Silkworm Rearing

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FAO Agricultural Services: Bulletin 73/2

Published by: Food and Agriculture Organization of the United Nations
Publications Division
Via delle Terme di Caracalla
00100 Rome
Italy

Available from: UNIPUB
4611-F Assembly Drive
Lanham MD 20706-4391
U.S.A.

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FAO
AGRICULTURAL
SERVICES
BULLETIN

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FOOD AND
AGRICULTURE
ORGANIZATION
OF THE
UNITED NATIONS
Rome, 1988

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M-24
ISBN 92-5-102692-0

FOREWORD

Silk, "the queen of fibres", is admired by people the world over, and silk and silk products are always in great demand. Endowed with favourable conditions for mulberry cultivation and silkworm rearing, the Asia-Pacific Region has great potential for sericulture; many developing countries in this region are eager to tap this potential. In order to meet their needs and promote development of sericulture in the region, the Government of the People's Republic of China and the Food and Agriculture Organization and the United Nations Development Programme (FAO/UNDP) have jointly established the Regional Sericulture Training Centre for the Asia-Pacific Region (RSTC) in the South China Agricultural College, Guangzhou, for training professionals in sericulture in 200-day sessions.

These manuals, which offer an outline of sericultural science and technology, have been compiled as teaching materials for RSTC participants. In view of the specific circumstances of the participants, the manuals stress technical expertise for sericultural production in tropical and sub-tropical areas and introduce China's unique experience in silkworm rearing. It is hoped that the manuals will be useful to sericulturists not only in the Asia-Pacific Region but also in other parts of the world.

The authors wish to express their deep appreciation to FAO for making possible the publication of these manuals and place on record their special thanks to Mr. R. Karam for his invaluable advice. They also wish to thank the Sericulture Research Institute of the Academy of Agricultural Sciences of China and the Sericulture Department of Zhejiang Agricultural University for their valuable comments on the manuscripts.

The manuals are a joint effort. The many co-authors and translators from Chinese to English are listed below:

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58. [illegible]arketing improvement in the developing world, 1984 (E*)
59. Traditional post-harvest technology of perishable tropical staples, 1984 (E*)
6[illegible]. The retting of jute, 1984 (E* F*)
[illegible]. Producer-gas technology for rural applications, 1985 (E* F*)
62. Standardized designs for grain stores in hot dry climates, 1985 (E* F*)
63. Farm management glossary, 1985 (E/F/S*)
64. Manual on establishment, operation and management of cereal banks, 1985 ([illegible] F*)
65. Farm management input to rural financial systems development, 1985 (E* [illegible]
[illegible]. Construction of cribs and storage of maize, 1985 (E*)
67. [illegible] skins improvement in developing countries, 1985 (E* F* S*)
68. Tropical and [illegible], 1986 (E*)
68/2. Honeybee mites and their control: a [illegible]cted annotated bibliography, 1986 [illegible])
68/3. Honey and beeswax control (E***)
68/4. Beekeeping in Asia, 1987 (E*)
68/5. Honeybee diseases and enemies in Asia: [illegible] practical guide, 1987 (E*)
69. Construction and operation of small solid [illegible]all bins, 1987 (E*)
70. Paddy drying manual, 1987 (E*)
71. Agricultural engineering in development [illegible]Guidelines for establishment of [illegible]llage workshops, 1988 (E*)
72/1. Agricultural engineering in developmen[illegible] — Vol. 1, 1988 (E*)
72/2. Agricultural engineering in developme[illegible] — Vol. 2, 1988 (E*)
73/1. Mulberry cultivation (E***)
73/2. Silkworm rearing, 1988 (E*)

Availability: October 1988

Ar	—	Arabic	* Avai[illegible]ble
E	—	English	** [illegible] of print
F	—	French	*** [illegible] preparation
S	—	Spanish	
Multil.	—	Multilingual	

The FAO Agricultural Services [illegible]lletins can be [illegible]sed locally through FAO sales agents or directly from Distribution and Sales Se[illegible]tion, FAO, Via delle Terme [illegible]Caracalla, 00100 Rome, Italy.

M-24
ISBN 92-5-102692-0

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Significance of Sericulture Development

Insects of the order Lepidoptera that produce silk that can be utilized by man include mulberry silkworms (Bombyx mori), tussah silkworms (Antheraea), eri silkworms (Philosamia), and others. The focus of this publications is the mulberry silkworm.

