Chemical Control of Diamondback Moth in Japan with Special Reference to Cartap

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Abstract

Incidence of diamondback moth, *Plutella xylostella* L, in Japan is increasing as the area planted to crucifers increases. Insecticides are frequently used to control this pest. More than 50 formulated products, consisting of 29 active ingredients, have been registered for diamondback back moth control in Japan. Most of these insecticides are organophosphorus compounds, however, other compounds such as cartap methomyl, and combinations of fenvalerate and organophosphorus chemicals are frequently used. Since farmers tend to use exclusively the more potent chemicals, only a few of the registered insecticides are actually utilized. As a result of the application of only a limited number of chemicals this insect has developed resistance to some of the frequently used organophosphorus compounds. Cartap is one of the standard chemicals recommended in most prefectures of Japan. It is being used over 30% of the crucifer growing areas of Japan. As a result of cartap's characteristic mode of action, despite its widespread use over the past 15 years the incidence of diamondback moth becoming resistant to it is far lower than that recorded for most other chemicals. Because of this, cartap is adopted widely in insecticide spray rotation.

Introduction

Since the 1960s, diamondback moth (DBM), *Plutella xylostella* L (Lepidoptera: Yponomeutidae), has been an important pest of crucifers in Japan. Its abundance is associated with the increased area under crucifers, especially cabbage which is grown over 40,000 ha every year (Yamada 1977, Koshihara 1981). Cruciferous vegetables are grown all year-round which provides an easily accessible food source for DBM as well as for other pests, as a result of which these crops suffer DBM depredation throughout the year (Sakai 1981). Due to its rapid generation turnover and short lifespan DBM has become the chief insect pest of crucifers.

As the area under crucifers has increased and the infestation of DBM with it, so has the use of insecticides to combat this pest. Various chemicals are playing an important role in the production of quality vegetables with high yields. More than 50 insecticide products, most of them organophosphorus compounds, are registered for the control of DBM in Japan. Among non-organophosphorus, cartap, methomyl, and fenvalerate are important. Cartap has been widely used for DBM control for the past 15 years. Our survey indicates that this insecticide is used over 30% of the total crucifer area treated with insecticides in 1983.

This paper summarizes the present status of the DBM control by insecticides in Japan in general and discusses the role of cartap in combating this pest in the field.

Cropping Pattern and Insect Damage

Cropping pattern

Major cruciferous crops in Japan are cabbage (*Brassica oleracea*), Chinese cabbage (*B. campestris* ssp *pekinensis*), and radish (daikon) (*Raphanus sativus*). Their year-round cropping pattern varies from area to area. The cropping pattern is established by the latitude, altitude, and cultivars used (Matsumura 1981). The crucifer cropping pattern of Japan is briefly described in Table 1.

Table 1. Cropping systems for important crucifers in Japan

Crops	Cropping type	Transplanting[a] or sowing time[b]	Harvesting time
Cabbage	Spring harvested 1	e Oct - l Nov	m May - l May
	2	Mar - l Apr	e Jul - l Jul
	Summer-autumn harvested	e Apr - l Jul	m Jul - mOct
	Winter harvested	m Aug - e Oct	e Nov - e Mar
Chinese cabbage	Spring harvested	m Jan - l Feb	e Mar - l May
	Summer harvested	m Apr - l Jul	e Jul - l Sept
	Autumn-winter harvested	e Aug - e Sept	e Oct - e Mar
Radish	Spring harvested 1	e Feb - l Apr	e Apr - l Jun
	2	m Apr - e May	m Jun - l Jun
	Summer harvested	Jul - e Aug	e Aug - l Oct
	Autumn-winter harvested	e Aug - l Dec	e Mar - e Apr

[a] cabbage. [b] e, early; m, mid; l, late.

Yields of cabbage differ little from season to season but those of Chinese cabbage and radish are much greater in autumn and winter than in spring or summer (Table 2). Production of cabbage is concentrated only in a few prefectures. About 30% of each spring and winter harvested cabbage is produced in Chiba, Kanagawa, and Aichi Prefectures where winter climate is mild. Summer-autumn harvested cabbage is mostly supplied from the highlands or the cooler regions of Gunma and Nagano Prefectures where 50% of the country's total cabbage is produced. Nagano Prefecture supplies about 80% of the summer harvested and Kanto district about 40% of the autumn-winter harvested Chinese cabbage. Cultivation of radish is much more generalized than that of other crucifers.

