

## Use of Benfuracarb in the Integrated Management of Diamondback Moth

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### Abstract

Integrated pest management (IPM) is important in the control of diamondback moth, *Plutella xylostella* (L.), on brassicas in Japan. Recent investigations showed that benfuracarb 5% granules (5G) (trade name: Oncol 5G), a new carbamate insecticide, possesses useful properties in the IPM of diamondback moth. In order to obtain the best effect from benfuracarb 5G, application timing is very important. Pot tests and field trials indicated that application of 1-2 g of the granules in the hole or on the soil around the cabbage plants was effective up to 28 days after application. Effectiveness of benfuracarb 5G against susceptible and resistant strains of diamondback moth was determined using newly hatched larvae. Benfuracarb 5G applied to soil at a rate of 2 g per plant was highly effective against all strains on potted cabbage. Over 90% control was observed up to 28 days after application. Effect of benfuracarb 5G on the beneficial arthropods was also investigated. When 2 g of the granules were applied to the soil around cabbage and broccoli in the field, no adverse effect was observed on the population of spiders, important predators of diamondback moth.

### Introduction

Diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae), is a serious and widespread pest of many brassica crops, especially cabbage, and the development of resistance in this pest to a number of organophosphorus and carbamate insecticides has become a serious problem worldwide. Many researchers point out that integrated pest management (IPM) is an important way to control DBM. Recent investigations indicated that benfuracarb [ethyl *N*-[2,3-dihydro-2,2-dimethylbenzofuran-7-yloxy-carbonyl (methyl) aminothio]-*N*-isopropyl- $\theta$ -alaninate], a new carbamate insecticide from Otsuka Chemical Co., Ltd. (Goto et al. 1983; Takagi 1989) possesses useful properties for the IPM of DBM. Benfuracarb 5% granular formulation (5G) is now widely used in Japan for the control of DBM.

This report describes our recent studies indicating the useful properties of benfuracarb 5G in the IPM of DBM.

### Materials and Methods

#### Insecticides

The following insecticides were used throughout the study: benfuracarb (98.5% pure) and benfuracarb 20EC; acephate (>98%, Wako Pure Chemical Industries Ltd.); acephate 50WP (Takeda Chemical Industries Ltd.); permethrin (92.8%) and permethrin 20EC (Sankei Chemical Co., Ltd.); fenvalerate; malathion 40WP (Nihon Nohyaku Co., Ltd.); methomyl 45WP (Shell Chemical Co., Ltd.); chlorfluazuron 5EC (Sankyo Co., Ltd.).

## **Insects**

Susceptible strains (S), resistant strains (R) and highly resistant strains (HR) of DBM were used. The S strain was provided in 1988 by Dr. H. Hama, Chugoku National Agricultural Experiment Station. The R strain was collected in 1989 and 1990 from a cabbage field of Otsuka Chemical Co. Ltd. in Tokushima Prefecture. The HR strain was collected in 1990 from the cabbage field of Mizobe-cho, Kagoshima Prefecture, Japan, where DBM populations have developed resistance to pyrethroid insecticides. The S strain was reared for several successive generations. The R and HR strains were reared for three to four generations in the laboratory at  $25 \pm 1^\circ\text{C}$ , photoperiod 16L:8D, by the method by Kaoshihara and Yamada (1976) with slight modification.

## **Susceptibility of DBM to benfuracarb and other insecticides**

Susceptibility to benfuracarb and other insecticides was determined by the leaf-dipping method. Excised cabbage leaves, about  $4 \times 4$  cm, were dipped for 1 min in aqueous solution containing a spreader (64 ppm) and each chemical. The treated and untreated leaves were put in a plastic cup (diam 8 cm, depth 4 cm) where 10 3rd instar larvae of DBM were released. The insects were maintained at  $25 \pm 1^\circ\text{C}$ , photoperiod 16L:8D for 48 hours. There were six replications per concentration of each insecticide.

