Insect Pest Control of Summer Chinese Cabbage in Taiwan

N. S. TALEKAR, W. F. SHIAO and Y. H. LIN
Asian Vegetable Research and Development Center, Shanhua, Tainan 741, Taiwan, China

*As a result of the increase of lowland area cropped to Chinese cabbage cultivation during hot rainy summer months due to the introduction of heat tolerant cultivars, a previously less important pest, cabbage webworm (*Hellula undalis *F), has become a major pest of this crop. The insect lays eggs on the growing point or on older leaves and the larvae feed on the growing point, or burrow into the stem of older seedlings. As a result the infested plants are killed or give side shoots which do not form heads. The larva has five instars and there is overlapping of generations in the field during summer months. Pupation takes place in the soil or on plants and the entire life cycle takes 21-28 days. This pest has a wide host range among crucifers but prefers radish and Chinese cabbage. Infestation occurs almost exclusively during the hot and rainy June to August months. Out of 451 accessions of Chinese cabbage and related species that were screened for resistance to this pest, four accessions were the least infested in two tests. Intercropping with bittergourd, water melon, sweet potato and mungbean reduced cabbage webworm infestation of Chinese cabbage. Among insecticides screened, soil incorporation of mephosfolan, terbufos, fensulfothion, carbofuran weekly sprays of chlorpyrifos, EPN, triazophos, methidathion, methomyl, parathion, tempophos, evisect and thiometon gave satisfactory control. On an active ingredient basis parathion was the cheapest and the most effective insecticide.*

Until recently, production of Chinese cabbage (*Brassica campestris* ssp *pekinensis*) in lowland areas of Taiwan was predominantly confined to the cooler period of the year, November to April. A very small proportion of the total crop was harvested from mountain areas during the remainder of the year to supply urban markets. Chinese cabbage generally requires cooler temperatures. As a result, there is overproduction between November and March, and scarcity between June and September.

In recent years, however, this pattern of production is slowly changing and lowland production during the hot and rainy June to September period is increasing. This is mainly due to the introduction of heat tolerant Chinese cabbage cultivars by seed companies and by the Asian Vegetable Research and Development Center.

Insect pest infestation follows the production pattern. The classic cruciferous insect pests, aphids (*Myzus persicae* and *Lipaphis*

erisemi), striped flea beetle (*Phyllotreta striolata*), diamondback moth (*Plutella xylostella*), cabbage worm (*Pieris rapae*) and cabbage looper (*Trichoplusia ni*) are most abundant during the peak production period of December to March and almost nonexistent, at least in lowland areas, from June to September. However, with an increasing area under Chinese cabbage cultivation from June to September, a previously insignificant insect pest, cabbage webworm (*Hellula undalis*) has become a serious threat. The insect larva eats the growing point and burrows into the stem of young seedlings both in seedbeds and in freshly transplanted crops in the field. During later growth stages, if infestation occurs at all, the damage is confined to larger leaves, especially along the veins. Young infested seedlings either die or produce side tillers which do not form heads.

Infestation by this insect occurs in summertime in Taiwan (Tau 1965), India (Fletcher 1921, 1923), Malaya (Bunting and Milsum 1930; Gater 1924), Java (Leefmans and Awibowo 1933), Ceylon (White 1917), Burma (Ghosh 1923), Hawaii (Carpenter 1918), Guam (Hartenbower 1917), Japan (Watanabe 1927; Yanagihara 1923), Canada (Sheppards 1925), USA (Worshan 1917), New Zealand (Meyrick 1934), Australia (Tryon 1918), the Pacific Islands (Meyrick 1934), Zimbabwe (Bunting and Milsum 1930), Uganda (Hargreaves 1926), South Africa (Brain 1928), Egypt (Harakly 1969), and the Sudan (Johnston 1930).

At the Asian Vegetable Research and Development Center where work is conducted on development of heat tolerant Chinese cabbage, cabbage webworm is the major concern in entomological studies. This paper describes our work during the past two years on the biology and ecology of this pest and on various biological, cultural and chemical controls to combat it.

BIOLOGY OF CABBAGE WEBWORM

The biology of this pest was studied both in the field during summer and in the laboratory.

