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Research Article

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Developmental and Morphological Characterization of the Wild Silkmoth, *Actias gnoma*, in Korea

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The wild silkmoth, *Actias gnoma*, was firstly collected at Suwon located in the middle part of Korea. The developmental and morphological characteristics of *A. gnoma* reared under the laboratory conditions were analysed. The egg shape was shorter elliptic. The major and minor diameter of the eggs were 2.04 mm and 1.83 mm, respectively. White mucous material was remained inside the eggs after hatching. Also, the body color of the larvae was completely changed from dark brown to light yellowish-green at the 3rd instar, but it did not occur until pupation. In the feeding test on several plants, the oak tree, *Quercus acutissima*, was newly identified as a host plant. The final larval instar was mostly 6th, but in some larvae it was 7th. A few of larvae ate their own casts just after ecdysis. The whole larval duration ranged from 45 to 59 days. The single cocoon weight, cocoon shell weight and cocoon shell percentage were 1.65 g, 31.3 cg and 18.9%, respectively. The cocoon shape and color were spindle and light brown, respectively. The morphology of the silk gland was greatly different from those of *Bombyx mori*, *Antheraea yamamai* and *Antheraea pernyi*: the thickness of the middle and posterior silk glands was almost identical.

Key words: Wild silkmoth, *Actias gnoma*, Body color change, Host plant

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Introduction

The wild silkmoth, *Actias gnoma* (Saturniidae), is widely distributed in many Asian countries such as Korea, Japan, China, Taiwan, India and Malaysia (Nam, 1998). This wild silkmoth has very beautiful wings colored with a light jade green, so the common name (in Korean language) of this moth is derived from the beautiful jade-colored wings and its shape with long tail (Nam, 1998). Also the moth is bivoltine and feeds Japanese maple *Acer plamatum* and camphor tree *Cinnamomum camphora* (Nam, 1998). However, more detailed informations on developmental and morphological characteristics of the moth are not yet well understood because it is a wild insect. In the previous report, we characterized the developmental profile, quantitative and qualitative characters of another wild silkmoth, *Samia synthia pryeri,* reared under the laboratory conditions (Kim *et al.*, 2001). In the present study, we collected *A. gnoma* at Suwon located in the middle part of Korea, and reared the larvae on oak tree, *Quercus acutissima,* which was newly identified as a host plant in the present study, under the laboratory conditions. We report here some developmental and morphological features, and quantitative characters of *A. gnoma* based on the data obtained from the artificial rearing. This is the first report on the life history of the wild silkmoth, *A. gnoma,* by artificial indoor rearing of the worm under the laboratory conditions.

Materials and Methods

Collection of *A. gnoma* and indoor rearing under the laboratory conditions

The wild silkmoth, *A. gnoma,* was collected in Suwon located in the middle part of Korea, August, 2001. The moth laid about two hundred eggs. The newly hatched larvae were reared on the leaves of oak tree *Quercus acutissima,* which was identified as a host plant of the moth from the feeding test of several plants (not shown in the present data). The rearing temperatures for the larvae under the laboratory conditions were 25 – 27°C during the first, second and third instars, and 22 – 25°C during the 4th to 7th instars. The humidity was optimally controlled in the range of 70 – 85% during all the larval period. The fresh leaves of the host plant were supplied to the larvae during feeding time.

Observation of the developmental characteristics

Egg characters and developmental profiles during the larval and pupal stages were evaluated morphologically and quantitatively: morphology and hatchability of the eggs, larval duration, larval body weight, larval body length, mortality, color change of larval body, cocoon characters such as single cocoon weight, cocoon shell weight, cocoon shell percentage, cocoon color, cocoon shape etc.

Results and Discussion

Observation of egg characters

The moths of *A. gnoma* were collected from the agricultural mountainous area in Suwon, Korea. The moths were kept in an appropriate place for egg layings, and just after collection they laid about two hundreds of eggs on the sheet of paper prepared. About ten days later, the eggs were hatched, and the larvae just after hatching showed brownish-black body color. The morphology of the eggs and their some characters were evaluated (Table 1, Fig. 1). The post-stage embryo just before hatching broke the shell, bited and swallowed a part of the egg shell (Fig. 1 A-1 and Fig. 1 B-1). White mucous materials were attached inside the egg interspersedly (Fig. 1A-2, 3 and Fig. 1B-2, 3). Number of eggs laid per moth was 208 eggs, and hatchability was 93.8%. Longer and shorter diameter of the eggs were 2.04 mm and 1.83 mm, respectively (Table 1). Also the egg shape was shorter elliptic and the egg color was brownish-grey (Table 1 and Fig. 1). Generally, a domesticated lepidopteran such as the silkmoth *Bombyx mori* lays about 400 – 500 eggs, but the wild silkmoth *A. gnoma* has been found to lay about 200 eggs from this study (Table 1). The number of eggs laid by *A. gnoma* is less compared with that of *B. mori,* but is very similar to that of the wild Japanese oak silkmoth, *Antheraea yamamai* or the wild Chinese oak silkmoth *Antherae pernyi* (Akai and Shigeharu, 1990). *B. mori* has been bred

