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# Adult Eclosion and Emergence of the Black Pine Bast Scale, *Matsucoccus thunbergianae* (Homoptera: Coccoidea: Margarodidae)

솔껍질깍지벌레 성충의 우화습성

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**ABSTRACT** Adult eclosion and emergence behavior of the black pine bast scale, *Matsucoccus thunbergianae* Miller and Park, was studied in a laboratory. Adult eclosion in males did not appear to be limited to a specific time of the day. Newly molted male adults, at room temperatures, usually remained in the cocoons as pre-emergence adults for 0.5-2.5 days before emerging; most males emerged within one hour after the onset of photophase, and emergence was faster at higher light intensity. Most females molted into adults within three hours after the onset of photophase, and they were active immediately after molting. Quiescence in males appears to help the scales concentrate their sexual activity within a particular period of the day as well as to protect newly molted adults until sexual and locomotive maturity.

**KEY WORDS** *Matsucoccus thunbergianae*, black pine bast scale, Homoptera, Coccoidea, Margarodidae, eclosion, emergence, pre-emergence male

**초 록** 솔껍질깍지벌레 성충의 탈피(우화 : eclosion) 및 우화후의 탈출(emergence)습성이 실내조건에서 조사되었다. 수컷성충의 탈피는 일중 특정한 시간에 국한되지 않으며 갓 탈피한 성충은 실온에서 정지성충(pre-emergence adult)으로서 0.5~2.5일 경과후 고치로부터 탈출하였다. 대부분의 수컷성충은 일조후 1시간 이내에 탈출하였으며 이러한 탈출현상은 광도가 높은경우 더욱 빨리 진행되었다. 암컷성충은 우화후 곧 탈피장소에서 이동하며 대부분 일조후 3시간이내에 우화하였다. 수컷이 우화후 고치속에 일정기간 정지하여 있는 것은 갓 우화한 성충의 생리적 성숙을 돕고 또한 번식활동을 일중 특정한 시간에 하기 위한 것으로 풀이된다.

**검 색 어** 솔껍질깍지벌레, 매미목, 깍지벌레상과, 짚신깍지벌레과, 우화, 우화후 탈출, 정지성충

Aspects of adult life and behavior of females vary considerably within the superfamily Coccoidea. Some females are mobile, while others are sessile. Some females, such as those of the genus *Matsucoccus*, have no functional mouthparts and live only a few days, while many others are able to feed and live considerably longer. All coccoid males are lacking mouthparts and short lived. Most males, such as those of the red pine scale(*Matsucoccus resinosae* Bean & Godwin) (Doane 1966), the yellow scale [*Aonidiella citrina*(Coquillett): Diaspididae] (Moreno et al. 1974) and the California red scale [*Aonidiella aurantii*(Maskell)] (Rice & Moreno 1970), were reported to live less than a day.

Recently, epidemic populations of the black pine bast scale (*Matsucoccus thunbergianae* Miller &

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Park) have been causing serious damage to Japanese black pine(*Pinus thunbergiana* Franco) forests in the southwestern coastal area of Korea (Park & Park 1985, Miller & Park 1987). In males, two nymphal instars are followed by the wingless pre-adult, the pupa, and the adult, whereas the female adult directly emerges from the second nymphal instar (Park & Park 1985). Female adults leave the cast skins immediately after eclosion, but we found that newly molted male adults remained quiescent for a few days. The callow male adult is pale brown and about 1.5 mm long, with short caudal waxy filaments which approximates the length of the two posterior abdominal segments, and with soft full length wings which extrude out of the loosened cocoon. Although it has mobile legs, it can hardly walk; the legs are mainly used for shedding the pupal cat skin. The caudal waxy filaments grow longer than the body, and the color of the body and wing veins grows darker during this quiescent period(Park 1988).

We report the behavior of adult eclosion and emergence in males and females of *M. thunbergianae* with special reference to photoperiodism.

## MATERIALS AND METHODS

### Time of eclosion and duration of quiescence in males

Pupae of *M. thunbergianae* were collected from the laboratory colony and placed in a petri dish at 10 p.m., February 12, 1987. The eclosion of males, i.e. molting form pupae to pre-emergence males, was monitored three times a day, at 8 a.m., 3 p.m. and 10 p.m. of February 13 and 14. Each newly molted male was put in a separate vial, and its emergence was examined daily at 10 a.m. until emergence ceased. Temperature and light were maintained at 21 ± 1℃ and LD 14 : 10(600 lux of fluorescent light between 8 a.m. and 10 p.m.). A Topcon IM-2D luxmeter was used to measure the light intensity throughout the experiments.