OVIPOSITION:

Females laid eggs usually on stems, sprouts and on upper or lower surfaces of leaves, singly or in small clusters of two or three. Out of 2200 eggs examined in the laboratory reared culture we found 48.7% on the lower and 47.2% on the upper surfaces with the remainder on the sprouts. In the field, out of 100 infested plants observed 42.3% of the eggs were on the lower surface, 25.4% on the upper surface and 32.3% on the sprouts. Oviposition began soon after pairing and continued into the life span of five to nine days, with peak oviposition occurring two to four days after emergence. In laboratory culture, a single female laid 63 to 305 eggs. The eggs were smooth, white to yellowish in color and of oval shape, measuring 0.46±0.04 mm long and 0.33±0.03 mm wide. The egg stage lasted two to four days.

LARVA:

There were five larval instars. The larva had a brownish to black head with yellow to brownish body. The body had dark brown longitudinal stripes on the back and sides. Observation of 50 larvae showed that body length of each instar was 1.01±0.06 mm, 4.48±0.15 mm, 6.60±0.61 mm, 7.66±0.85 mm and 13.86±0.70 mm, respectively. The width of the head capsule was 0.19±0.02 mm, 0.38±0.05 mm, 0.46±0.07 mm, 0.69±0.07 mm and 0.73±0.05 mm, respectively. The body length and head capsule width in different instars, follows Dyar's law (Dyar 1890). The larval period lasted nine to 20 days under laboratory conditions.

In July 1979 we surveyed 300 Chinese cabbage plants grown in an insecticide-free area to establish the percentage infestation and the location and instars of larvae feeding on various plant parts. The results are summarized in Table 1. We found up to 11 larvae feeding on a single plant. The higher the number of larvae feeding on one plant, the greater was the range of their ages. This implies that as larvae grow older, they either migrate from infested plants to fresh ones, or die. This may be the result of the limited carrying capacity of any one plant. We could observe larvae of each of the five instars during a single observation, indicating an overlapping of generations. Larvae fed both on sprouts and leaves, with younger individuals preferring to burrow into sprouts. When a larva prepares to enter the prepupal stage it shortens its body and spins a loose web. The prepupal stage varied from one to three days.

Table 1. Field observations of age distribution of *Hellula undalis* larvae on 300 plants[a]

Plant part	No. insects of various instars					
	I	II	III	IV	V	Total
Sprout	69	129	59	27	5	289
Leaf	48	45	18	3	3	127

[a]10 to 15 days (18 to 23 July 1979) after transplanting

PUPA:

In the field, pupation generally occurred on the plant or in the soil adjacent to the plant. In the laboratory, larvae pupated in the soil or on the sides of the containers in which they were reared or on the frames of the insect rearing cage. The newly formed pupa was light brown later becoming dark brown. The pupal length was 7.21±0.72 mm for females and 6.74±0.48 mm for males and pupal body weight 18.0±4.0 mg and 14.0±3.0 mg for female and male respectively. The pupal periods for female and male were three to seven days and two to six days respectively.

ADULT:

The adults were mottled, greyish moths with various black and silver striations. Sex ratio of the moths in the field survey was 1.28:1,

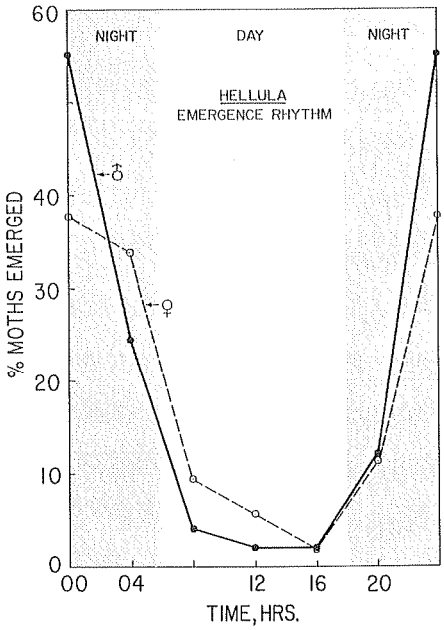

Figure 1. Diurnal rhythm of adult emergence in cabbage webworm

females to males. Longevity of adults ranged from one to seven days, with males lasting one to three days and females two to nine days. Adult emergence was predominantly at night (Figure 1). As with other pyralids, most flights and biological activities began at dusk and continued into the night. Mating usually occurred after dark and only occasionally in the morning. Pairing occurred soon after emergence. The preoviposition period varied from four hours to two days.