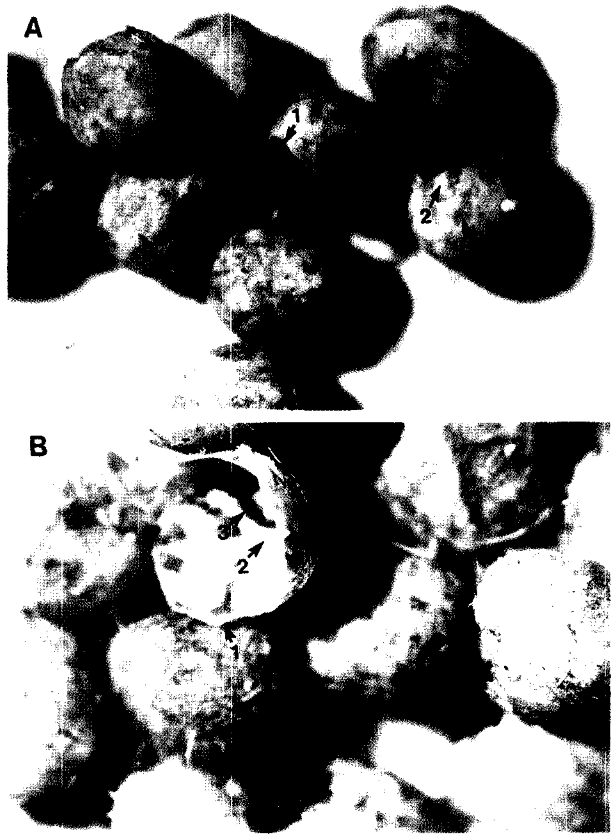

Fig. 1. Morphology of the *A. gnoma* eggs just after hatching. A-1, External shape of the eggs, in which a small part of the egg shell is removed by newly hatched larvae; A-2 and A-3, External appearance of the egg shell regions that are observed as transparent or not. Almost half of the egg shell was swallowed by the newly hatched larvae; B-2 and B-3, white materials are interspersedly distributed at the internal side of the egg shell.

Table 1. Morphology and hatchability of the eggs laid by the wild silkmoth *A. gnoma* reared under the laboratory conditions

No. of eggs laid per moth (eggs)	No. of eggs hatched (eggs)	No. of dead eggs (eggs)	Hatchability (%)	Size of eggs		Shape	Color
				Longer diameter (mm)	Shorter diameter (mm)		
208	195	13	93.8	2.04	1.83	shorter elliptic	grey white

for almost a century. Thus, the number of eggs laid has been improved up to 500 eggs in most breeds. On the contrary, the wild silkmoth *A. gnoma* of a wild life may have been adapted for other ways. There are many ways for mechanisms of hatching in insect species. Most insects force their way out of the egg by exerting pressure against the inside of the shell (Chapman, 1998). Lepidopteran larvae gnaw their way through the chorion and after hatching continue to eat the shell until the base is left (Chapman, 1998). In the case of this *A. gnoma*, it can be concluded to be identical with lepidopteran hatching mechanism because the newly hatched larvae of the worm in the study ate some or majority part of the egg shell (Fig. 1 A and B). Also, it is very interesting that some white mucous materials were remained inside the empty eggs hatched (Fig. 1 A and B). However, it is unclear why they remain inside the eggs after hatching.

Developmental profile of the *A. gnoma* during the larval stages

Feeding test of the newly hatched larvae *A. gnoma* onto the leaves of the several plants such as Japanese maple *Acer plamatum*, camphor tree *Cinnamomum camphora*, oak tree *Quercus acutissima* and cartor leaves *Ricinus communis* was performed as soon as they were hatched from the eggs. Oak tree *Q. acutissima* was newly identified as a host plant for *A. gnoma* larvae (Fig. 2 A, B, C, D). However, more detailed feeding test on another several plants will be required. The larvae just after hatching had many setae on the body surface and the body color was dark brown (not shown in the data). The body color of the 2nd instar larvae after the first larval ecdysis was changed to light brown similar to that of the newly hatched larvae (Fig. 2 A). The color was rechanged into a dark brown in the molting period (Fig. 2 B-1). In the 3rd