Crop damage

Although the DBM is prevalent from early spring to late autumn, the insect is more abundant from June to August. All crucifers suffer depredation by this pest practically throughout the growing season. In major production centers, cabbage is grown on a large scale. DBM prefers cabbage over other crucifers, hence the monoculture of cabbage provides an ideal niche for the insect. Recent increases in area as well as year-round production of cabbage is providing perfect conditions for insect damage to occur.

Table 3 shows the rate of injury caused by major insects to crucifers in insecticide-treated areas. DBM is the most prevalent pest followed by aphids, common cabbage worm (*Pieres rapae crucivora* Boisduval), and the cabbage armyworm (*Mamestra brassicae*). It is observed that the area infested by DBM is always greater than that infested by any other insect. Also the DBM-infested areas receive greater quantities of insecticides than other insect-infested areas. The spraying frequency is greater for summer-autumn harvested cabbage than for crops grown at other times of the year.

Table 2. Area and yield of main crucifer crops in Japan (1982 - 1983).

Harvesting time	Area planted[a] (ha)	Yield[b] (1000 t)
Cabbage		
Spring	11880	443
Summer - autumn	13250	498
Winter	17056	684
Total	42186	1625
Chinese cabbage		
Spring	2037	98
Summer	4340	222
Autumn - winter	28848	1319
Total	35225	1629
Radish		
Spring	5827	225
Summer	10901	307
Autumn - winter	50176	2177
Total	66904	2709

Source: [a] MAFF 1984a. [b] MAFF 1984b.

Table 3. Infestation and measures for three important lepidopterous insect pests of cruciferous vegetable in Japan (1982-1983)[ab]

Crop	Diamondback moth			Cabbage armyworm			Common cabbage worm or aphids		
	Infest area (ha)	Spray area (ha)	No. of sprays	Infest area (ha)	Spray area (ha)	No. of sprays	Infest area (ha)	Spray area (ha)	No. of sprays
Cabbage							Common cabbage worm		
Spring	4,351 (36.6)	6,052 (50.9)	2.3	822 (6.9)	5,219 (43.9)	1.7	1,821 (15.3)	4,597 (38.7)	1.7
Summer-autumn	5,076 (38.3)	9,572 (64.7)	4.2	2,256 (17.0)	9,279 (70.0)	2.9	2,879 (21.7)	9,374 (70.7)	2.9
Winter	8,133 (47.7)	10,904 (63.9)	3.0	5,356 (28.4)	9,420 (46.2)	2.5	4,838 (31.4)	7,872 (55.2)	2.5
Chinese cabbage								Aphids	
Spring	1,158 (56.8)	63 (3.1)	2.7	152 (7.5)	618 (30.3)	1.2	147 (7.2)	121 (5.9)	2.3
Summer	1,168 (26.9)	2,129 (49.1)	3.5	309 (7.1)	2,129 (49.1)	3.4	706 (16.3)	2,014 (46.4)	3.9
Autumn-winter	5,596 (19.4)	9,608 (33.3)	2.3	5,881 (20.3)	16,670 (57.8)	1.9	7,078 (24.4)	10,823 (37.8)	2.2

[a] Source: MAFF 1984a. [b] Figures in parenthesis are percent of planted area.

Insecticides for DBM Control

Insecticides

Table 4 lists the major insecticides registered and recommended for the control of DBM and other crucifer insect pests by various prefectures. There were 39 single formulations and 19 mixtures recommended for DBM control in Japan in 1984. These preparations have 28 active ingredients, the majority of which are organophosphorus compounds. Cartap (tertiary amine), methomyl and carbaryl (carbamates), and fenvalerate (pyrethroid) are the only non-organophosphorus insecticides included in the recommendation. Fenvalerate is available only as mixtures with organophosphorus insecticides in Japan. One microbial insecticide, an endotoxin of *Bacillus thuringiensis* Berliner, is also recommended. Cartap, being a depressive postsynaptic blocker of the insect central nervous system (Sakai 1969), has a different mode of action from the other group of chemicals used in DBM control.

Besides DBM, these chemicals also give degrees of control over other cruciferous pests. All of the insecticides recommended for DBM control also give effective contol of common cabbage worm. Table 4 lists the other insect species that are also controlled by insecticides recommended for DBM control. The simultaneous control of a wide range of pests is useful as several injurious insects can coexist in one growing season.

