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Determination of Optimum Spraying Time for Chemical Control of Mulberry Scale, *Pseudaulacaspis pentagona* (Targioni) (Hemiptera: Diaspididae) in Tea Fields

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Abstract

Monitoring methods of mulberry scale larvae, *Pseudaulacaspis pentagona*, were evaluated for determining the spraying time of effective chemical control. Among them, the calculation of the ratio of "more than half hatched egg batches" which was found to be suitable due to its accuracy, is however, time-consuming. Optimum spraying time is defined as the duration of the period required to achieve a ratio of more than half hatched eggs in egg batches (60 to 90%), which is referred to as "more than half hatched egg batches." The use of sticky traps set inside a tea bush to capture crawlers of the mulberry scale is a simple and accurate monitoring method. The optimum spraying time occurs 2 to 5 days after the peak capture of the crawlers by the traps. The traps should be set up from the beginning of the egg hatching period, and should be examined daily or every other day to determine the peak capture of the crawlers. The use of sticky traps for monitoring is suitable for only the first generation of mulberry scale. Thus observations of "more than half hatched egg batches" are needed to determine the optimum spraying time for the second and third generations of the mulberry scale.

Discipline: Insect pest / Tea industry
Additional key words: sticky trap, crawler, egg batch

Introduction

The mulberry scale, *Pseudaulacaspis pentagona* (Targioni), has been a serious pest of tea in Japan. Outbreaks have been reported sporadically since 1955 in Shizuoka Prefecture[3]. Recently an outbreak was reported in 1994–1996 and the scales occurred in 40% of the tea-cultivated area in Japan[2]. The scale population frequently breaks out and occasionally even kills tea hosts. Three generations can occur per year in central Japan. The female lays eggs under her shell. The crawlers, i.e. walking first instar larvae, just after hatching walk out from under the shell. After 30 m to 11 h, the crawlers settle on tea branches and molt to the succeeding developmental stage within 15 days[3].

It is difficult to find the crawler scale in the tea fields because the mulberry scale lives only on branches inside the tea bushes and the body size of the crawler is very small (0.2 mm). However, in the case of the mulberry scale, the effective period for pesticide application is very short[9]. Even if farmers detect the occurrence of this scale, it is difficult to determine the time of optimum control. Three monitoring methods were proposed to determine the spraying time for mulberry scale. These methods were evaluated in terms of accuracy and simplicity.

Effect of insecticide application to mulberry scale

Generally, chemical control for scale insects is applied to larvae and adults. In the case of the larvae, it is effective only for young ones. Therefore chemical control methods for adult scales which do not involve a selection of the spraying time were examined. Spraying of petroleum oil during winter enabled to control effectively the arrow-head scale, *Unapsis yanonensis* (Kuwana), which is a kind of armored scale, that injures citrus[7]. However, the control by the use of some pesticides including petroleum oil in the case of the adult female of mulberry scale in winter is less effective than in the case of the larvae[12]. Though fumigation with hydrocyanic acid gas applied to the adult of the mulberry scale and the arrow-head scale is effective[4,6], this method is very dangerous to man and its application is not realistic presently.

Some of the insect growth regulators and organophosphates are known to be effective insecticides against the larval stage of armored scales. The optimum period of pesticide application lasts for more than 4 weeks for the California red scale, *Aonidiella aurantii* (Maskell)[14]. Organophosphates are effective for the control of the first and the second instar larvae and also for that of the immature adults of the arrow-head scale[11]. Many insecticides have been tested for the control of the mulberry scale. Some insecticides (e.g. buprofezin and methidathion) are effective against the larvae of the mulberry scale. However, the optimum period of application of these insecticides is very short and the effectiveness markedly decreases when spraying is performed 6 days after the optimum time[9]. Therefore, since pesticide control of the mulberry scale is more difficult than that of the California red scale or arrow-head scale, it is important to determine the spraying time for the control. Consequently, accurate and efficient monitoring methods are required for determining the optimum spraying time.

Monitoring methods for insecticide application

1) Observation of the number of crawlers

Pesticides should be applied during the period of egg hatching[3]. A farmer goes to his tea fields and observes the walking crawlers on the tea branches. Pesticides should be applied when the farmer finds many crawlers on the branches. This is the easiest method. Alternatively, a farmer brings the branches with mulberry scale females to his house from his tea fields. Spraying of pesticides should be performed when the farmer observes the crawlers on the branches in water[1].