### Effect of light intensity on male emergence

Pre-emergence males reared under natural day length were collected at 5 p.m., March 15, 1986, and emergence was monitored the next morning at 10 minute intervals. One group of pre-emergence males collected was maintained under natural photophase. The other group of individuals was maintained at darkness from 7 p.m., and were exposed to fluorescent light of 600 lux at 6 : 50 a.m. the next morning. Rearing was done at 18-22℃ of daily fluctuating temperature in a laboratory.

### Timing of exposure to light and male emergence

Nine hundred pre-emergence males reared under natural photophase were collected at 3-5 p.m., March 14, 1987. One hundred pre-emergence males were put in separate petri dishes and kept at 600 lux until 9 p.m., when each petri dish was placed into a separate dark chamber. Three separate petri dishes were exposed to 600 lux of fluorescent light at 6 a.m., 9 a.m. or noon the next day, and the numbers of males emerged were examined every hour. Rearing was done at 21 ± 1℃ and 60 ± 10% RH.

### Timing of exposure to light and female emergence

Japanese black pine branches(ca. 30 cm long, 2 cm in diameter) infested with female intermediate nymphs were stored at 21 ± 1℃ and LD 15 : 9 with photophase from 6 a.m. to 9 p.m. at 600 lux of fluorescent light. On March 15, 1987, after three days of storage, all emerged females were removed from nine branches at 9 p.m., and each branch was put into a separate dark chamber. Branches in groups of three were exposed to 600 lux at 6 a.m., 9 a.m. or noon the next day, and the numbers of newly emerged females were monitored at three

**Table 1. Eclosion and emergence of *M. thunbergianae* males[a]**

| Eclosion of males | | No. individuals emerged at each morning of: | | | | | Number of successful emergence |
|---|---|---|---|---|---|---|---|
| Time interval | No. molted | Feb. 13 | Feb. 14 | Feb. 15 | Feb. 16 | Feb. 17 | |
| 10 p.m. Feb. 12 – 8 a.m. Feb. 13 | 19 | 0 | 12 | 3 | 0 | 0 | 15 |
| 8 a.m. – 3 p.m. Feb. 13 | 17 | – | 12 | 2 | 0 | 0 | 14 |
| 3 p.m. – 10 p.m. Feb. 13 | 11 | – | 2 | 7 | 0 | 0 | 9 |
| 10 p.m. Feb. 13 – 8a.m. Feb. 14 | 24 | – | 0 | 14 | 4 | 0 | 18 |
| 8 a.m. – 3 p.m. Feb. 14 | 18 | – | – | 10 | 5 | 0 | 15 |
| 3 p.m. – 10 p.m. Feb. 14 | 13 | – | – | 6 | 5 | 1 | 12 |
| Total | 102 | | | | | | 83 |

[a] Rearing was done at 21 ± 1℃ and LD 14 : 10(photophase between 8 a.m. and 10 p.m.).

**Table 2. Duration of pre-emergence males(quiescence) in *M. thunbergianae***

| Duration of quiescent phase (hours) | 0-10 | 10-17 | 17-24 | 24-34 | 34-41 | 41-48 | 48-58 | 58-65 |
|---|---|---|---|---|---|---|---|---|
| Number of individuals | 0 | 8 | 22 | 26 | 12 | 7 | 7 | 1 |

hour intervals.

## RESULTS

### Male eclosion and emergence

The males do not appear to molt into adults at a specific time of the day. Of 102 pre-emergence males which molted between 10 p.m., February 12 and 10 p.m., February 14, the numbers molted between 10 p.m. and 8 a.m, 8 a.m. and 3 p.m., and 3 p.m. and 10 p.m. were 43, 35, and 24, respectively. Most males emerged in the first or second morning after eclosion(Table 1). As mentioned below, most males emerged within 30 minutes after first light. Thus, male adults observed at 10 a.m. were regarded as having emerged at 8 a.m. the same day, and the duration of quiescence(pre-emergence male adult phase)was estimated from Table 1(Table 2). It appears that newly molted males must remain quiescent at least 10 hours before emerging. Of 83 male adults, most emerged between 24 and 34 hours after eclosion. The longest duration of the quiescent phase studied was 58 to 65 hours. Most males were able to fertilize females shortly after emergence.