Domesticated from Bombyx mandarina over a long period of time, the Bombyx mori has developed into a great variety of geographical species through differentiation, selection and breeding.

The silk produced by the mulberry silkworm and its byproducts can be used for many purposes. The filament is thin and long, light and soft. It is well known for its water absorbency, dyeing affinity, thermotolerance, insulation properties and lustre. It is a raw material good not only for producing precious fabrics, but also for making parachutes, tire linings, electric insulation materials, artificial blood vessels and surgical sutures. Silkworm pupae pressed for an oil from which soap and plasticizers can be made and to extract hydrolyzed protein, amino-acids and vitamin B_2. Muscardined silkworms or pupae can be used in Chinese medicine. Phytol, an important raw material that is used to make vitamin E and K, and cholrophyll can be extracted from the faeces of silkworm. The faeces can also be used to make activated carbon and acid-resistant plastic sheets and serve as the raw material for plastic substances. Rich in protein, silkworm faeces are good feeds for fish, pigs, cattle and sheep. Finally, they are superb organic manure.

Mulberry cultivation is indispensable to silkworm rearing. The mulberry tree itself gives a fine wood. Its branches can be used to make farm tools and its bark to make high-grade paper and artificial fibre. The fruit is edible and can be used to make wine. Every part of the mulberry tree is of medicinal value.

Mulberry growing and silkworm rearing are considered a sideline in most rural areas. In some areas where the silkworm can be raised all year round, silkworm rearing is actually a specialized production activity. The silkworm industry plays an active part in the development of the national economy. It stimulates the rural economy, promotes the overall development of agriculture, forestry, animal husbandry, sideline occupations and fisheries; it spurs the development of local light industry and helps to expand trade.

1.2 The Origin and Spread of Sericulture

China is the cradle of sericulture. It was the first country in the world to rear silkworms with mulberry leaves, reel cocoons and weave silk fabrics.

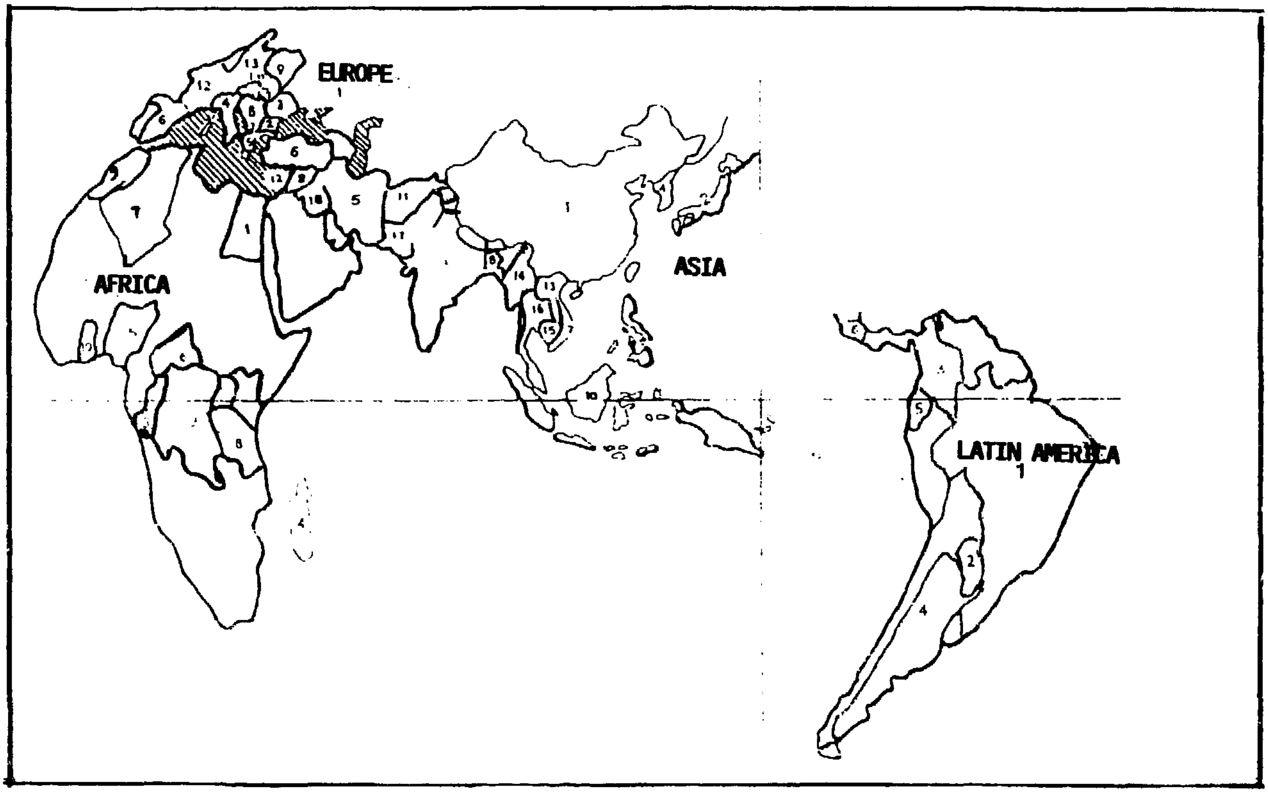
China has a history of more than 5 000 years in sericulture. China was known in antiquity for producing large amounts of silk fabrics. The Greek and Romans called China "Seres", meaning the country of silk. During the West Han Dynasty (206 BC-AD 25), envoys bearing gifts of silk fabrics were twice sent to establish ties with countries west of Pamir. The next thousand years saw large amounts of silk fabric sent to Central Asia and Europe over what was called the "Silk Road".