2) "More than half hatched egg batch ratio"

It is time-consuming to count the number of hatched eggs that would be statistically significant for calculating the hatchability. This is a simple method in which the ratio of "more than half hatched egg batch" is measured[8]. The female scales are observed under a microscope after their shells are peeled off using pointed tweezers. A group of eggs laid by one female is defined as one egg batch. If one or more eggs in one egg batch have hatched, the term "hatched egg batch" is used. If more than 50% of the eggs in one egg batch have hatched, the term "more than half hatched egg batch" is used. More than 100 live females in a tea field are required for this survey[13].

Table 1 shows the effect of applications of 2 kinds of pesticides (buprofezin 25W and methidathion 40E) on different days at short intervals and the ratio of "more than half hatched egg batches" on the day of pesticide application. The most effective date for pesticide application was May 26 for both insecticides based on the colony number of male cocoons. The numbers in the plots sprayed with Buprofezin were small on May 23 and June 1. The colony numbers in the methidathion plots were small when spraying took place on May 26 and 30. Many colonies were observed in both sprayed plots on June 1. Therefore, the effective duration of safe application of these insecticides for the control corresponded to the period around May 26 to 30 in this test. The ratio of "hatched egg batches" reached a value of 100% before the optimum spraying time, while the ratio of "more than half hatched egg batches" increased slightly from May 23 to 26. Therefore it is assumed that the ratio of "more than half hatched batches" is a useful index for determining the duration of the optimum control time. And the effective period of pesticide application coincides with a ratio of "more than half hatched batches" ranging between 60 to 90%.

3) Capture of crawlers by sticky traps

The crawlers of scale insects have been shown previously to disperse passively by the wind[5,10,15]. They can be caught by sticky traps. Ozawa (1994a)[8] who used a small sticky card trap (10 × 10 cm) placed inside the tea bush to monitor the crawlers and the male adults, tried to predict the optimum spraying time for chemical control by trap catches and the ratio of hatched eggs (Fig. 1). Since both the number of captured crawlers by the traps and the hatchability increased rapidly during a period of about 10 days, more detailed data are necessary to determine the optimum spraying time.

Fig. 2 shows the changes in the numbers of captured crawlers using the Ozawa trap and hatching ratio of egg batches for the first generation at short intervals[13]. The results of the survey conducted in 1995 are shown in Table 1. The optimum spraying duration in 1995 during the period between May 26 and 30 corresponded to the period of 1 to 5 days after the peak of crawler captures. In 1996, the duration of the period when the ratio of "more than half hatched egg batches" reached values of 60 and

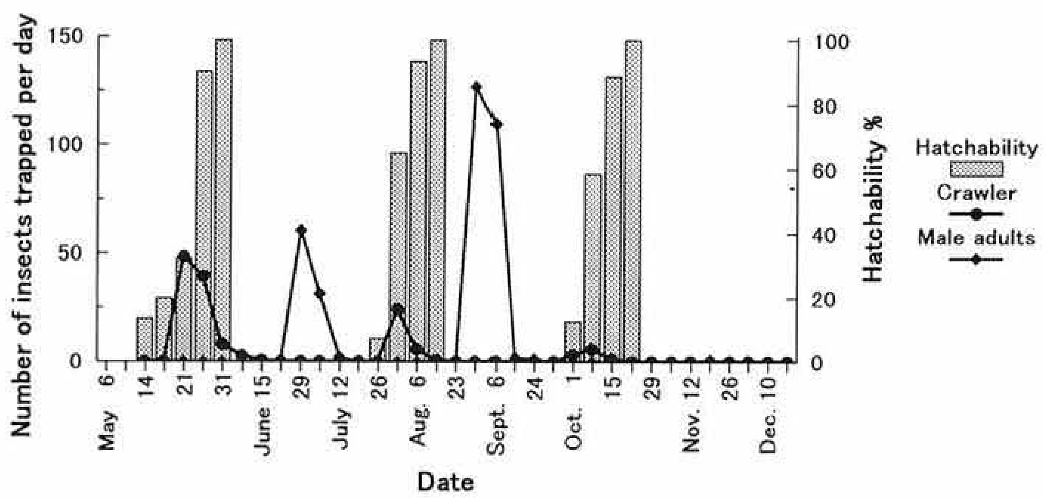

Fig. 1. Hatching ratio of egg batches and number of trap catches of crawlers[8]

