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Some Features of Silk-producing Moths

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Summary

Species and distribution of main silk-producing moths in the world are reviewed. Main biological characteristics, properties of cocoon and silk of four important silk-producing moths, such as Bombyx mori, Antheraea pernyi, Antheraea yamamai, Philosamia cynthia ricini *are described. Applications of cocoon and silk of the four important silkmoths are also shown.*

Résumé

La répartition des espèces et les principales particularités des vers à soie sont recensées dans le monde. D'importantes caractéristiques biologiques, de propriétés du cocon et des vers à soie de quatre importantes productions de vers à soie tels que Bombyx mori, Antheraea pernyi, Antheraea yamamai, Philosamia cynthia ricini *sont décrites et leurs applications présentées.*

1. Species and distribution

Silk-producing moths are member of those insects which spin cocoons or silk for human use. In the world, there are about 400-500 species of silk-producing moths. As the surface texture of their cocoons and communal webs look like paper, leather or cloth, the idea to exploitate them is very old. In fact sericulture, the process of rearing these silk-producing moths in captivity or collecting their cocoons or silk in the field for human use, has been practised for thousands of years. There are however only 8-9 moths which produce silk of commercial value. Nowaday the domestic silkworm or mulberry silkmoth, *Bombyx mori* provides probably more than 99% of the silk in the world. It is believed to have been cultivated for about 5000 years in China and is used today around the world for textiles production, but also for educational and scientific studies. In contrast ,other silk-producing moths are called wild silkmoths or non-mulberry silkmoths. They are not reared in captivity, cocoons are collected from field populations. In some cases, some rearing is done outdoors with little or even no protection of larvae. Most wild silkmoths belong to the families Saturniidae, Notodontidae, Lasiocampidae and Pieridae (5). Names and - distribution of main silkmoths are summarized in Table 1.

Table 1. Species and Distribution of Main Silk-producing Moths

Species name	Distribution
I. Bombycidae	
Bombyx mori	Temperate zone, Subtropical and tropical zone
B. mandarina	China, Japan, Korea
II. Saturniidae	
Antheraea pernyi	China, Korea, India, Japan, Russia
A. paphia	India
A. yamamai	Japan, China, Korea
A. assamensis	Assam (India)
A. polyphemus	Massachusetts (U.S.A)
Philosamia cynthia ricini	India, China, Japan, Cuba, Egypt, France, Italy
P. cynthia	China, Japan, India, Korea, Indonesia
Attacus atlas	Southeastern Asia
Actias seleme	Southeastern Asia
Dictyopoea japonica	Japan, China
Eriogyna pyretorum	China, Vietnam, Burma, India, Malaysia
Saturnia boisduvali	China, Eastern Siberia
Rhodinia fugax	China, Japan
Hyalophora euryalus	California (U.S.A)
III. Notodontidae	
Anaphe venata	Zaire, Togo and Neighbouring Countries
A. infracta	Zaire, Togo and Neighbouring Countries
A. reticulata	Uganda
Epanaphe carteri	Cameroon
E. moloneyi	Zaire, Togo and Neighbouring Countries
E. vuilleti	Cameroon
IV Lasiocampidae	
Borocera cajani	Madagascar
Gonometa postica	Africa
G. ruforunnea	Botswana
Gloreria psidii	Mexico
Malacosoma incarvum azteam	Mexico
Pachypasa otus	Southeastern Europe
V. Pieridae	
Eucheira socialis	Mexico

2. Biological characteristics

2.1 *Bombyx mori*

The domestic silkworm, *Bombyx mori* produces at least one generation a year (7). Generation time varies with the silkworm variety or geographic site. In general, its oversummering and overwintering eggs are diapause and hatch in late of April of the next