NATURE OF DAMAGE:

Newly emerged larvae fed on growing points and burrowed into stems (Figure 2) and veins of larger leaves. Early instar larvae preferred to mine sprouts or leaves and left feces outside the feeding area. The older larvae ate sprouts, and some fed on larger leaves beneath a protective silken web. Young infested seedlings either died or produced side tillers in later growth stages which did not form heads.

HOST RANGE:

A host range study was conducted in the field using nine cruciferous species or subspecies. The species chosen were: *Brassica campestris* ssp *pekinensis*, *B. campestris* ssp *chinensis*, *B. campestris* ssp *parachinensis*, *B. juncea*, *B. campestris* ssp *B. oleracea* var *botrytis*, *B. oleracea* var *capitata*, *B. oleracea* var *caulorapa*, and *Raphanus sativus*, as well as several Chinese cabbage cultivars of a distinct plant type or which displayed earliness in heading or heat tolerance. All were transplanted in two rows on a 4 m × 1.5 m bed in four replicated RCBD design experiments, once during the dry month of April and again during the rainy month of July 1979. Plants were allowed to be infested by natural populations of cabbage webworm. Three weeks after trans-

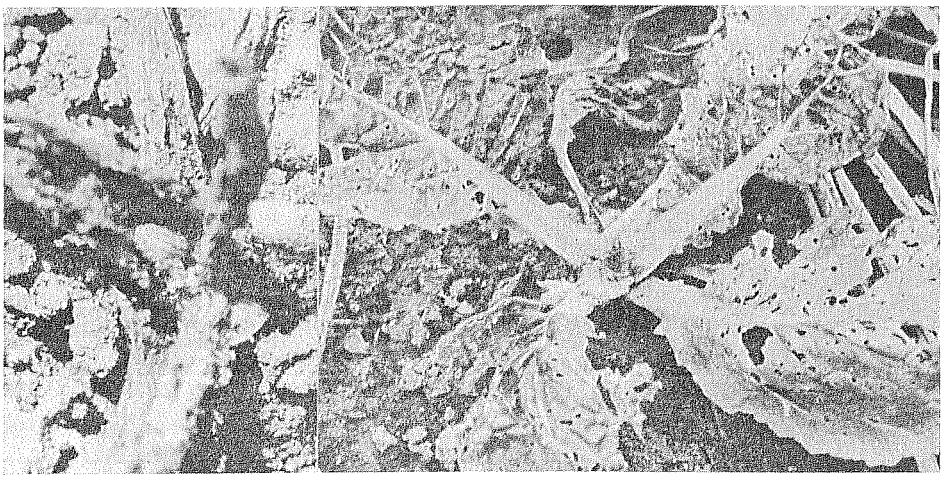

Figure 2. Cabbage webworm larva feeding on growing point (left) and the damage caused by such feeding in Chinese cabbage seedling (right)

planting we recorded the number of larvae and pupae per plant as well as the number of damaged plants. The results for the wet season indicated that Chinese cabbage and radish were the most favoured hosts for this pest. All cultivars of Chinese cabbage were equally infested. A similar trend was observed in an earlier study in April-May when the population was slightly lower. Since the females did not lay eggs on severely damaged or dead plants, but rather on healthy ones, this slightly lower preference of other cruciferous hosts will not be significant with increased insect populations.

For July planting the temperature range was 23.5°C to 32.4°C, and the humidity range 73.1% to 100%. There was 96 mm rainfall between transplanting and observation.

ECOLOGY OF CABBAGE WEBWORM

Since July 1977 we have monitored the incidence of this pest to study its seasonal occurrence in an effort to devise appropriate control measures. Once every month we plant Chinese cabbage (cv Feng Luh) in three 20m x 1m rows and, beginning one month after transplanting, monitor each week for four weeks the number of larvae on a 30 plant sample. During 1977 and 1978 this insect was abundant almost exclusively during the hot, humid June through September monsoon season (Figure 3). However, during 1979 the insect was abundant from much earlier, in February-March, and remained high until September. Thereafter the population declined sharply. Although the insect population was high before the hot, humid monsoon months, plant damage was at a maximum only during June through September. Most of the insects found during February, March and April were early instar larvae feeding mainly on older leaves and rarely burrowing in the growing point, the most common and destructive kind of damage caused by this insect during June-September. This shift in the nature of damage cannot be explained at this stage and will be investigated during 1980.