Longer than 10 000 km, in ancient times the Silk Road was a road for friendship and cultural exchanges between China and Central Asian countries. It began from the current Shaanxi Province, passing through Kansu Province, Xinjiang Autonomous Region and over Pamir to Afghanistan and Iran. The other route went through the southern parts of the USSR to Central Asia and reached the Mediterranean countries.

Silk was also transported by sea, first reaching the Arabian Gulf and Arabian Sea coast, then spreading out. In the ninth and eleventh centuries, silk had spread to Egypt, the coast of North Africa, Spain and Sicily. It came to Italy in the twelfth and thirteenth centuries, but did not reach France until the fifteenth century. The Russians began to rear silkworms in the southern regions of Russia during the time when the Silk Road was prospering and developing. It was only in the tenth century when Russia had had more dealings with Greece that sericulture prospered in Russia. Sericulture spread from China to Korea about 3 000 years ago. Korea, in turn, introduced it to Japan 300 years later. Sericulture was introduced to India and the Indo-China peninsula around the beginning of the Christian era. Later, it spread to Indonesia. Sericulture was introduced to the Americas about 1522 AD, when Spain conquered Mexico. The Spanish rulers encouraged people to grow mulberry and to rear silkworms on the outskirts of the cities. Later, sericulture spread to countries in North and South America, such as the USA, Peru and Brazil.

1.3 The World Distribution of Sericulture and its Present Situation

Sericulture's long history spans several thousand years and embraces more than 50 countries. Different conditions in social and economic development have meant variation in the rise and fall of sericulture in different countries. In general, silk production has been advancing since the 1960s: the total output of mulberry silk has increased and silkworm rearing areas have expanded. The main silk producing regions are distributed in the temperate and sub-tropical zone in Asia, from latitude 20°N to 40°N. The largest silk producers in the world are China and Japan, which produce two-thirds of the world's output of cocoons, followed by India, the USSR and the Republic of Korea (Figure 1-1 and Table 1-1).



Asia:	1. China 2. Japan 3. India 4. Korea 5. Iran 6. Turkey 7. Viet Nam 8. Bangladesh 9. Syria 10. Indonesia 11. Afghanistan 12. Lebanon 13. Laos 14. Burma 15. Kampuchea 16. Thailand 17. Pakistan 18. Iraq
Europe:	1. USSR 2. Bulgaria 3. Romania 4. Italy 5. Greece 6. Spain 7. Hungary 8. Yugoslavia 9. Poland 10. Albania 11. Czechoslovakia 12. France 13. Germany
Africa:	1. Egypt 2. Zaire 3. The Congo 4. Madagascar 5. Nigeria 6. Central African Republic 7. Algeria 8. Tanzania 9. Morocco 10. Ghana
Latin America:	1. Brazil 2. Paraguay 3. Colombia 4. Argentina 5. Ecuador 6. Costa Rica

