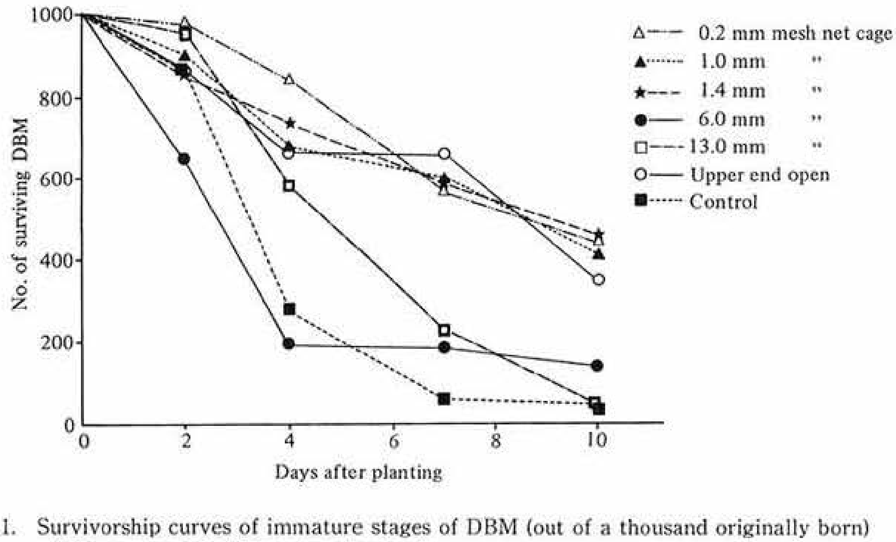

Fig. 1. Survivorship curves of immature stages of DBM (out of a thousand originally born) within cages with different mesh sizes[4]

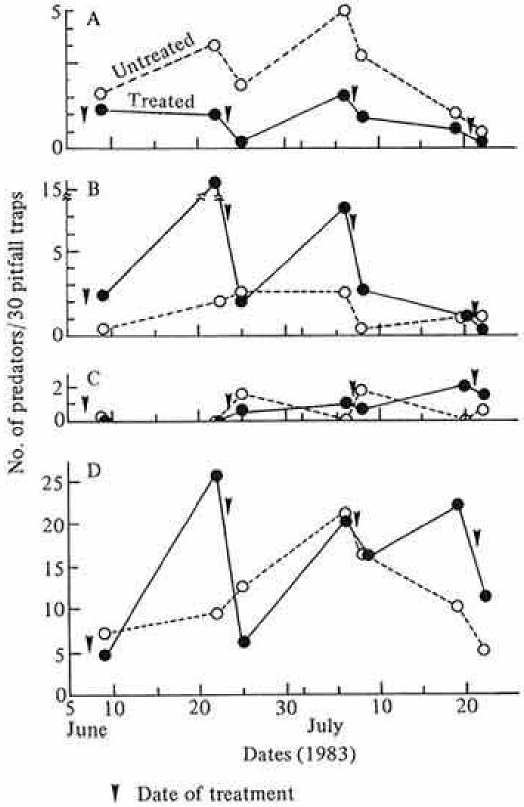

Fig. 2. Effect of methomyl treatments on predatory arthropod populations captured in pitfall traps from cabbage field at SHES
A: Lycosid spiders, B: *Cicindela japana*,
C: Harpalidae, D: *Labidura riparia japonica*[2].

of lycosid spiders, particularly *Pardosa astrigera* L. Koch and *Lycosa pseudoannulata* (Bös. et Str.), were reduced by the application of methomyl while other predatory insects were not affected (Fig. 2)[2].

Susceptibility of DBM and *Pardosa astrigera* to methomyl

P. astrigera was the most common lycosid in the cabbage field. The LC_{50} value to lycosid was around 10 ppm against about 7,500 ppm for the fourth instar DBM larvae using the dipping method and about 20,000 ppm for third instar larvae by feeding methomyl-contaminated cabbage leaves (Fig. 3)[2]. Methomyl is generally sprayed at 450 ppm to control pests on *Brassica*.