## **Relation between leaf position and efficacy against DBM**

Benfuracarb was applied onto the soil around the cabbage plant at four true leaf stage in Wagner pots at a rate of 1 or 2 g/plant. Each cabbage leaf was excised and put in plastic cups (diam 12 cm, depth 6 cm), where 10 first instar larvae of R strain DBM were released. The cups were maintained at  $25 \pm 1^\circ\text{C}$ , photoperiod 16L:8D, for 48 hours. Mortality of larvae was recorded 2 days after the release. Cabbage leaves were separated into three positions, i.e. upper, middle and lower positions. The test had six replicates.

## **Application timing of benfuracarb**

Benfuracarb 5G (1 or 2 g/plant) was applied when cabbage plants had 3-4 leaves (in nursery bed) at 7 days before transplanting, at transplanting (4 leaf stage) and 7 days (5-6 leaf stage) or 14 days (8-9 leaf stage) after transplanting in 16 cm diameter Wagner pots. As a control, acephate 5G was applied at a rate of 2 g/plant. Cabbage leaves were excised at predetermined intervals (3, 7, 14, 21 or 28 days after transplanting) and placed in plastic cups where 10 hatched larvae of DBM (R strain) were released. The cups were maintained at  $25 \pm 1^\circ\text{C}$ , photoperiod 16L:8D, for 48 hours. Testing was conducted at six replications for each rate. In the case of application at transplanting, third instar larvae of R strain DBM were used for the evaluation of insecticidal activity of benfuracarb.

## **Efficacy of benfuracarb against three different strains of DBM**

Benfuracarb 5G (2g/plant) was applied on the soil around cabbage plants at transplanting from the vinyl pots to 16 cm Wagner pots. Cabbage leaves were excised 3, 7, 14, 21 and 28 days after the transplanting and placed in the plastic cups where 10 hatched larvae of DBM were released. The cups were maintained in the laboratory at  $25 \pm 1^\circ\text{C}$ , photoperiod 16L:8D, for 48 hours. There were six replications for each rate. Acephate 5G was used as a control at a rate of 2 g/plant.

## Field trial of benfuracarb in cabbage

The field trial for the efficacy of benfuracarb 5G against DBM, green peach aphid and common cabbage worm was conducted at our experimental farm in Tokushima Prefecture. Benfuracarb 5G (1 or 2 g/plant) was applied to the soil around the cabbage plants (Shikidori) at 5-6 leaf stage on 5 June 1990 on three 20-m rows (spacing 0.5 m). Acephate 5G was used as a control at a rate of 2 g/plant. The number of pest insects on 20 cabbage plants in each row was counted.

## Efficacy of benfuracarb on spiders

To study the effect of benfuracarb 5G on the population of spiders one experiment each was conducted in a cabbage field (30 m × 2 rows) in Hiketa-cho, Kagawa Prefecture, Japan, and in a broccoli field (25 m × 2 rows) in Ichiba-cho, Tokushima Prefecture, Japan. Benfuracarb 5G (2 g/plant) was applied to the soil around cabbage plants (Kogetsu) of 6-7 leaf stage on 8 September 1990 and broccoli plant (Haitsu) of 5-6 leaf stage on 7 September 1990. The number of spiders on 50 plants in each row was counted 5, 12, 19 and 27 days after the application to cabbage, and 7, 15, 22 and 32 days after the application to broccoli. In the conventional application plots methomyl 45 WP was applied to cabbage on 23 September 1990 and fenvalerate: malathion 40WP, chlorfluazuron 5EC and permethrin 20EC were applied to broccoli on 15 and 24 September and 1 October, respectively.

## Results

### Comparison of susceptibility of DBM larvae to benfuracarb and other insecticides

The LC<sub>50</sub> values of benfuracarb and other insecticides for three different strains of DBM larvae are shown in Table 1. The LC<sub>50</sub> of benfuracarb in the 1990 testing was 14, 48 and 573 ppm for S, R and HR strains, respectively. The resistance ratio was 3.4 in the R strain and 40.9 in the HR strain. The data indicated similar susceptibility of both S and R strains in 1989 and 1990, while HR strain showed high levels of resistance.