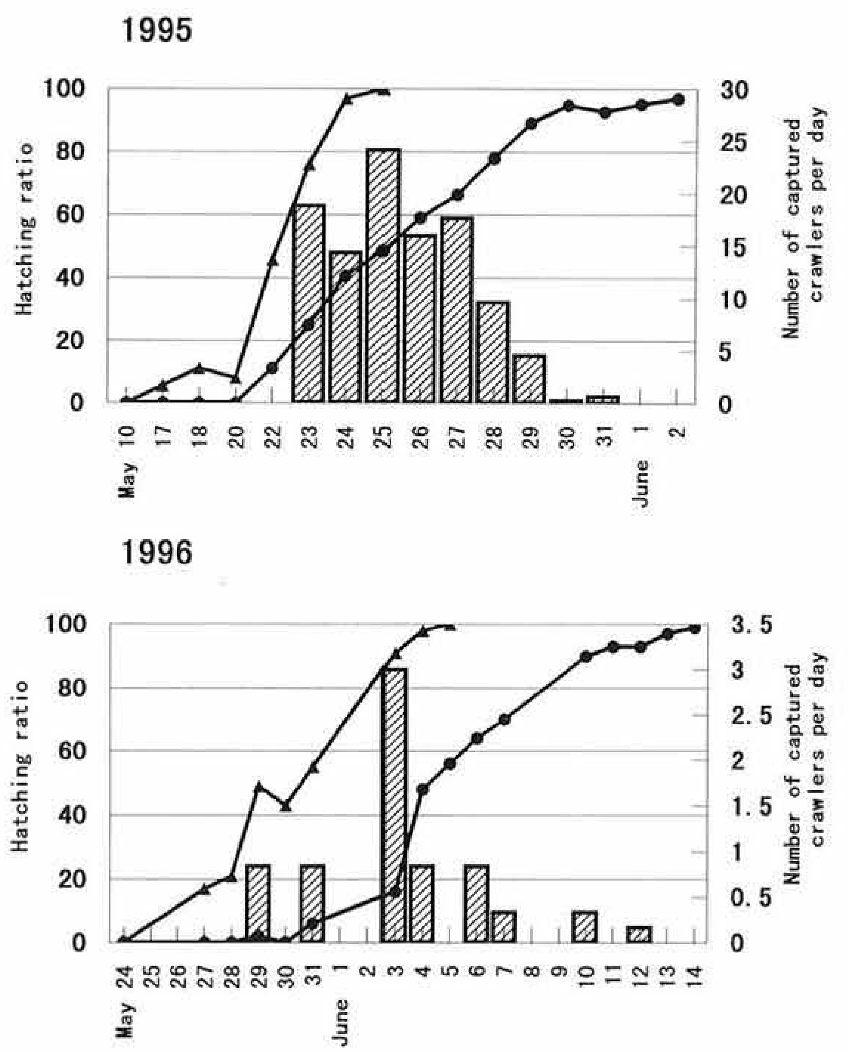

Fig. 2. Hatching ratio of egg batches and number of trap catches of crawlers in the first generation

—●— Ratio of "more than half hatched egg batches,"

—▲— Ratio of "hatched egg batches,"

▨ Number of captured crawlers by trap.

Table 1. Optimum spraying time for *P. pentagona* control[13]

Pesticide[a)]	Spraying date	Ratio of "more than half hatched egg batches" on spraying day (%)	Mean number of colonies of male cocoons on June 20[b)]
Buprofezin 2.5 ppm	May 23	25.0	2.75
Buprofezin	May 26	59.0	0.25
Buprofezin	May 30	94.9	2.40
Buprofezin	June 1	95.2	0.95
Buprofezin	June 5	100.0	14.35
Methidathion 4 ppm	May 23	25.0	10.60
Methidathion	May 26	59.0	6.65
Methidathion	May 30	94.9	6.80
Methidathion	June 1	95.2	22.95
Methidathion	June 5	100.0	30.30
Unsprayed	—		30.90

a): 1,000 L per 10 a were sprayed to each plot.
b): When male cocoons covered a large part of the tea branch, male cocoons 2 cm long were counted and defined as one colony.