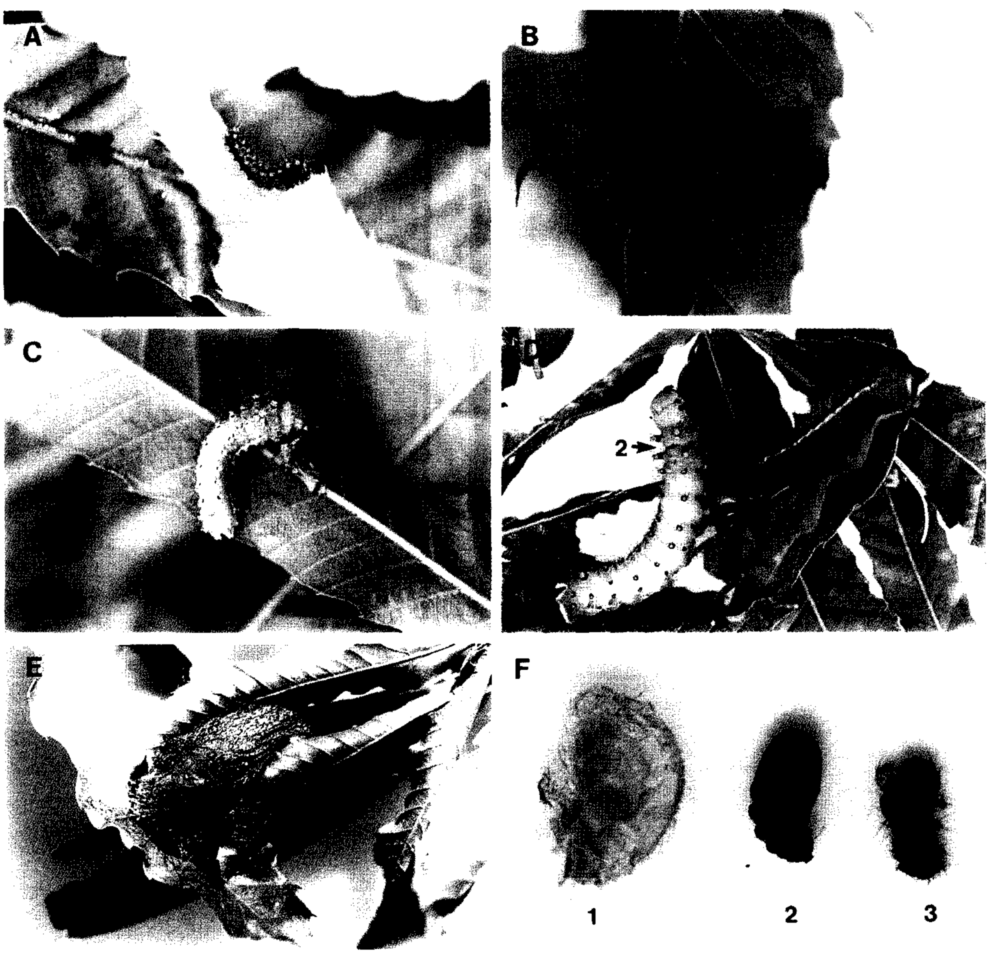

Fig. 2. Developmental profile of the wild silkmoth *A. gnoma* reared under the laboratory conditions. A, The 2nd instar larvae is feeding on the leaves of oak tree, *Quercus acutissima*; B, the 2nd instar larvae in molting period (B-1) and the newly ecdysed 3rd instar larvae (The color of the integument was changed into light yellowish green). C, The 4th larvae is feeding on its own cast just after shedding; D-1, the 6th instar larvae in molting period; D-2, and the newly ecdysed 7th instar larvae; E, The matured larva is spinning cocoon; F-1, cocoon shell; F-2, pupa; F-3, the cast of the matured larva metamorphosed to pupa.