In contrast to this, both R and HR strains showed quite high levels of resistance to other insecticides. The level of resistance to insecticides was extremely high in the HR strain.

Table 1. Susceptibility of 3rd instar DBM larvae to benfuracarb (leaf dipping method).

Insecticides		LC <sub>50</sub> (ppm)		
		S strain <sup>c</sup>	R strain <sup>d</sup>	HR strain <sup>e</sup>
Benfuracarb	Technical <sup>a</sup>	9	24	—
	Formulation <sup>b</sup> (20 EC)	14	48	573
Methomyl	Formulation (45 WP)	145	613	1579
Acephate	Technical	8	173	—
	Formulation (50 WP)	5	97	3984
Permethrin	Technical	9	73	—
	Formulation (20 EC)	5	44	364
Fenvalerate (10%)	Formulation (40 WP)	26	359	3943
Malathion (30%)				

<sup>a</sup>Trial in 1989; <sup>b</sup>Trial in 1990; <sup>c</sup>Susceptible strain; <sup>d</sup>Resistant strain; <sup>e</sup>Highly resistant strain.

### Relation between leaf position and efficacy against DBM

Benfuracarb 5G at a rate of 2 g/plant showed 100% mortality in all leaf positions 10 days after treatment (Table 2). After 20 days 100% mortality was observed in middle and lower leaf position, while the mortality was lower (about 80%) in upper leaf position. The same tendency was observed at 1 g/plant.

Table 2. Efficacy of benfuracarb 5G against 1st instar DBM larvae (R strain) fed on cabbage leaf of different positions.

Leaf position	Mortality (%) at indicated days after treatment			
	10 days		20 days	
	1 g/plant	2 g/plant	1 g/plant	2 g/plant
Upper	91	100	54	81
Middle	100	100	100	100
Lower	100	100	100	100

### Application timing of benfuracarb

Application timing is very important to obtain the highest level of effectiveness of benfuracarb 5G against DBM (Fig. 1-3).

The best effect was obtained by application of granules at transplanting. Complete mortality was obtained up to 28 days after the application even at a rate of 1 g/plant. Slightly lower efficacy was observed with other application timings. Benfuracarb 5G was also effective against 3rd instar larvae when applied at transplanting (Fig. 3).

### Efficacy of benfuracarb against three strains of DBM

Insecticidal activity of benfuracarb against S, R and HR strains was determined using hatched larvae and excised cabbage leaves of middle leaf position from the potted cabbage plants which were treated with benfuracarb 5G. As shown in Fig. 4, benfuracarb 5G was highly effective against all three strains of larvae by plant foot application at a rate of 2 g/plant. Over 90% control was observed from 7 to 28 days after the application. Acephate 5G used as a control was less effective and lacks residual activity especially against the HR strain.

### Field trial for benfuracarb in cabbage

A field trial was conducted in 1990 in order to confirm the effectiveness and residual activity of benfuracarb 5G which was observed in the potted plant test. In the field trial efficacy of benfuracarb 5G was determined not only for DBM, but also for green peach aphid and common cabbage worm because of the occurrence of the three pests in the field trial. As shown in Fig. 5, effectiveness of benfuracarb 5G against all three pests was observed 28 days after the treatment at a rate of 1 or 2 g/plant.

### Effect of benfuracarb on spiders

In order to see the effect of benfuracarb 5G on the beneficial arthropods, field trials were conducted in 1990 on cabbage and broccoli. The effect of benfuracarb 5G on the population of spiders in each field was determined following plant foot application of the granules (2 g/plant). Benfuracarb 5G did not have any effect on the population of spiders, important predators of DBM, in cabbage and broccoli fields. Mean number of spiders per plant in both

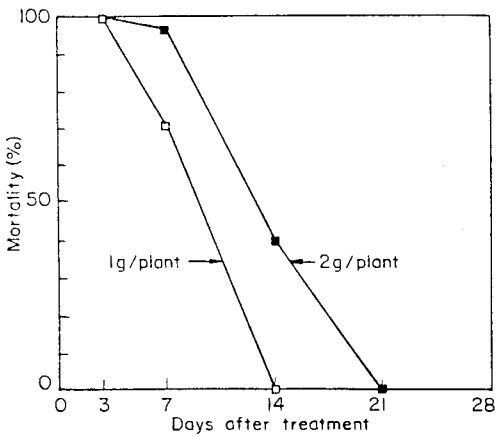


Fig. 1. Efficacy of benfuracarb 5G against 1st instar larvae (R strain) of DBM on potted cabbage treated 7 days before transplanting in nursery bed.