Most male adults emerged immediately after the onset of photophase. Emergence was faster at higher light intensity. While most adults under artificial lighting emerged within 30 minutes of the onset of photophase, it took about an hour for most adults to emerge at dimmer and gradually increasing light

**Table 3. Onset of photophase and male emergence of *M. ihunbergianae* when exposed to natural and artificial lighting in the laboratory[a]**

| Time interval | Natural light intensity (lux) at the end of each time interval | No. male emergence | |
|---|---|---|---|
| | | Natural light | Artificial lighting[b] |
| a.m. | | | |
| 6 : 10 - 6 : 20 | 0 | – | – |
| 6 : 20 - 6 : 30 | 0.1 | 1 | – |
| 6 : 30 - 6 : 40 | 0.7 | 21 | – |
| 6 : 40 - 6 : 50 | 5 | 59 | 0 |
| 6 : 50 - 7 : 00 | 12 | 35 | 58 |
| 7 : 00 - 7 : 10 | 24 | 22 | 80 |
| 7 : 10 - 7 : 20 | 40 | 15 | 33 |
| 7 : 20 - 7 : 30 | 50 | 5 | 7 |
| 7 : 30 - 7 : 40 | 60 | 3 | 6 |
| 7 : 40 - 7 : 50 | 75 | 5 | 3 |
| 7 : 50 - 8 : 00 | 85 | 3 | 1 |
| 8 : 00 - 8 : 10 | 100 | 2 | 0 |
| 8 : 10 - 8 : 20 | 120 | 1 | 2 |
| 8 : 20 - 8 : 30 | 145 | 0 | 1 |
| 8 : 30 - 8 : 40 | 145 | 0 | 0 |
| 8 : 40 - 8 : 50 | 180 | 2 | 1 |
| 8 : 50 - 9 : 00 | 190 | 1 | 0 |
| 9 : 00 - 9 : 10 | 215 | 0 | 0 |
| 9 : 10 - 9 : 20 | 220 | 0 | 0 |
| Total | | 175 | 192 |

[a] Rearing was done at daily fluctuating temperatures of 18-22℃ in the laboratory.
[b] 600 lux of fluorescent light from 6 : 50 a.m.

(Table 3).

With a nine hour scotophase, no males emerged before the onset of photophase. While the males reared at daily fluctuating temperatures of 18-22℃ did not emerge during approximately 12 hours of scotophase(Table 3), a few of the males(6.0%) reared at 21 ± 1℃ emerged at the same period of scotophase. When scotophase was 15 hours, 25.8% of males emerged before the onset of photophase. In all treatments, more than 90% of the males emerged within one hour of exposure to light (Fig 1).

**Female emergence**

As in males, female emergence was largely affected by exposure to light, but it appeared less concentrated at the onset of photophase. A few females (2.7%) emerged before the termination of a nine hour scotophase, whereas no males emerged during the same period of scotophase. Most male emergence was terminated within two hours of exposure to light, but more than 10% of the females, in all treatments, emerged three hours after the onset of photophase(Fig. 2).

## DISCUSSION

**Male eclosion and emergence**

Although males do not molt into adults at a particular period of the day, their emergence and initiation of reproductive behavior are governed by photoperiodism. Most male adults studied in the lab-