Stimulation of reproductive potential

1) Larval treatment with methomyl

Effects of sublethal concentrations of methomyl applied to fourth instar larvae on the fecundity of DBM are shown in Table 3. The adult females derived from the treated larvae deposited a larger number of eggs than the control irrespective of the methomyl concentration. At concentrations of 10 and 100 ppm, in particular, methomyl significantly promoted 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 the pupal weight, the differences were highly significant[3].

Table 3. Effect of treatment of the fourth instar larvae with sublethal concentrations of methomyl on the fecundity of DBM[3]

Methomyl concentrations (ppm)	No. of eggs laid[a,b]		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 the control at 5% level (*) and 1% level (**) by t-test.
c): No. of eggs deposited per mg of fresh body weight of pupa.
d): Mean ± standard deviation.

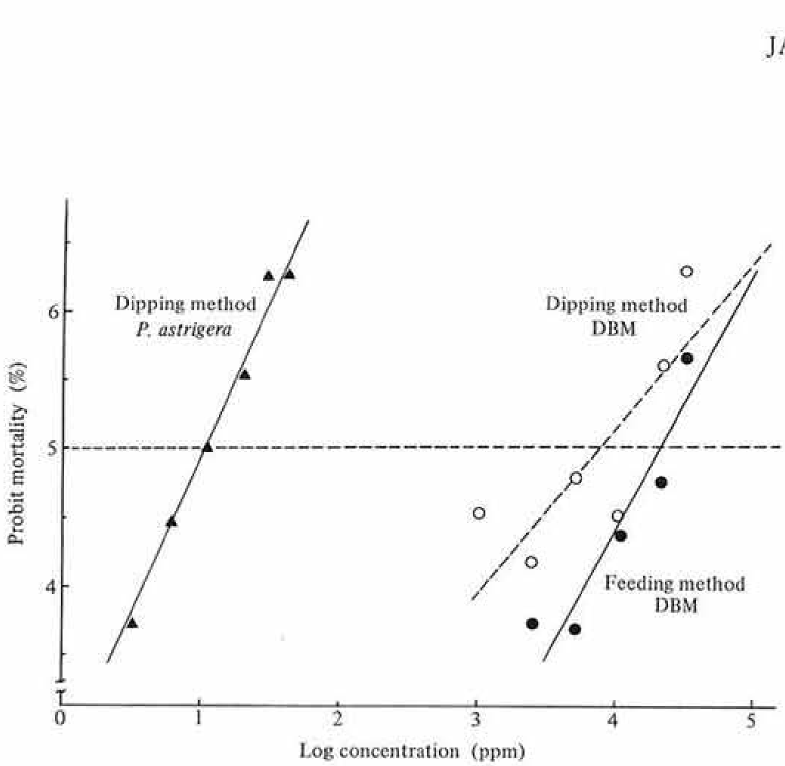

Fig. 3. Concentration-mortality curve of methomyl for the spider, *Pardosa astrigera* and DBM[2)]

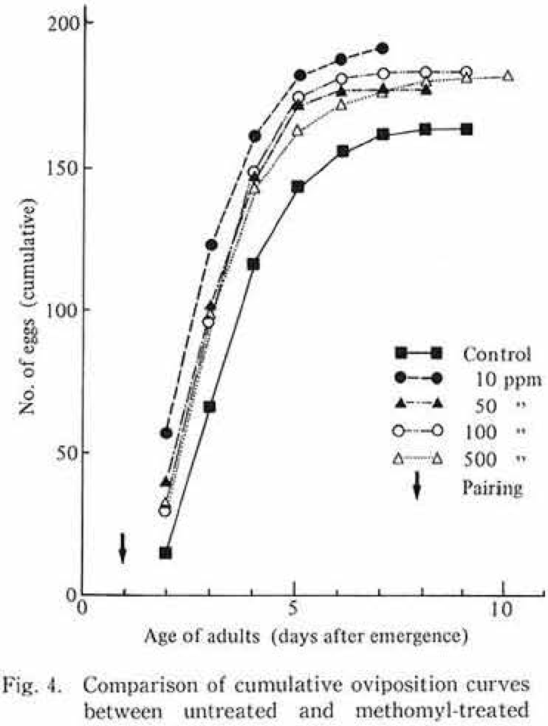

Fig. 4. Comparison of cumulative oviposition curves between untreated and methomyl-treated individuals