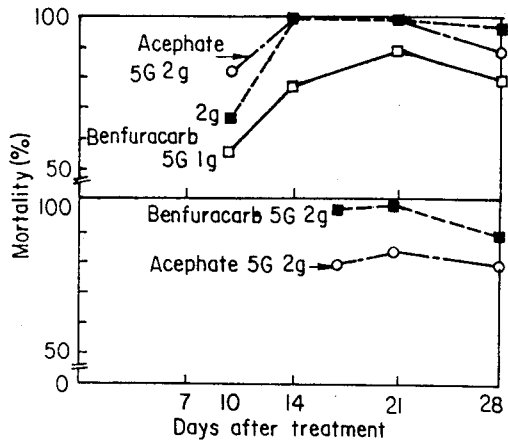


Fig. 2. Efficacy of benfuracarb 5G against 1st instar larvae (R strain) of DBM on potted cabbage treated 7 days after transplanting (above) and 14 days after transplanting (below).

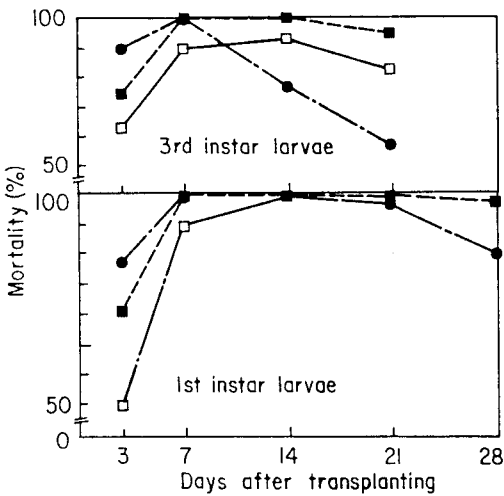


Fig. 3. Efficacy of benfuracarb 5G treated at transplanting against DBM larvae (R strain) on potted cabbage. (■) benfuracarb 5G 2g, (□) benfuracarb 5G 1g, (●) acephate 5G 2g a) Days after transplanting.

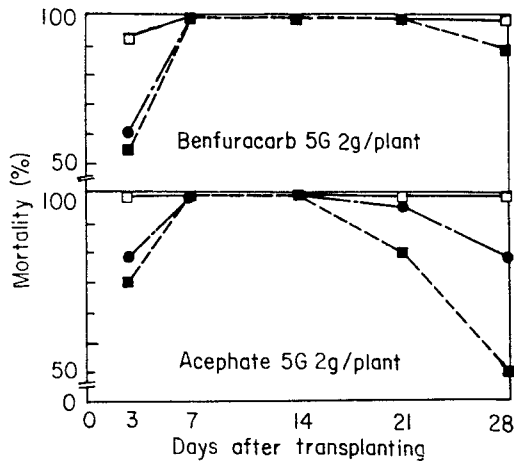


Fig. 4. Efficacy of benfuracarb 5G and acephate 5G treated at transplanting against 1st instar larvae of DBM strains on potted cabbage. (□) S strain; (●) R strain; (■) HR strain.