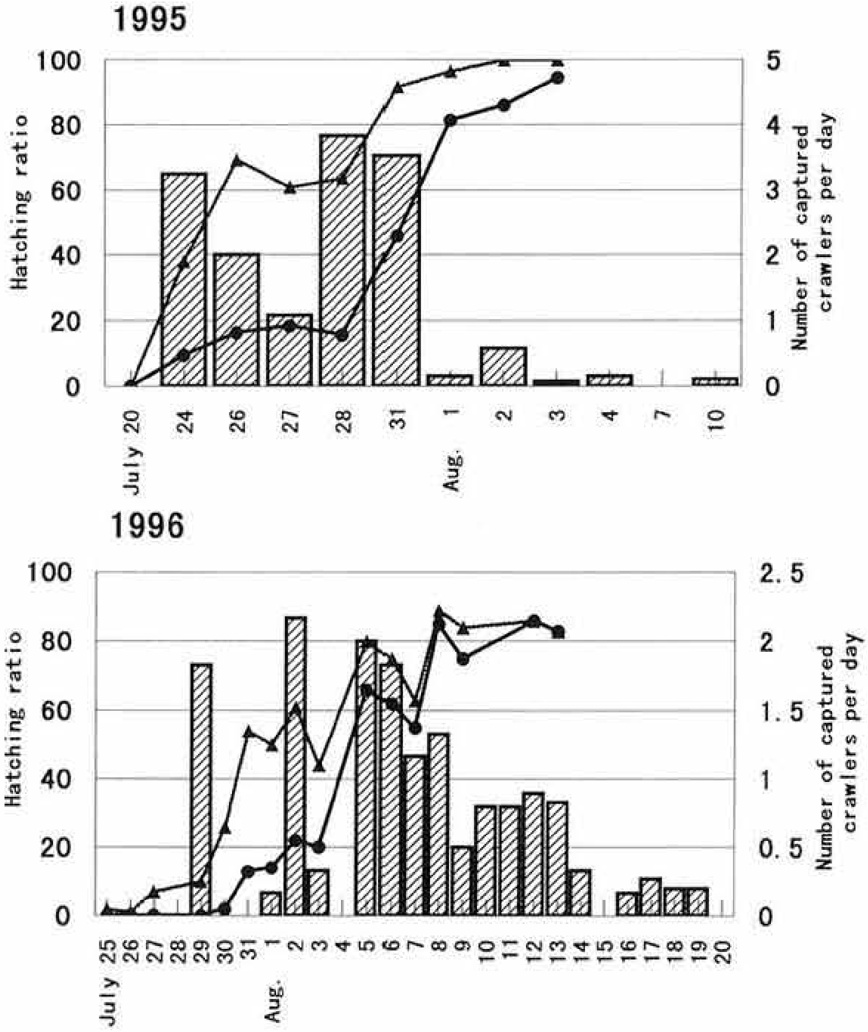

Fig. 3. Hatching ratio of egg batches and number of trap catches of crawlers in the second generation
—●— Ratio of "more than half hatched egg batches,"
—▲— Ratio of "hatched egg batches,"
▨ Number of captured crawlers by trap.

90% corresponded to the period of June 5 to 10. This period corresponded to 2 to 7 days after the peak of the trap catches. Though the dates of the optimum spraying period and the peak of trap catches were different in 1995 and 1996, the optimum spraying time can be estimated from the peak of trap catches of the crawlers.