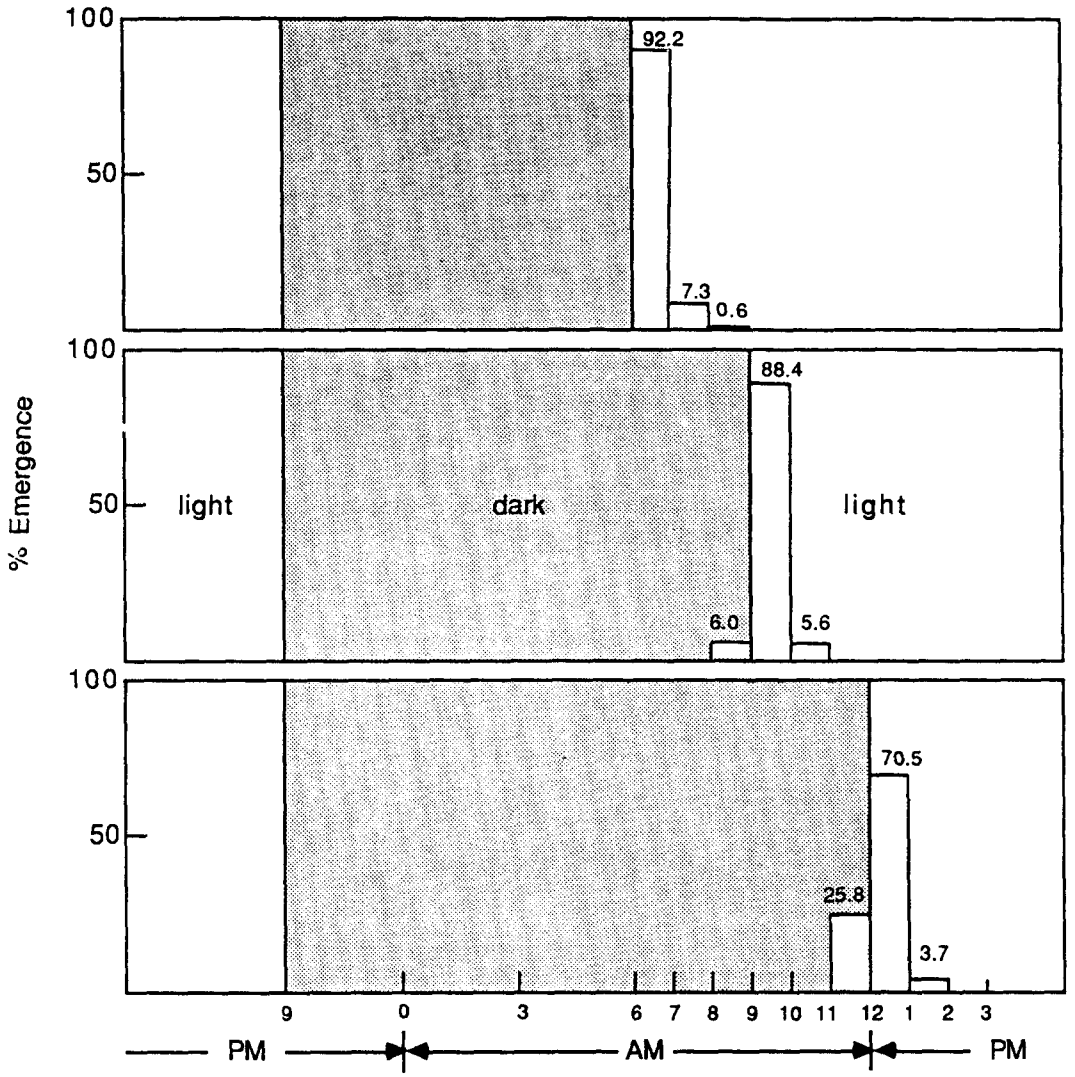


**Fig. 1.** Duration of scotophase and emergence of *M. thunbergianae* males at each time interval. (Numbers in shaded area are percentages emerged before the onset of photophase. Rearing was done at 21 ± 1℃)

oratory emerged at the onset of photophase after 0.5 -2.5 days of quiescence.

No males emerged during nine hours of scotophase at 21 ± 1℃, or during 12 hours of scotophase at daily fluctuating temperatures of 18-22℃. However, some males (6.0%) emerged during a 12 hour scotophase when they were reared at a constant temperature of 21 ± 1℃, which was ca. 2 −3℃ higher than the might temperatures of the fluctuating regime. When the period of scotophase was longer (15 hours), more males (25.8%) emerged without exposure to light. These results suggest that a physiological condition that is reached under prolonged scotophase and accelerated temperature forces emergence of males without the normal requisite onset of photophase.