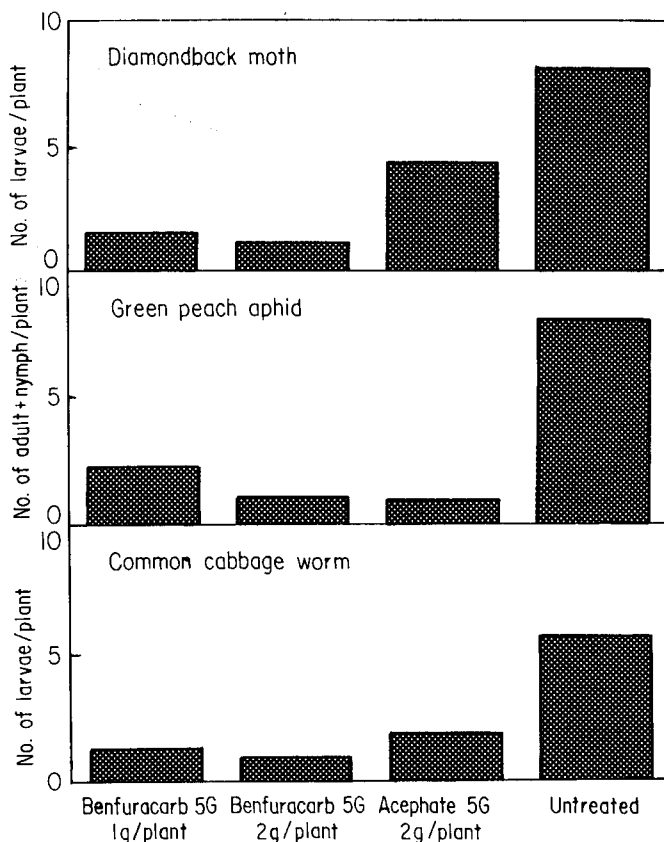


Fig. 5. Efficacy of benfuracarb 5G against cabbage pests in the field trial. Observations were made 28 days after transplanting.

benfuracarb 5G-treated and untreated plots increased from 1 to 2 during the 1-month test period. On the other hand, populations of spiders decreased significantly in the plots where methomyl or synthetic pyrethroids were sprayed.

## Discussion

Development of pyrethroid resistance in DBM in Japan was first confirmed in Kagoshima, Miyazaki and Okinawa prefectures in 1984 (Koshihara 1988), and existence of resistance was reported all over Japan including Hokkaido by the summer of 1990. Development of cross-resistance among pyrethroid insecticides (Hama 1987) in addition to cross-resistance among organophosphorus insecticides (Hama 1986) has become a serious problem for growers in controlling DBM by insecticides.

Current studies indicated that benfuracarb, a new carbamate insecticide, is effective in controlling DBM, even R and HR strains when granular formulation (5G) is applied to the soil. The systemic activity of benfuracarb 5G is probably responsible for insecticidal activity and residual effectiveness. The effectiveness of benfuracarb 5G against the HR strain, one of the most resistant strains in Japan (Horikiri and Makino 1987), was also confirmed in the field trial by Tanaka et al. (1990).

It is very important that an insecticide used in IPM is not toxic to predators. The results indicated that benfuracarb 5G does not affect the population of spiders — in cabbage and broccoli

fields following soil treatment. In the same field trial, the population of spiders was significantly reduced by conventional use of methomyl or pyrethroid insecticides. Nemoto (1986) reported that application of methomyl 45WP caused reduction in the population of the spider *Pardosa astrigera*.

Benfuracarb 5G thus possesses useful properties for the IPM of DBM. A number of trials have been conducted by researchers in Japan using benfuracarb 5G in an IPM program, i.e. a combination with foliar insecticides, protective net or DBM sex pheromone. Horikiri (1989) proposed a reduction in the number of applications of conventional insecticides by combined use of benfuracarb 5G and other insecticides.

Morishita and Azuma (1990) reported the usefulness of combined use of benfuracarb with nets in DBM control programs in cabbage fields. Iwata (1989) also studied the use of DBM sex pheromone with two applications of benfuracarb at transplanting and conventional insecticides (one time) 30-40 days after the transplanting, instead of five applications of conventional insecticides, which provided excellent control of DBM. It would be of interest to consider using benfuracarb 5G in combination with *Trichogramma chilonis*, an egg parasite of DBM (Iga 1985), in a DBM control program.

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