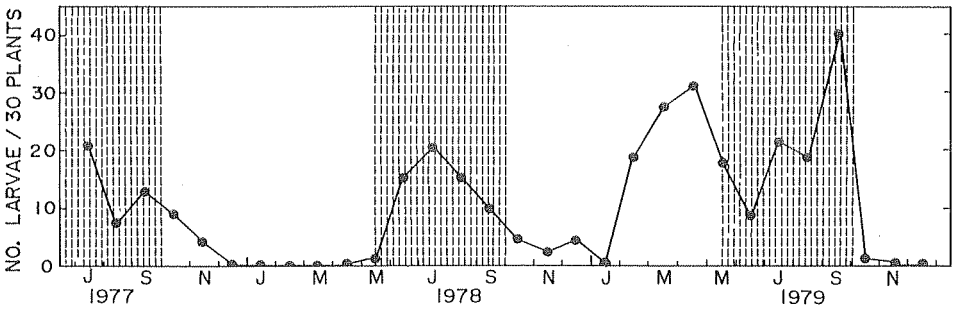

Figure 3. Seasonal incidence of cabbage webworm on Chinese cabbage

CONTROL OF CABBAGE WEBWORM

HOST PLANT RESISTANCE:

We screened our entire germplasm collection of Chinese cabbage and related species for resistance to cabbage webworm in a preliminary nonreplicated field experiment during July 1978. We transplanted 451 accessions into the field on 2m x 1.5m raised beds and allowed the plants to become infested by natural populations of cabbage webworm. Three weeks after transplanting we evaluated the resistance reaction by counting the number of larvae per ten plant sample as well as by assessing the percentage of damaged plants, and then by subjecting the insect count as well as the plant damage data to a statistical analysis based on the mean and standard deviation of these parameters. Thirteen accessions were judged as having moderate to high resistance. When these 13 accessions, along with three susceptible ones, were screened a second time by an identical procedure in a replicated test, four accessions (B159, B186, B488 and B501) were found to be the least affected during three insect counts and plant damage observations. The level of resistance in these accessions was not high enough to be of any immediate use in breeding for resistance.

CULTURAL CONTROL:

During the summer of 1979 we studied various cultural practices such as intercropping, mulching, covering the planted area with protective net cover, and plant spacing, in order to explore the possibility of reducing cabbage webworm infestation. Chinese cabbage seedlings were transplanted between two lines each of 22 other crops. These crops were: common cabbage, nonheading Chinese cabbage, radish, cucumber, bittergourd, watermelon, soybean, mungbean, snapbean, asparagus bean, lima bean, sweet potato, tomato, eggplant, potato, pepper, sugarbeet, marigold, onion, corn, spinach and carrot. At the same time, we tested the benefits of four commonly used mulching materials: black plastic, clear plastic, aluminium foil and rice straw. We also tried covering with nylon net the planted area and transplanting at spacings of 50 cm × 60 cm, 50 cm × 40 cm and 50 cm × 20 cm. Each treatment had three replicates. Two and four weeks after transplanting we counted the number of cabbage webworm larvae and pupae per ten plant sample in each plot.

Chinese cabbage intercropped with bittergourd, watermelon, sweet potato and mungbean had the lowest infestation of cabbage webworm. No other treatment reduced infestation significantly.

CHEMICAL CONTROL:

During 1978 we screened 38 insecticides in various formulations - as granules, wettable powders and emulsifiable concentrates - in six insecticide screening tests in the field. Granular insecticides were incorporated in the soil in transplanting spots immediately prior to transplanting and WP and EC formulations were sprayed on the plants once every week, beginning within a week of transplanting. The results of the most effective insecticide treatments are summarized in Table 2.

Table 2. Summary of results obtained with the most effective insecticides for cabbage webworm control[a-f]