**Quiescence in newly molted male adults**

Some papers lead us to speculate that the quiesc-

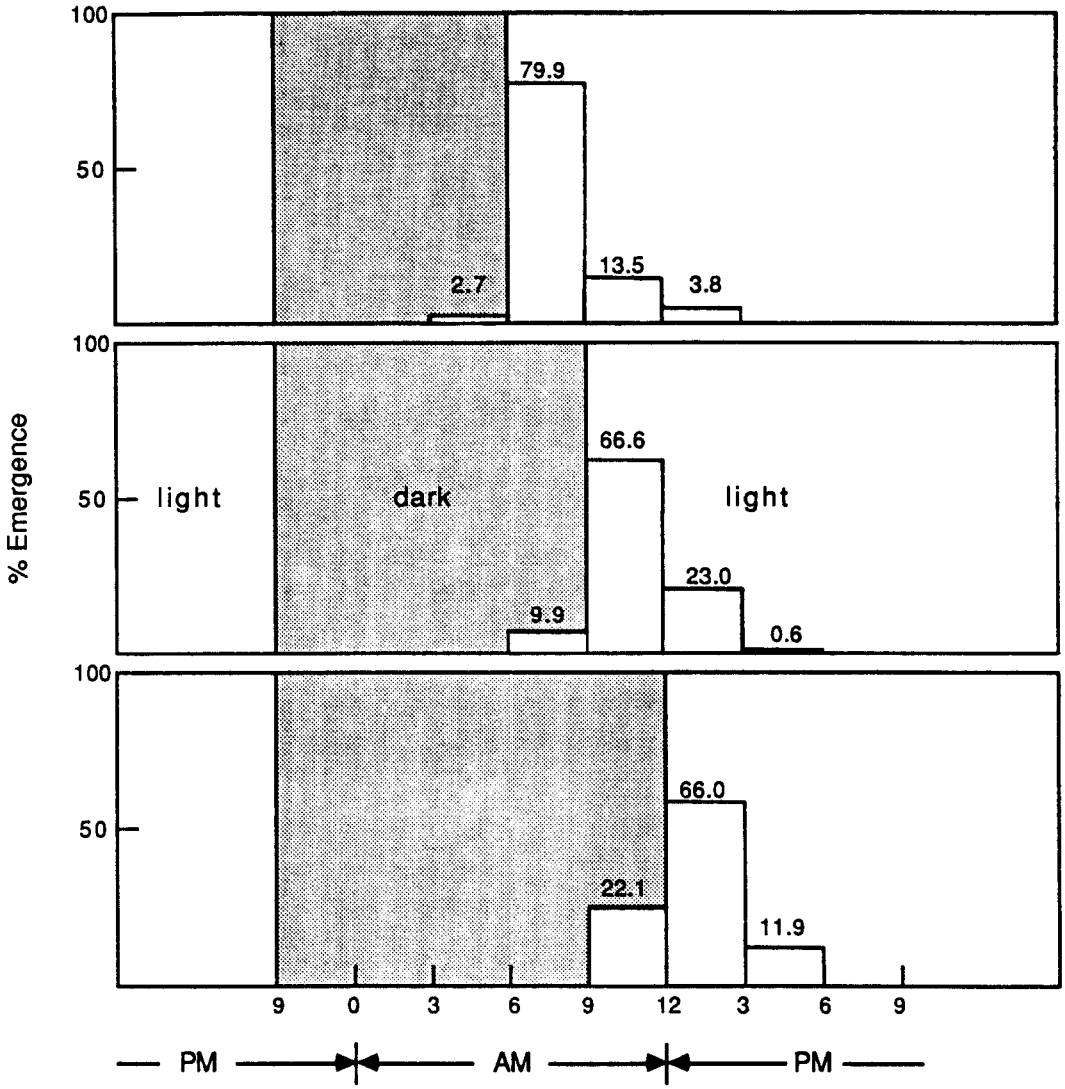


**Fig. 2.** Duration of scotophase and emergence of *M. thunbergianae* females at each time interval.(Numbers in shaded area are percentages emerged before the onset of photophase. Rearing was done at 21 ± 1℃.)

ence of male adults exists in other *Matsucoccus* species. McKenzie(1942) demonstrated this phase in *M. bisetosus* Morrison, though he did not name it. Ducasse(1938) stated that males of *M. matsumurae* (Kuwana)(a misidentification of *M. feytaudi*, which was described by Ducasse in 1941) survived three days. However, the longevity of the male adult of the same species studied by Riom and Fabre(1977) was 12-24hours. In every occasion where the life span of the male adult of *Matsucoccus* has been studied, it was less than one day. It is suspected that Ducasse(1938) recognized the pre-emergence male adult in *M. feytaudi*, and that the life span reported was from ecdysis to death. Doane(1965) stated that dead males of *M. resinosae* were usually found in the cocoons, but the males he recognized as dead might have been pre-emergence males.

A very similar phenomenon is also present in other coccoid families. Tashiro and Beavers(1968) used the term "pre-emergence adult" for an individ-

ual of the California red scale which had molted from the pupa, and found that 88% of those became active adults within three days of the final molt. Gary(1954) found that the males of the citrus mealybug[*Planococcus citri*(Risso) : Pseudococcidae], following the final molt, remain within the cocoons for 1-2 days during which time the anal filaments are extended and the wings and antennae become hardened. D. R. Miller (personal communication) also observed that newly molted *Eriococcus* males (Eriococcidae) remain in the cocoon for a certain period of time, when the anal filaments are developed. Presence of the above mentioned period, between the final molt and the time of male emergence, may be a common phenomenon in males of the superfamily Coccoidea.