instar larvae, however, the body color just after the 2nd ecdysis was surprisingly changed from dark brown to light yellowish-green (Fig. 2 B-2). Such a great body color change in the 3rd larval instar did not occur during the post-larval development. In addition to the observation of the amazing body color change in the 3rd instar, we observed that the 3rd instar larvae were feeding on his own cast just after shedding (Fig. 2 C). In the 3rd larvae just after shedding, the body color was light yellowish-green (Fig. 3 C). The larval body color before the 3rd instar was dark brown or light brown. This color change on the body surface is very interesting, and it is considered to be a morphological color change which is due to synthesis or degradation of pigments, and is consequently slow in the changing process of body color (Fuzeau-Braesch, 1985). This phenomenon is different from physiological color change which is due to a structural shift within the integument. Furthermore feeding on his own cast just after ecdysis is very interesting phenomena, even though all the individual larvae reared under laboratory conditions did not do so (Fig. 2 C). It can be considered in some cases that the feeding of its own cast will be helpful for compensating the ecdysed larval cast for the supply of nutrient in wild habitat. The newly hatched larvae continued to grow up to the 6th or 7th instar larvae (Fig. 2 D-1, 2). From this observation, the final larval instar is not fixed because it can be prolonged or shortened according to the enviromental situations that the worm is faced with. All the final larvae, regardless to the 6th or 7th instar larvae, spinned cocoons colored with brown by using oak tree leaves as their foot hold for cocooning and were metamorphosed into pupae (Fig. 2 E and F). Larval duration, body weight, body length and number of dead larvae are listed in Table 2. Larval duration in each instar was ranged from 4 days in the 1st instar to 14 days in the 7th instar, and whole larval duration was 46 days (for the larvae with the 6th instar as final larval stage) or 59 days (for the larvae with the 4th instar as final one). The larval body weights were ranged from 2.9 mg in the 1st instar to 2,390 mg in the 7th instar, and the increase rate between adjacent instars was highest between the 1st instar and the 2nd instar. The body lengths were ranged from 6 mm in the 1st instar to 43 mm in the 7th instar. The percentage of dead larvae to the newly hatched larvae was highest in the 1st instar, and it is thought to be attributed to non-feeding of the larvae for non-host plant during the identification of the host plant to the newly hatched larvae.

Table 3. Cocoon characters of wild *A. gnoma* reared under the laboratory conditions

Single cocoon weight (g)	Cocoon shell weight (eg)	Cocoon shell percentage (%)
1.65	31.3	18.9

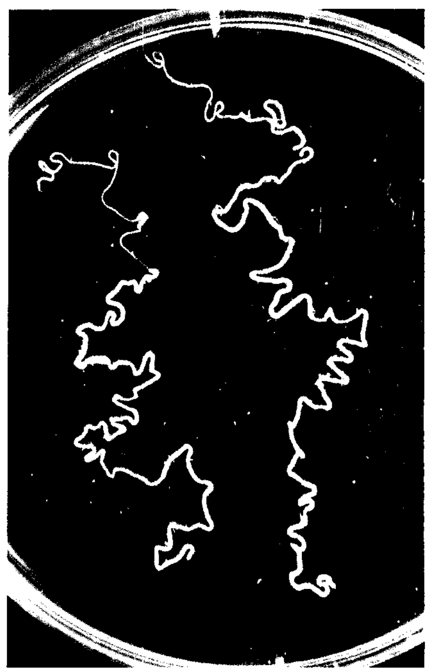

Fig. 3. The silk gland of the wild silkmoth *A. gnoma* larvae in the last instar. 1, Anterior silk gland; 2, middle silk gland; 3, posterior silk gland.

Table 2. Characteristics of larval development of the wild *A. gnoma*

	Larval instar							
	1st	2nd	3rd	4th	5th	6th	7th	
Larval duration (days)	7(1)[a]	4(1)[a]	4(1)[a]	7(4)[a]	10(2)[a]	13(4)	14(–)[a]	59
Body weight of larvae (mg)	2.9	16.5	54.7	187.8	586.7	1460.0	2.390	–
Body length of larvae (mm)	6	10	14	21	32	39	43	–
No. of dead larvae	179(91.8)[b]	4(2.1)[b]	–	–	–	1(0.5)[b]	–	–

a, Molting periods denoted in days; b, Percentage of dead larvae to the newly hatched larvae (see Table 1). The number of newly hatched larvae in Table 1 is 195 individuals.

Morphology of silk gland and cocoon characters. Single cocoon weight, cocoon shell weight and cocoon shell percentage were 1.65 g, 31.3 g and 18.9%, respectively (Table. 3). To compare the morphology of the silk gland among lepidopteran silkmoths, the silk gland of the wild silkmoth *A. gnoma* was dissected out (Fig. 3). Morphology of the *A. gnoma* silk gland was considerably distinct from that of domestic silkworm *Bombyx mori* (Doira *et al.*, 1978; Veda *et al.*, 1997), the wild silkmoth *Antheraea yamamai* (Akai and Shigeharu, 1990) and *A. permyi* (data are not shown). The fattest part of the *Bombyx* silk gland is the middle part with two curves, where the sericin protein is synthesized. The 2nd fattest part is posterior silkgland with many convolutions which can synthesize fibroin protein of major components consisting of silk filament (Kim *et al.*, 2001). However, in the silk gland of *A. gnoma* the middle and posterior silk glands are almost indentical in the thickness and number of convolutions or middle ad posterror pacts of in the each part (Fig. 3-2, 3). Thus, the shape of *A. gnoma* silkgland was very different from those of the other lepidopteran wild silkmoths.

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