Table 4. Main insecticides registered for DBM control[a]

Insecticide	Formulation[b]	Insects controlled[c]
TERTIARY AMINE		
Cartap	50SP, 2D	Pr, Mb, Ap, Hu
CARBAMATE		
Methomyl	45WP	Pr, Mb, S, Pn
ORAANOPHOSPHORUS		
Acephate	50WP, 5G	Pr, Mb, Sl, Pn
Chlorfenvinphos	5D	Pr, Ap
Chlorpyriphos-methyl	25EC	Pr, Mb, Sl, Ap
Cyanophos	50EC	Pr, Mb, Pn, Ap, Ps
Diazinon	40EC, 3D, 3G, 5G	Pr, Ap, Ps
Dichlorvos	50EC, 75EC	Pr, Mb, Sl, Pn, Ap, Ps, Hu
Dimethylvinphos	50WP	Pr, Mb
Isoxathion	50EC	Pr
Naled	46EC	Pr, Mb, Ap
Phenthoate	50EC, 2D	Pr, Mb, Sl, Ap, Ps
Piridafenthion	40EC	Pr
Pirimiphos-methyl	45EC	Pr, Mb, Ap
Prothiophos	45EC, D	Pr, Mb, Sl, Pn, Ap
Salithion	25EC	Pr, Mb, Sl, Ap
Tetrachlorvinphos	50WP	Pr, Sl
Trichlorfon	50EC	Pr, Mb, Ap, Ps, Hu
MIXTURES		
Cartap. methomyl	20.20WP	Pr, Mb, Sl, Ap
Chlorfenvinphos. dichlorvos	15.25EC	Pr, Mb, Ap
Diazinon. disulfoton	3.3G	Pr, Ap
Dichlorvos. isoxathion	30.30EC	Pr, Mb, Sl, Pn, Ap
Dichlorvos. phosalone	40.20EC	Pr, Mb, Sl, Ap
Dichlorvos. trichlorfon	20.30EC	Pr, Mb, Ap
Dimethoate. fenvalerate	15.4EC	Pr, Mb, Ap
Fenvalerate. malathion	4.30WP	Pr, Mb, Pn, Ap
Isoxathion. methomyl	30.15WP	Pr, Mb, Ap
MICROBIAL		
Bacillus thuringiensis endotoxin	7WP	Pr, Mb

[a] Only those insecticides that conform to 1984 prefectural standards are listed. [b] EC, emulsifiable concentrate; WP,wettable powder; SP, soluble powder; D, dust; G, granules; figures indicate percent active ingredient in formulations. [c] Pr, *Pieris rapae* spp *crucivora*; Mb, *Mamestra brassicae*; Sl *Spodoptera litura*; Pn, *Plusia nigrisigna*; Ap, Aphids; Ps, *Phyllotreta striolata*; Hu, *Hellula undalis*. (source JPPA 1984)

Most of the insecticides are applied as foliar sprays. Some dust and granule formulations are applied into the soil at sowing or transplanting time. With each insecticide recommendation the number of days that should elapse before harvest as well as the maximum number of applications of a particular insecticide during a cropping season, is also indicated (Table 5).

Every year each prefectural government in Japan also sets guidelines for the use of insecticides. A summary of their recommendations in 1984 indicated that 34 formulations including nine mixtures consisting of 23 active ingredients were recommended for DBM control (Table 6). Acephate, cartap, phenthoate, and mixtures of fenvalerate and organophosphorus chemicals are more common than the others. These insecticides have certain characteristics which results in their more frequent use. For example cartap,

Table 5. Directions for use of major insecticides in crucifer insect pest control in Japan