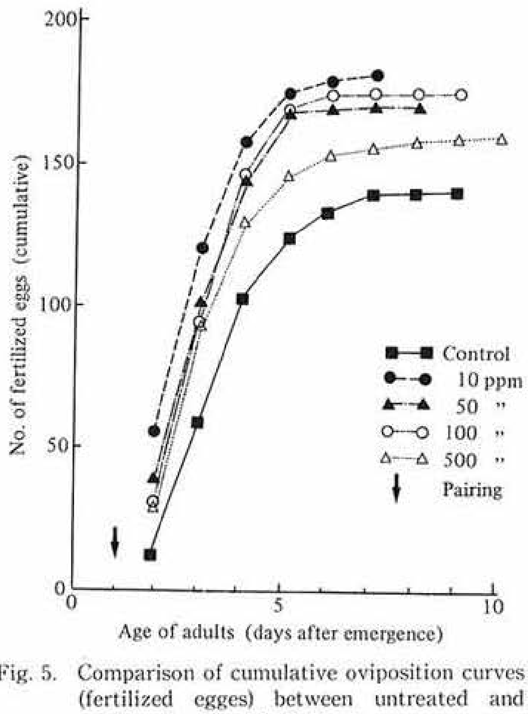

Fig. 5. Comparison of cumulative oviposition curves (fertilized egges) between untreated and methomyl-treated individuals

2) Pupal treatment with methomyl

Dipping of pupae (5.5 to 6.5 mg/each) in sublethal concentrations of methomyl also resulted in the increase of the fecundity of the adults[3]. The adult females derived from these treated pupae laid a larger number of eggs with higher rates of fertilization, than the untreated ones, irrespective of the concentrations of methomyl. Fig. 4 shows a comparison of cumulative oviposition curves between control and methomyl-treated individuals at the pupal stage. At 10 ppm, there was a 17% increase in the 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 adults derived from the treated pupae deposited a larger number of eggs for the first two days than the untreated ones. The number of fertilized eggs per female also increased 1.3 times at 10 ppm and 1.15 times at 500 ppm as compared with the untreated ones (Fig. 5).

Conclusion

Using cages covered with a mesh netting to artificially exclude predators, the importance of the role of indigenous predators in the reduction of the DBM population was clearly demonstrated. The number of lycosid spiders was reduced by the application of methomyl, and an immunological test revealed that they were the major biotic mortality agents of DBM. Ground-dwelling predators like these spiders thus appear to be effective in reducing the DBM population. Ooi listed *Apanteles plutellae* Kurdj. (Hymenoptera: Braconidae) and *Entomophthora sphaerosperma* as the main natural mortality factors affecting the population of DBM in Cameron Highlands[6]. Muckenfuss et al.[1] reported that the parasitoid *Diadegma insulare* (Cress.) and indigenous communities of arthropod predators were the major mortality factors of the DBM larvae in South Carolina, U.S.A. In Saitama Pref. Japan, the effect of the parasitoids and pathogens was not always conspicuous.

Pardosa astrigera is the most common lycosid species in the field. Methomyl was substantially less deadly to DBM than to the lycosid. Waage[8] stated that "Killing natural enemies is not a bad thing if, at the same time, the pesticide used makes up, in direct kill of pests, the natural enemy distribution which it eliminates". Resistance to an insecticide is an essential factor which induces a resurgence of the target insect pest.

Applications of sublethal concentrations of methomyl to the larvae and pupae of DBM resulted in the increase of the fecundity of the adults which emerged.

It is suggested that the application of methomyl may cause a resurgence of the insect population through the following mechanisms: (1) resistance to the insecticide, (2) differential mortality levels between DBM and its predator which is responsible for most of the pest mortality, and (3) stimulation of the reproductive potential. The first two are the main factors inducing the resurgence of DBM in Saitama Pref.

On the basis of these results, I consider that the pest management of *Brassica* spp. requires a non-chemical control approach and information to identify an insecticide which is selective in its target. The pesticide impact on indigenous communities of natural enemies needs to be investigated.

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