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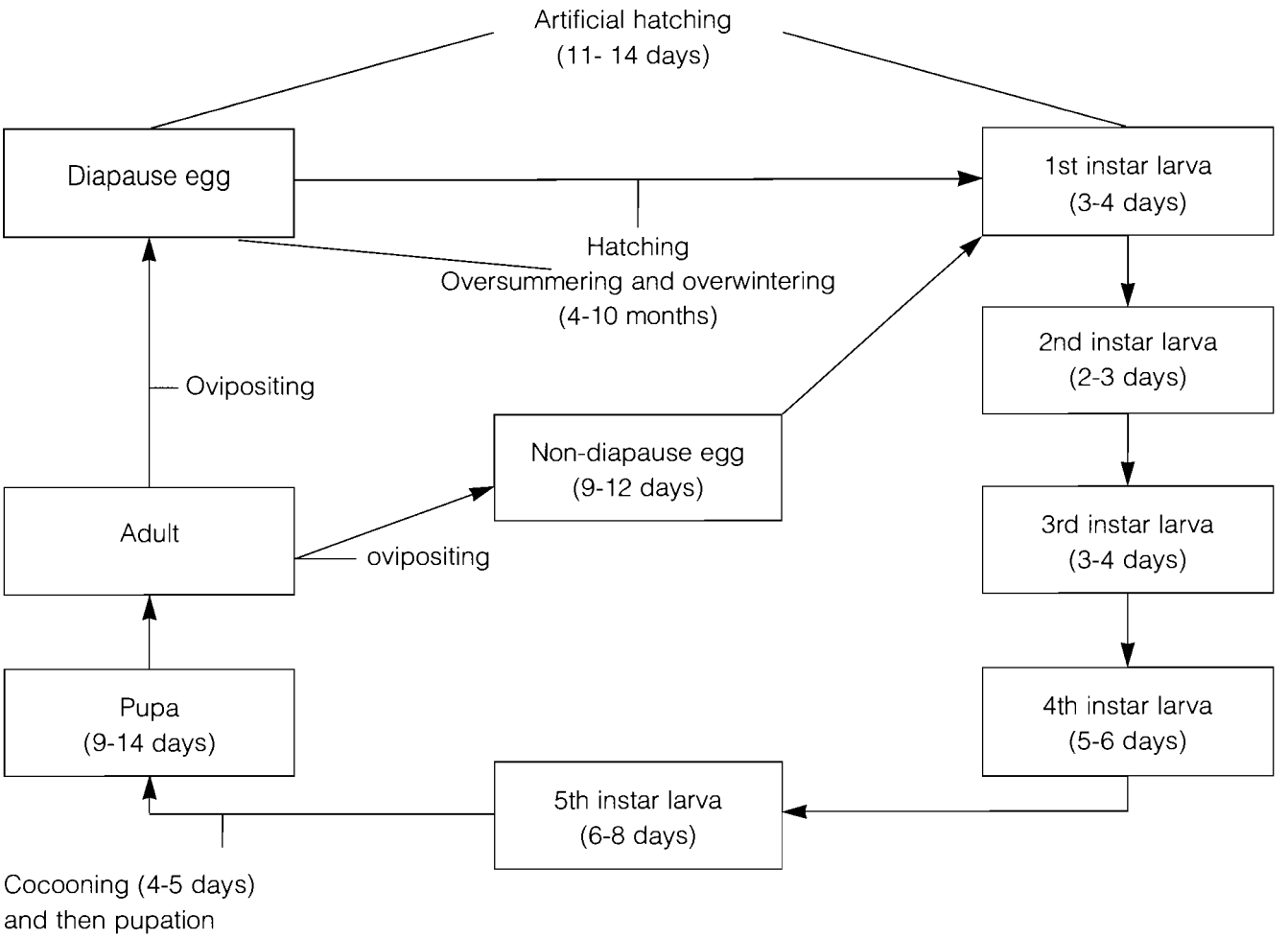

Fig. 1. Life cycle of *Bombyx mori* (7)

year. Diapause eggs could hatch after treatment with brine acid with specific gravity of 1.075 for 4.5-5.5 minutes under 46°C. The larvae mainly feed mulberry leaves. Each larva ingests about 20-25g fresh leaves during the whole larval period, and 85-88% of that quantity during the 5th instar or last instar. Its life cycle is summarized in Fig. 1