Figure 1-1 World distribution of sericulture

Table 1-1

Types of silk producing countries and regions in the world

Types	Regions and Countries
(1) Self-sufficient: Silk produced only for their consumption	Asia: India, Pakistan, Bangladesh, Sri Lanka, Thailand, Iran, Afghanistan, Turkey, Syria, Lebanon, Burma, Laos, Indonesia Africa: Egypt, Madagascar Europe: USSR, Poland, Hungary, Romania, Yugoslavia, Denmark, Greece
(2) Stress on export: More than half the total output for export	Asia: China, DPR of Korea, Republic of Korea, Viet Nam Latin America: Brazil, Paraguay Europe: Bulgaria
(3) Partly imported: Production cannot meet demand; one-third of silk used is imported	Asia: Japan Europe: Spain
(4) Processing of reselling: Countries produce no or little silk. Imported raw silk is partly for home use and partly for export after processing	Countries producing some: Europe: Italy Countries producing no silk: Europe: Switzerland, Federal Republic of Germany, France, U.K.
(5) Pure consumers: Countries producing no silk and which rely on imports	North America: USA
(6) Developing countries: Countries that have just made a start or worked out a plan for the development of sericulture	Asia: Philippines Africa: Algeria, Niger, Kenya, Côte d'Ivoire, Malawi, Zaire, Tanzania, Ghana, Central African Republic, Morocco Latin America: Argentina, Colombia, Ecuador, Costa Rica

1.4 World Trends in the Development of Silk Production

Mulberry silk is superior in quality to any other textile fibres. Up to now, no artificial synthetic fibres have been able to replace it. According to the statistics of the world textile fibre output in 1977, the world textile fibre yield amounted to 25 million metric tons, 54 percent of which was natural fibre. The output of mulberry silk was 49 000 metric tons, which accounted for 0.19 percent of the total fibre yield. The world average silk consumption rate per caput was only about 12 grams. The average consumption rate is 14 grams per head for the five European countries (U.K., France, Italy, Switzerland and Federal Republic of Germany) and 217 grams for Japan. At present, world silk production is far from sufficient to meet demand. Japan, once the largest silk producing country, now has to import raw silk and the United States, the largest consumer of silk, has increased its demands. As the living standards improve, the silk industry advances. (see Table 1-2).

1.5 Scope of Study and Objectives of this Publications

Silkworm rearing is an applied science based on the theory of anatomical physiology of the silkworm and silkworm diseases. There are two patterns of silkworm rearing with different purposes: silkworm rearing for egg production and silkworm rearing for silk production. The former aims at producing high-quality and disease free silkworm eggs. These will be dealt with in the volume on silkworm egg production. The latter is concerned with cocoon production for reeling purposes, emphasizing maximum economic benefit. In addition to study of basic science, basic theories and advanced technology, attention must be paid to the interrelations of the following three triads: (1) rearing techniques, mulberry leaves and silkworm eggs; (2) agriculture, industry and commerce; (3) techniques, management and economy. In order to attain stable and high cocoon production, better quality and low consumption, and for energy saving and high economic value, this publication can be considered as a basic text.

Table 1-2

World output of fresh cocoons and raw silk (1981)

	Fresh Cocoons				Raw Silk		
	No.	Output (ton)	% of Total	% of 1980	Output (bale)	% of Total	% of 1980
China	1	231 640	50.4	95	373 950	43	95
Japan	2	64 800	14	87	247 000	28	92
India	3	62 000	14	117	75 000	9	114
USSR	4	49 000	11	100	73 500	9	100
Republic of Korea	5	13 500	3	68	40 400	5	74
Thailand	6	8 600	2	100	11 400	1	100
Brazil	7	8 200	2	85	16 400	1	84
PDR of Korea	8	6 500	1	100	11 500	1	100
Iran	9	3 500	1	100	7 200	1	100
Bulgaria	10	2 100	0.5	100	4 200	0.5	100
Turkey	11	2 050	0.4	128	4 800	1	112
Others		5 080			7 010		
TOTAL		456 970	100	97	872 360	100	95

CHAPTER 2

THE SILKWORM AND THE ENVIRONMENT

2.1 Life Cycle of the Mulberry Silkworm

In the taxonomic classification, the mulberry silkworm belongs to:

Phylum	-	Arthropoda
Class	-	Insecta
Order	-	Lepidoptera
Family	-	Bombycidae
Genus	-	Bombyx
Species	-	Mori

It is a completely metamorphic insect, undergoing four stages of growth and development - egg, larva, pupa, moth - to complete one generation. In the first stage, the embryo grows and develops into a larva. The second is a vegetative stage, in which the larva takes nutrients in from feed. The third is a metamorphic stage in which the larva becomes adult. In the last stage, known as the reproductive stage, the moths will mate and the female moths will lay eggs, producing the next generation. It is only in the larval stage that the silkworm takes food, grows enormously and accumulates nutrition for the moth stage.