Insecticide	Formulation	Days between last spray and harvest/application frequency per season[a]		
		Cabbage	Chinese cabbage	Radish
Cartap	50SP	14/4	7/3	7/3
	2D	14/4	7/3	7/3
Methomyl	45WP	3/3	14/2	7/3
Acephate	50WP	7/3	14/3	14/3
	5G	21/3	a/3	b/1
Chlorfenvinphos	5D	14/4	—	30/3
Chlorpyriphos-methyl	25EC	7/6	30/2	30/2
Cyanophos	50EC	3/6	7/6	21/4
Diazinon	40EC	30/2	14/2	—
Diazinon	G	30/2	a/2	b/2
Diazinon	D	30/2	30/2	b/2
Dichlorvos	50.75EC	c/n.l.	7/5	14/n.l.
Dimethylvinphos	50EC	7-3	—	—
Isoxathion	50EC	21-2	—	—
Naled	46EC	3/n.l.	—	—
Phenthoate	50EC	7/4	14/4	14/4
	2D	7/4	14/4	14/4
Piridafenthion	40EC	7/3	—	—
Pirimiphos-methyl	45EC	14/4	—	—
Prothiophos	45EC	7/3	—	—
	D	21/3	—	—
Salithion	25EC	7/6	14/6	21/3
Tetrachlorvinphos	50WP	7/4	21/3	—
Acephate.carbaryl	30.20WP	7/3		
Chlorfenvinphos				
Dichlorvos	50EC	14/4	—	—
	75EC			
Dichlorvos. isoxation	30.30EC	21/2	30/2	30/2
Dichlorvos. phosalone		c/3	—	7/5
Dichlorvos. trichlorfon	20.30EC	7/6	7/6	14/6
Dimethoate. fenvalerate	15.4EC	7/3	14/3	35/3
Disulfoton. diazinon	3.3G	a/l	—	b/l
Fenvalerate. malathion	4.30WP	7/5	7/5	35/3
Isoxathion. methomyl	30.15WP	21/2	30/2	30/2
Bt[b] endotoxin	7WP	n.l.	n.l.	n.l.

[a] a: Sowing or transplanting time; b: sowing time; c: one day before harvest; n.l.: no limits. [b] *Bacillus thuringiensis*. For other abbreviations please see footnotes of Table 4.

Table 6. Status of major insecticide recommendations for DBM control (1984)

Insecticide	No.of prefectures recommending for:			
	Cabbage	Chinese cabbage	Radish	Total
Acephate WP	38	36	35	109
Cartap SP, D	38	35	31	104
Fenvalerate. malathion WP	36	33	24	95
Phenthoate EC, D	26	32	30	88
Fenvalerate. malathion WP	34	30	24	88
Chlorpyrifos-methyl EC	26	20	17	63
Methomyl WP	21	22	18	61
Salithion EC	25	13	22	60
Cyanophos EC	20	20	20	60
Dichlorvos. isoxathion EC	22	20	17	59
Acephate G	26	17	12	55
B. thuringiensis WP	20	18	12	50
Dichlorvos EC	12	15	18	45
Prothiophos EC	39	—	—	39
Pirimiphos-methyl EC	39	—	—	39

beause of it peculiar mode of action, is useful in controlling DBM strains which have developed resistance to conventional insecticides. Acephate is systemic and has a broad spectrum of activity which gives simultaneous control of several pests. The recent introduction of fenvalerate is expected to give better control of insecticide-resistant DBM strains. The addition of malathion or dimethoate would add aphicidal properties to fenvalerate mixtures.

Spray program

Some insecticides are specific to DBM while certain chemicals are more effective against other pests compared to DBM. At the same time the required interval between last spray and harvest, and the frequency of spray for each chemical, are regulated individually. Therefore, it is important to select insecticides according to insect pest complex and the mandatory spray-free time between last spray and harvest. In the early plant growth stage, when insect injury is minor, insecticides with quick action, such as phenthoate and methomyl help to suppress insect populations. In later growth stages, insecticides with longer residual action, like cartap, prothiophos, and fenvalerate mixtures, are suitable for controlling multivoltine species including DBM (Nakagome and Kato 1981).

Repeated insecticide applications are required to control DBM, especially during the peak population period. However, spraying a single insecticide or insecticides with similar modes of action increases the chances of the insect becoming resistant. Therefore, rotation application of insecticides of different chemical groups is always recommended by the prefectural authorities. Table 7 exemplifies a spray calendar provided by a local agricultural cooperative officer under the supervision of the prefectural government extension service. Atsumi is located in the warm lowlands of Aichi Prefecture. DBM infestation tends to peak in late spring and in autumn in this area (Yamada 1977, Nakagome and Kato 1981) but damage caused by DBM, noctuids, and aphids to cabbage takes place throughout the season and even into November and December. Tsumagoi on the other hand is located in the highlands of Gunma Prefecture where cabbage is extensively grown in summer. All crop growth stages are subjected to severe insect pest infestation which peaks in August to September (Gunma Prefectural Agricultural Experiment Station 1984). Therefore, the dates of insecticide applications are not included in the spray schedule. Instead farmers are advised to establish optimum time on their own or to consult the extension service. Seven to eight or even more sprays are required in one cropping season in this area. Our survey indicates that cartap is used three times per cropping season on average.