2.2 *Antheraea pernyi*

The Chinese oak silkworm or Chinese tussah silkworm, *Antheraea pernyi* produces two generations a year in the region north of 35° N and one generation to the south of this region. It overwinters as diapause pupa. The adults of monovoltine silkworm emerge, oviposit from March to April. Eggs hatch from early to mid April and larvae cocoon and pupate from mid to late May. Pupae then diapause until eclosion appears in late March and early April of the next year. As for bivoltine silkworm, in the overwintering generation the adults emerge and oviposit in early April. Eggs hatch from April to May and larvae cocoon and pupate from mid to late June. Adults emerge and oviposit from early to mid July. The second generation eggs hatch from July to August and larvae cocoon and pupate from mid to late September(4).

Larvae feed on more than 30 plant species of 11 families. They mainly favour *Quercus* plants such as *Q. acutissima, Q. liaotungensis, Q. mongolica, Q. variabilis* and *Q. dentata*. The younger larvae favour tender leaves but the older ones mature leaves. The total amount ingested by the larva is 30-35g fresh leaves in spring and 50-55g in autumn. In China the stadia of 1st, 2nd, 3th, 4th and 5th instar larva of the first generation are 7, 10, 9, 11 and 15 days, respectively, and those of the second generation are 6, 5.5, 5, 8.5 and 18 days. The suitable temperature and relative humidity (R.H.) are 17-25 °C and 85-90%, respectively. The male and female moths can mate as from the first day after emergence. Each female moth oviposits about 200-300 eggs in the whole adult period. Generally egg period lasts about 10 days. The proper temperature and relative humidity (R.H.) for egg hatching are 22-26 °C and 75-85%.

2.3 *Antheraea yamamai*

The Japanese oak silkworm, *Antheraea yamamai* produces one generation a year and overwinters as pharate first-instar larva in the egg shell. In Northeast China the hatching larvae appear in early and mid May. Larvae cocoon and pupate from late June to

early July. Moths emerge and lay eggs in early August. The fertilized eggs complete their embryonic development for about 10 days after oviposition. Pharate first-instar larvae do not hatch at once but diapause. In Japan, the silkworm also has one generation a year and overwinters as pharate first-instar larva, eggs hatch from late April to early May. Larvae cocoon and pupate in early July, then some moths emerge and oviposit in late July. Others however exhibit summer dormancy and lay eggs in late September (1). Diapause of pharate first-instar larva could be broken down after treatment with midazole, l-binzyle-5-[(e)-2,6-dimethy-1,5-heptadienyl]-imidazole (KK-42) and its analogs (6).

The fodder plants of the silkworm are chiefly *Quercus* plants e.g. *Q. fabri, Q. acutissima, Q. mongolica, Q. dentata*. Among them *Q. fabri* is regarded as the best one (3,8). Total ingested leaves amount to 30-40g fresh leaves. Under 20 °C and R.H.of 70 %, the stadia of 1st, 2nd, 3rd, 4th, 5th, instar larvae are 7, 7, 11, 12 and 17 days, respectively. The optimal temperature and relative humidity (R.H.) for 1st-2nd, 3rd, 4th-5th instar larvae are 29 °C, 27 °C, 25 °C and 75-80%, 70%, 60-65%, respectively. The moths mainly emerge during 19:00-21:00 hours and 5:00-6:00 hours of the next day. The optimal temperature for mating is about 12-19 °C. Over 20° C mating percentage is very low. Each moth lays 120-190 eggs during the whole adult period (2).

2.4 *Philosamia cynthia ricini*

The number of generation per year for *Philosamia cynthia ricini* varies with the region. Seven to eight generations per year are recorded in Southern China, four to six generations in Eastern China, three generations in Northern China and two to three generations in Northeast China (4).

The larvae feed on leaves of *Ricinus communis, Manihot utilissima, Hetropana fragrans, Carica papaya, Evodia fraxinifolia, Ailanthus excelsa* or *Coriaria sinica. R. communis* is widely cultivated in China. Each larva consumes about 30-35g *R. communis* fresh leaves. The total larval stadium is 23-30 days under 15-20 °C,18-23 days under 20-25 °C and 14-18 days under 25-30 °C. A female lays about 500 eggs during the whole adult period.