Screening test	Insecticides	Rate, kg ai/ha	No. larvae/10 plant I observ.	No. larvae/10 plant II observ.	Yield t/ha
I	Mephosfolan 2G	2	2.3b	2.0a	4.8ab
	Terbufos 10G	2	7.3b	5.3a	6.3a
	Carbofuran 3G	2	3.5b	4.8a	5.2ab
	Control	-	40.3a	2.5a	0 c
II	Carbofuran 3G	3	0.3b	3.3a	5.4a
	Carbofuran 3G	1	5.3ab	9.5a	4.5a
	Fensulfothion 5G	2	6.0ab	1.5a	4.0abc
	Control	-	27.8ab	6.8a	0 c
III	Chlorpyrifos 40.8EC	0.25	1.5c	0 b	5.3a
	Control	-	23.3ab	*g*	0 d
IV	EPN 45EC	0.25	2.0b	0.3a	4.2a
	Triazophos 40EC	0.25	6.0ab	4.0a	4.3a
	Control	-	16.3ab	*g*	0 b
V	Methidathion 40EC	0.25	4.8bc	2.0a	4.9ab
	Methomyl 24EC	0.25	10.0abc	1.0a	4.8ab
	Parathion 50EC	0.25	1.5bc	0.5a	5.2a
	Triazophos 40EC	0.25	0.5c	0.3a	5.3a
	Control	-	25.8a	7.8a	0.9de

[a]Cultivar, AVRDC breeding line B189C_1. [b]Transplanting dates: tests I and II 4 July, III and IV 12 July and V 20 July. [c]Observation dates: tests I and II 18 July and 3 August, III and IV 24 July and 2 August and V 2 and 8 August. [d]Data are means of four replicates. Means followed by the same letter are not significantly different at 5% level. [e]Harvest dates: tests I and II 14 August. III and IV 18 August and V 24 August. [f]Plot size:13.5 square meters (4.5m × 3m). [g]All plants died

Soil application of mephosfolan, terbufos, carbofuran, and fensulfothion at the time of transplanting as well as weekly foliar

sprays of chlorpyrifos, EPN, triazophos, methidathion, methomyl and parathion gave good control. On an active ingredient basis, parathion was the cheapest insecticide to give good control.

During the summer of 1979 we continued the chemical control studies with a view to getting the highest yield at minimum insecticide application and cost. Based on the 1978 results in which we found soil incorporation of carbofuran, mephosfolan and terbufos prior to transplanting, or a weekly foliar spray of parathion starting within the week of transplanting, gave better control of cabbage webworm, in one experiment we studied the incorporation of these insecticides in the soil and weekly foliar application of parathion. Weekly parathion foliar spray at the rate of 0.5kg ai/ha gave the best insect control and comparable yields. However, parathion alone was the cheaper of the two. In another experiment we sprayed parathion once a week, once every two weeks, once every three weeks and once every four weeks without and with soil incorporation of carbofuran 3G at the rate of 2kg ai/ha. Weekly or biweekly spraying of parathion alone, with the first application three days after transplanting, gave as good control and yields as parathion with soil incorporation of carbofuran. Parathion spray alone was obviously the cheapest.

Once parathion was established as the cheapest and most effective insecticide we studied the timing of its application to get the best control at lowest cost. For practical reasons, all spray schedules started with the first application three days after transplanting, since plant damage within the first week, especially to the growing point, reduces yield most. Application of insecticide once every two weeks, with the first application three days after transplanting, was cheapest and as effective as any other more frequent spray schedule.

We also screened eight new insecticides using parathion as standard check. Temephos, evisect and thiometon controlled cabbage webworm as effectively as parathion.

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DISCUSSION

C.T. LEE: Is parathion a restricted insecticide in Taiwan?

N.S. TALEKAR: Parathion is available in the market in Taiwan. However, its use for vegetable insect pest control is not recommended.

C.T. LEE: What is the time interval between the last parathion application and safe harvest?

N.S. TALEKAR: Based on our residue analysis data one week is adequate. I must point out though that our experiments were carried out in June-July and it rains quite frequently and at times heavily during that time of the year in Taiwan.

T. SAITO: What is the mechanism of resistance to cabbage webworm?

N.S. TALEKAR: We are not quite sure yet. We need to test the promising

materials once or twice during the coming summer under heavier insect pest population pressure. Then if they still are resistant we will study the mechanism.

T. SAITO: Why is there reduced cabbage webworm infestation after intercropping Chinese cabbage with certain crops?

N.S. TALEKAR: It is possible that these crops act as repellents. I must also mention here that these particular crops grow faster than Chinese cabbage and grow all around the Chinese cabbage plant. That probably confuses the insect pest when it tries to visit the host plant for oviposition. We will work on this aspect during summer 1980.

M. SAKAI: How does intercropping work to decrease webworm damage in Chinese cabbage? Does it work as a trapping plant or a repellent?

N.S. TALEKAR: It certainly doesnot act as trapping plant because these crops are not hosts of cabbage webworm. It is possible that they act more as repellents.