Quiescence in newly molted coccoid males is probably related to their fragile nature. If they emerged before sexual maturity, the majority of such fragile creatures, without feeding ability, would be lost or damaged by adverse environmental factors and loss of energy. Quiescence in males appears to allow them to sexually mature and harden the wing muscles, and provide them with capability of flying and fertilizing females shortly after the emergence. Also, quiescence apparently reduces temporal variation among males due to different rate of ecdysis and sexual or physical maturation during the teneral adult period. Fully matured males can concentrate their sexual activity within a certain period of the day by being activated by an environmental cue, the onset of photophase.

On the contrary, *M. thunbergianae* females are mobile immediately after ecdysis. Hardening of muscles in females does not appear to be as important as in males. They are very sluggish, walking only about 8 cm / min on filter paper, and they do not show any active mating behavior before or during the copulation (Park 1988). As in most other coccoid species, fully grown female nymphs of *Matsucoccus* species are sexually matured(neotenic); even the females in the course of molting are frequently observed to be inseminated by the males.

### Mate finding and the daily rhythm of male and female emergence

Most males and females emerge shortly after the onset of photophase. Without doubt, synchronization of sexual activity in both sexes within a certain period of the day is advantageous for the scale. Most males, after the emergence, are able to locate and fertilize females for less than 12 hours. Females live a few days, but they release sex pheromones and attract males on a daily rhythm, from the first day of emergence, mostly between 8 a.m. and 2 p.m.(Park & Abrahamson, submitted). Daily synchronization of male activity and female pheromone release clearly maximizes successful mate finding in this species.

## REFERENCES CITED

Doane, C. C. 1965. The red pine scale. Conn. Agri. Exp. Sta. Circular 207(revised). 7 pp.

Doane, C. C. 1966. Evidence for a sex attratant in females of the red pine scale. Jour. Econ. Entomol. 59 : 1539~1540.

Ducasse, G. 1938. Quelques observations sur une Cochenille : *Matsucoccus matsumurae* Kuwana. Rev. Zool. agric. 37 : 129~133(French).

Ducasse, G. 1941. Notes sur *Matsucoccus feytaudi*, sp. Rev. fr. d'Entom. 8 : 217~225 (French).

Gary, H. E. 1954. The development of the citrus mealybug. Jour. Econ. Entomol. 47: 174~176.

McKenzie, H. L. 1942. Seasonal history of the margarodid scale *Matsucoccus bisetosus* Morrison, occurring on Ponderosa and Jeffrey pines in California. Microentomology 7: 19~24.

Miller, D. R. & S. C. Park. 1987. A new species of *Matsucoccus* (Homoptera: Coccoidea: Margarodidae) from Korea. Korean J. Plant Prot. 26: 49~62.

Moreno, D. S., G. E. Carman, J. Fargerlund & J. G. Shaw. 1974. Flight and dispersal of the adult male yellow scale. Ann. Entomol. Soc. Amer. 67: 15~20.

Park, S. C. & N. C. Park. 1985. Life history and summer

diapause of the black pine bast scale, *Matsucoccus* n. sp. in Korea. Res. Rep. For. Inst. Korea 32: 11~16 (Korean, English summary).

Park, S. C. 1988. Biology and pheromone-mediated behavior of *Matsucoccus thunbergianae* in Korea with reference to *M. resinosae* in the United States. Ph. D. dissertation, State University of New York College of Environmental Science and Forestry, Syracuse, New York. 166 pp.

Park, S. C. & L. P. Abrahamson. Daily rhythm of pheromone production and release by females of the black pine bast scale, *Matsucoccus thunbergianae* (Homoptera: Coccoidea: Margarodidae). Korean J. Appl. Entomol. 30: 94~99.

Rice, R. E. & D. S. Moreno. 1970. Flight of male California red scale. Ann. Entomol. Soc. Amer. 63: 91~96.

Riom, J. & J. P. Fabre. 1977. Etude biologique et ecologique de la Cochenille du pin maritime, *Matsucoccus feytaudi* Ducasse, 1942(Coccoidea, Margarodidae, Xylococcinae) dans le sud-est de la France. 2. Regulation du cycle annuel, comportements des stades mobiles. Ann. Zool. Ecol. anim. 9: 181~209 (French, English summary).

Tashiro, H. & J. B. Beavers. 1968. Growth and development of the California red scale, *Aonidiella aurantii*. Ann. Entomol. Soc. Amer. 61: 1009~1014.

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