Fig. 3 shows the changes in the numbers of catches and hatching ratio of the egg batches for the second generation. The optimum spraying time was estimated to occur around August 1 based on the ratio of "more than half hatched egg batches." While the traps captured the crawlers on July 24 initially, the peak occurred on July 28. Since the difference in the number of catches between July 24 and 28 was not appreciable, it is difficult to detect the peak of trap catches in this case. In 1996, the optimum spraying time was estimated to occur from August 5 to 8 based on the 60 to 90% ratio of "more than half hatched egg batches." It is difficult to detect the peak because the number of trap catches markedly fluctuated from the trap setting. Based on the results obtained in both years for the second generation, it is difficult to detect the peak date from the changes in trap catches. The peak date of trap catches could be detected in the third generation in 1995, while crawlers were not caught in the traps in 1996. Therefore it is difficult to determine whether the sticky traps are useful to estimate the optimum spraying time for the third generation based on the results of both years (Fig. 4).

The hatching duration of crawlers is longer in the second and third generations than in the first generation. It is very difficult to control the mulberry scale in the second and third generations with insecticides because the hatching of eggs continues

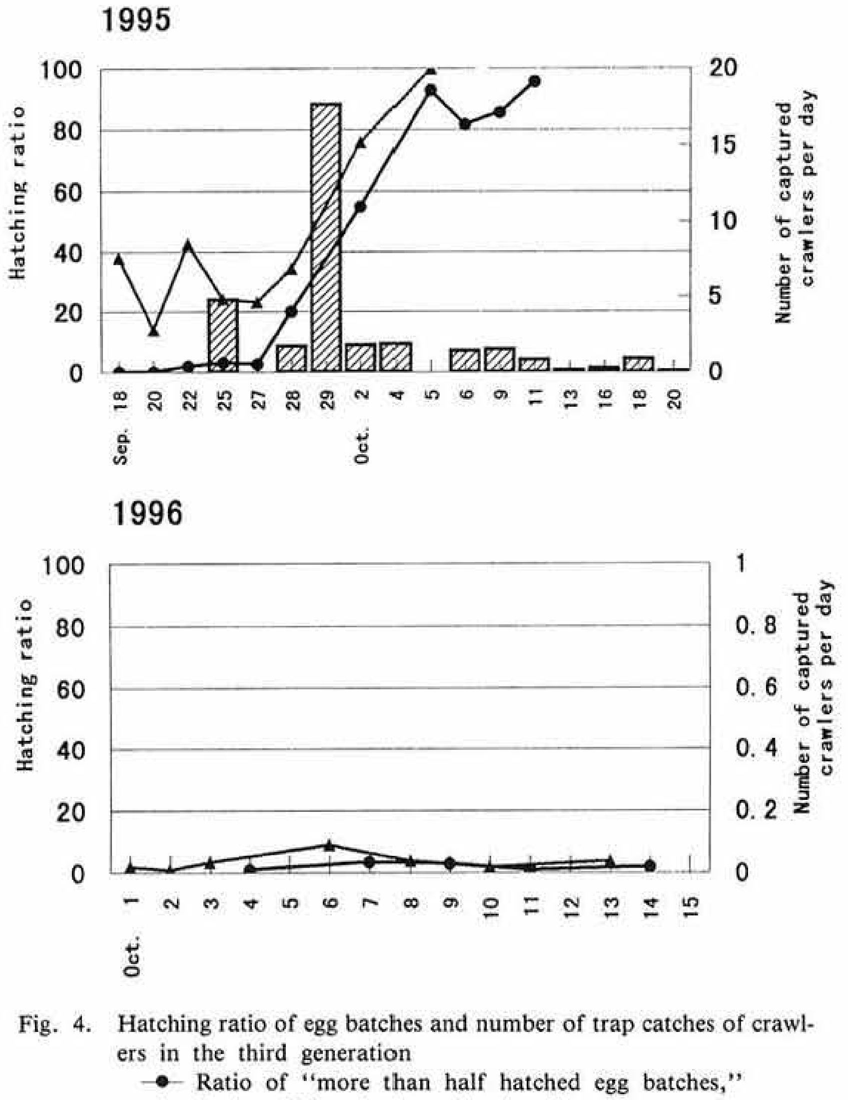

Fig. 4. Hatching ratio of egg batches and number of trap catches of crawlers in the third generation
—●— Ratio of "more than half hatched egg batches,"
—▲— Ratio of "hatched egg batches,"
▨ Number of captured crawlers by trap.

for a long period. Even though monitoring by using sticky traps is possible only for the first generation, this method is suitable because the control of the first generation of the mulberry scale is very important to achieve further control.