Table 7. Examples of spray calender for controlling DBM[a]

Example 1 Atsumi, Aichi Prefecture		Example. 2 Tsumagoi, Gunma Prefecture	
Date	Chemical spray	Date	Chemical spray
Aug 15-20	(Sowing)	late Feb -late Jun	(Sowing)
early Sep	Dichlorvos	late Apr -late Jul	(Transplanting)
mid Sep	Salithion		
Sep 20-25	Acephate G (soil appl)	late Jul -mid Nov	(Harvesting)
early Oct	Salithion	May-Nov	spray the following insecticides to control common cabbage worm, cabbage armyworm, diamondback moth and beet semi-looper: cartap, fenvalerate + malathion, fenvalerate + dimethoate, prothiophos, methomyl, acephate, salithion, pirimiphos-methyl, dichlorvos.
mid Oct	Prothiophos		
late Oct	Fenvalerate + malathion		
early Nov	Cartap		
mid Nov	Acephate		
late Nov	Pirimiphos-methyl		
early Dec	Methomyl		
mid Dec	Cartap		
Mar	(Harvesting)		

[a] Fungicides are omitted. Aphicides are omitted in Example 2.

Insecticide resistance

Dichlorvos was widely used in the early years when DBM infestation first started to become severe. However, in the mid-1970s its effectiveness started declining in many parts of Japan. This was followed by reports of the insect becoming resistant to several organophosphorus compounds and even to methomyl.

From 1980 to 1982, the Japan Plant Protection Association surveyed resistance levels of DBM to various chemicals (JPPA 1980, 1981, 1982). Laboratory assays were conducted with 3rd instar larvae collected from various locations. The insects were released onto cabbage leaves dipped in concentrations of various insecticides and LC_{50} values were compared (Table 8). Dichlorvos and acephate were found to be less effective. Prothiophos and cyanophos seemed effective but results for several locations indicated the development of resistance. In the case of cartap, the LC_{50} values were smaller than for most organophosphorus chemicals and differed little among locations. This implies that DBM has not developed resistance to cartap. If any, the level of resistance is very low even in organophosphorus insecticide-resistant populations. Other examples of susceptibility of DBM to cartap are shown in Table 9. Some of the insects strains which have developed resistance to organophosphorus insecticides were assayed simultaneously with susceptible strains maintained in our laboratory (Kyoto lab S strain). The resistance factor for cartap was less than 7.1. The data obtained from Nagoya University (Noppun et al 1983) also demonstrated very low levels of resistance in DBM to cartap.

Table 8. Susceptibility of 3rd instar DBM larvae from different locations to selected insecticides (leaf dip method)

Location		Year	cartap[a]	LC50 ppm, (48 h) dichlorvos	acephate	prothiophos	cyanophos	fenval + [b] mala.	*Bt* endotoxin
Miyagi	Natori	'80	22	446	199	46	14	19	
		'81	38	700	160	19	4		
		'82	86	1928	360	53			21
	Miyagi	'81	46	995	346	33	7	8	
		'82		772	512	48	110		
Gunma	Kitayama	'80	86	634					
		'81	48	994	614	842	306		
	Showa	'80	66	612	220	157	26		
		'81	104(40)	1146	507	437	269		
	Higashi	'82	146(72)	822	364	448	30		
Aichi	Nagakute	'81	49	630	306	128	78		
Nara	Kashihara	'80	63	940	580		70		
	Uda	'81	313(91)	1462	658	58	47		
Kagawa	Hase	'80	133	694	241	104	5.2		
	Kawaoku	'80	158	229	48	16	6.7		
	Gogo	'80	208	421	236	23	7.4		
		'81	133						
	Susceptible[c]	1	13	229	48	16	3.7		
		2	41						
		3	(19)						
		4	49						
		5	38						

[a] Figures in parenthesis are LC50 after 72 h. [b] Fenvalerate + malathion. [c] 1; Sumitomo Laboratory strain, 2; Takeda Laboratory strain (tested in 1971). 3; Takeda Laboratory strain (tested in 1974), 4,5; Takeda Laboratory strain (1984). Source: JPPA 1980, 1981, 1982. (except Takeda Laboratory strain).