3. Cocoon and silk

3.1 *Bombyx mori*

The cocoon of mulberry silkworm, *B. mori* consists of four parts i.e. cocoon floss, cocoon shell, pupal body and cast skin, of which the cocoon shell is for reeling. Depending on the shape, cocoons are classified as elliptic, peanut-shaped, spindle-shaped and globe-shaped. The prevailing colour is white, but yellow, red or green also exists. Properties of cocoon and silk are summarized in Table 2.

Table 2. Cocoon and silk properties of *B. mori*

Properties	Spring	Summer and Autumn
Cocoon weight (g)	2.0-2.5	1.5-1.8
Cocoon shell weight (g)	0.45-0.55	0.23-0.30
Silk weight (g)	0.35-0.45	0.22-0.27
Cocoon filament length (m)	1000-1400	700-1000
Cocoon filament size (denier)	2.5-3.0	2.0-2.7

B. mori silk is widely used for producing various silk fabrics such as dresses, kimonos, quiltcovers and ties. By-products of cocoons such as inferior cocoon, unreelable cocoon, pupal shirt, cocoon floss and waste filaments are utilized as raw materials in cosmetics, foodstuffs and in the electric industry.

3.2 *Antheraea pernyi*

In *A. pernyi* the shape of cocoon is long-elliptic. For bivoltine silkworm, length and width of spring cocoon are 4.2-4.8 cm and 2.1-2.5 cm, respectively, those of autumn cocoon are individually 5.1-5.5 cm and 2.4-2.5 cm. For monovoltine silkworm, those are 4.0-4.2 cm and 2.0-2.1 cm, respectively. The whole cocoon weights of monovoltine and bivoltine silkworm are 8-9 g and 9-10 g. Their cocoon shell and cocoon filament weights are 0.7-1.0 g and 0.60-0.80 g, respectively. Its filament is thicker, more resistant to acid and alkali than that of mulberry silkworm.

The long filaments are used for weaving silk fabric as cloths and ornaments. It can also be mixed with cotton, flax or sheep wool for making various cloths. It is also used in the electric industry.

3.3 *Antheraea yamamai*

In *A. yamamai* the cocoon is long-elliptic. Its colour is mainly green but light green or golden yellow also exists. The length and width of the cocoon are 4.5-5.3 cm and 2.3-2.7 cm. The whole cocoon weight, cocoon shell weight are 2.4-3.6 g and 0.19-0.35 g, and they vary with the season, fodder plants and temperatures.

This silk has great cultural and ritualistic significance. It is utilized for producing small tablecloths, neckties, obis (belts) and cloths for Buddhist altars. Many of these fabrics are very costly.

Differences of cocoon and silk characteristics between *B. mori, A .pernyi* and *A. yamamai* are summarized in Table 3.

Table 3. Cocoon and silk characteristics of the three important silk-producing moths

Characteristics	*B. mori*	*A. pernyi*	*A. yamamai*
Cocoon colour	White	Brown	Green
Whole cocoon weight (g)	2.0	8.0	3.5
Cocoon shell percentage(%)	24.0	10.0	9.0
Cocoon filament length (m)	1300-1500	600-700	500-600
Cocoon filament weight (g)	0.38	0.26-0.30	0.30-0.35
Cross shape of filament	Round triangle	Depressed triangle	Depressed triangle
Tenacity of silk (g)	10	20	25
Elongation of silk (%)	22	32	53
Size of silk (denier)	2.8-3.0	5.0	5.0-6.0

3.4 *Philosamia cynthia ricini*

The cocoon of *P. cynthia* ricini is spindle-shaped. Its colour is white, grey yellow, cream-coloured or red brown. Its length and width of cocoon are 3.5-4.5 cm and 1.5-1.8 cm. The whole cocoon weight, cocoon shell weight, filament length and filament size are 2.3-3.2 g, 0.35-0.49 g, 300-567 m and 2.35-2.36 denier, respectively (4).

The silk is only used for producing spun-silk fabrics. It can be mixed with the silk of *B. mori* or *A. pernyi* and plant fibres.

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