Ozawa[8] indicated that the optimum spraying time of the mulberry scale by sticky traps under the plucking surface of the tea tree corresponded to 5 days after the first catch by the trap. However, it is preferable to determine the pesticide application date based on the peak number of crawlers caught in the sticky traps. The optimum spraying time was 1 to 5 days after the peak of the trap captures in 1995 and 2 to 7 days in 1996 (Fig. 2). Considering the safety of the effect of chemical control, the period of optimum spraying time should correspond to 2 to 5 days after the peak.

Fig. 5 shows simulations of different intervals of trap changes using an actual data set[13]. The actual peak of the number of captured crawlers occurred on May 25. In the case of 2-day intervals, if the traps were set on May 19 or 20, the peak occurred on May 25 or 26 and the optimum duration of spraying corresponded to May 27 to 30 or May 28 to 31, respectively. In the latter case, since the peak was detected on May 28, preparations for the control can be made. In case of 3-day intervals, if the traps are set on May 19, 20 or 21, the peak may occur on May 25, 26 or 27, respectively. When the peak occurred on May 27, the optimum spraying time should take place during the period from May 29 to June 1. But, in this case, the peak day can not be determined until May 30 when the next traps are set up. Since the actual period for optimum spraying to control the mulberry scale corresponded to May 27 to 30, preparations for the control cannot be made at that time. Therefore, traps should be changed daily or every other day.

Evaluation of monitoring methods for optimum spraying time

The method involving only observations is the easiest and requires little time. However, this method is not accurate since the results depend on the farmers' individual perception. For example, when a few percents of crawlers come out from the female shell under a high density of females, a farmer may make a mistake in deciding to spray due to the observation of a large number of crawlers. Though the observations of "more than half hatched egg batches" are accurate to determine the optimum spraying time for the control of the mulberry scale, this procedure is time-consuming.

Monitoring using sticky traps placed under the

Fig. 6. Setting of sticky trap under the plucking surface of tea tree

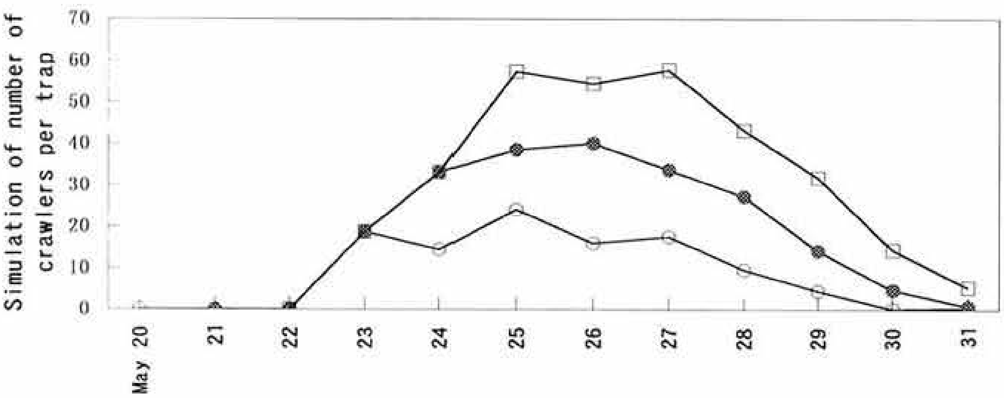

Fig. 5. Simulation of different intervals of trap change based on 1995 data
—○— Daily, —◉— 2-day intervals, —□— 3-day intervals.

plucking surface of the tea tree requires less time than monitoring of the egg hatching ratio. The adhesive sheet (8 × 10 cm) is stuck on both sides of an acrylic card (10 × 10 cm) which is used as a sticky trap. The traps are placed vertically at 10 cm under the plucking surface of the tea canopy (Fig. 6). The traps face the same direction as the tea hedge. The new traps were set in the same position after trap change. Captured crawlers are counted under a microscope. The sticky traps may enable to capture the crawlers over a wide area of tea fields. Since this monitoring method is not suitable for the second and the third generations, it is useful for the purpose of decision making for pesticide application only for the first generation of the mulberry scale. It is considered that the observation of egg hatching is necessary for the second and the third generations to identify the optimum spraying time.

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