Table 9. Resistance factors for cartap in some organophosphorus insecticide resistant DBM larvae

Test Method	DBM strain	Resistance factor cartap[a]	organophosphate
Leaf dip	Shiojiri	1.8	acephate 6.8
	Okinawa	7.1	dichlorvos 22.3
	Prothiophos-selected[b]	3.8	prothiophos >50
	Dichlorvos-selected	5.6	dichlorvos >50
	Cyanophos-selected	6.1	—
Topical[c] application	Okinawa	2.6	phenthoate 136
	Aichi	0.9	phenthoate 24.5

[a] Comparison with Kyoto laboratory susceptible strain. [b] Selected strains were obtained from Kagawa Agricultural Experiment Station. [c] Data from Noppun et al (1983)

Conclusion

Use of insecticides to control DBM and most other pests is unavoidable to ensure high yields of quality cruciferous vegetables. In many cases more frequent insecticide sprays are required to control this pest as opposed to other pests. Although a number of insecticides are registered, fewer than 10 of them are actually used; others are discarded due to their reduced effectiveness. Discarding of old chemicals will accelerate as newer more potent chemicals, such as pyrethroids, are introduced. However, since new groups of chemicals are frequently hard to come by, the chances of substitution of new chemicals for the presently used ones are diminishing. Therefore, careful timing of application and rotation of chemicals should be observed. Judicious rotation of chemicals with different modes of action will prolong the effectiveness of presently used insecticides substantially. Cartap has been used for DBM control for over 10 years, but there is little indication that DBM has developed resistance to it. This fact and its peculiar mode of action suggest that cartap should be an important chemical in any rotational spray application to control DBM or other pests.

Literature Cited

Gunma Prefectural Agricultural Experiment Station. 1984. Reports on highland vegetable experiments. (In Japanese). Highland Branch Station, Gunma Prefectural Agricultural Experiment Station, Gunma, Japan, 85 pp.

Hama, H. 1983. Insecticide resistance in diamondback moth. (In Japanese). Shokubutsu Boeki 37:471-476.

JPPA. 1980. Study report on control of insects difficult to be controlled. (In Japanese). Japan Plant Protection Association, Tokyo, 169 pp.

JPPA. 1981. Study report on control of insects difficult to be controlled. (In Japanese). Japan Plant Protection Association, Tokyo, 279 pp.

JPPA. 1982. Study report on control of insects difficult to be controlled. (In Japanese). Japan Plant Protection Association, Tokyo, 325 pp.

JPPA. 1983. Noyaku Yoran (Pesticide Yearbook). (In Japanese). Japan Plant Protection Association, Tokyo, 463 pp.

JPPA. 1984. 1984 list of registered pesticides. (In Japanese). Japan Plant Protection Association, Tokyo, 127 pp.

Koshihara, T. 1981. Occurence and control of diamondback moth in cruciferous vegetables. (In Japanese). pp 39-45. *In* Insects in Cruciferous Vegetables and their Control with Special Reference to Diamondback Moth. Takeda Chemical Industries Ltd., Tokyo.

MAFF. 1984a. Annual report of plant protection. (In Japanese). Plant Protection Division, Agricultural Production Bureau, Ministry of Agriculrture, Forestry, and Fisheries, Tokyo, 269 pp.

MAFF. 1984b. The 59th Statistical Yearbook of MAFF Japan 1982-83. Statistics and Information Department, Ministry of Agriculture, Forestry, and Fisheries, Tokyo. 625 pp.

Matsumura, T. 1981. The present status of Chinese cabbage growing in Japan. pp 29-40. *In* N. S. Talekar and T. D. Griggs (eds). Chinese Cabbage: Proceedings of the First International Symposium. Asian Vegetable Research and Development Center, Shanhau, Taiwan, ROC

Nakagome, T. and K. Kato. 1981. Control of insects in cruciferous vegetables in Aichi Prefecture with special reference to diamondback moth. (In Japanese). pp 79-92. *In* Insects in Cruciferous Vegetables and their Control with Special Reference to Diamondback Moth. Takeda Chemical Industries Ltd., Tokyo.

Noppun, V., T. Miyata, and T. Saito. 1983. Susceptibility of four strains of diamondback moth, *Plutella xylostella* L. against insecticides. J. Pestic. Sci. 8:595-599.

Sakai, M. 1969. Nereistoxin and cartap; their mode of action as insecticides. Rev. Plant Protec. Res. 2:17-29.

Sakai, M. 1981. Insecticides for pest control in cruciferous crops in Japan. pp 193-204. *In* N. S. Talekar and T. D. Griggs (eds). Chinese Cabbage: Proceedings of the First International Symposium. Asian Vegetable Research and Development Center, Shanhua, Taiwan, ROC.

Yamada, H. 1977. Infestation and ecology of diamondback moth. (In Japanese). Shokubutsu Boeki. 31:202-205.