In order to adapt itself to the changing environments, the silkworm has two characteristics. One is the number of broods per year, known as "voltinism" or diapause. Silkworms producing only one generation in a year are called monovoltines. Those that produce two generations in a year are called bivoltines and those that produce more than three generations, multivoltines.

The other characteristic is moulting or exuviation. The current races in production are mostly four moulters. There are also three moulters and five moulters. Voltinism and moulting depend upon heredity. However, they can be changed with changes in environmental conditions, feeding days, the body weight of the silkworm and the quantitative characteritics of cocoons, etc. For instance, if we provide low temperature at the larval stage, the number of moults will be reduced. As to voltinism, if the larva is reared in darkness and low temperature from the first moult to the third moult, then changed to high temperature and brightness until mounting, the voltinism will be increased.

In the larval stage, the period from the newly hatched larva to the first moult is called the first instar. The next instar begins with newly moulted larva. Therefore, the second instar follows the first moult, the third instar follows the second moult and so on. At the end of the fifth instar, the larva becomes mature. Silkworms in the first three instars are called the young larvae and in the fourth and fifth instars, the grown larvae. The growing period in every instar can be sub-divided into four stages: (1) the poor-appetite stage; (2) the good-appetite stage; (3) the gluttonous stage; and (4) the premoulting stage.

Different instars or stages call for different environmental conditions. Even in the same stage, the demands for environmental conditions vary with the species. Proper treatment should be given to the living environment according to different requirements of the species, so that the worm can grow normally and to maturity. Thus, the aim to make the worm secrete silk and to produce a cocoon, can be realized.

2.2 Meteorological and Environmental Conditions

Silkworms are closely affected by meteorological and environmental conditions. Under a controlled environment, through lengthy domestication, the mulberry silkworms have shared common living habits. Yet, due to the fact that different varieties are bred under different specific conditions, they react differently to external meteorological conditions. On the other hand, such environmental features as temperature, humidity, air, light, feed and pathogens, can exert a combined effect upon the physiological activities of the silkworms, thus affecting their life. Temperature has the most important role in their life cycle. Humidity, airflow and light, are only of secondary importance. They are, of course, related to and conditioned by each other. The task of sericulture is to study various effects exerted by different meteorological and environmental conditions upon the physiological functions of the worm. Appropriate feeding measures are taken in order to ensure the sound growth of the worms and the best possible crop of cocoons.

Temperature: Mulberry silkworms are poikilothermic (cold blooded). Although the silkworm does not possess a complete central nervous system to regulate the body temperature, it has a primitive mechanism that can regulate body temperature by itself. The body temperature conforms to outside temperatures. Generally, before the fourth instar, body temperature is lower than the air temperature. From the fifth instar on, it is higher. Within the same instar, body temperature is lower at the beginning and rises as the worm matures. When growth attains its highest peak, body temperature rises to a higher level then begins to drop. The body temperature of the worm comes from the heat energy produced by various nutrients taken from the mulberry leaves in a series of biochemical processes, which are involved in actions by different enzymes in the body. Body temperature is lowered by evaporation and conduction, and by radiation and convection. Within a certain range, body temperature rises as air temperature rises. In the meantime, the activation of the enzymes in the worm's body is increased, the physiological activities are accelerated, the blood circulation quickened, the pulse rate of the dorsal blood vessel and the respiration depth is increased. In a unit time (within a certain period of time), the intake of mulberry leaves by the worm increases and digestion, absorption and excretion of the worm increases accordingly. When the temperature is too high, the activation of enzymes is slackened or even stopped. When the temperature is very low, the activation of enzymes becomes weak, but does not disappear. At this time, the worms become sluggish, eat less, develop slowly and lose weight.

The worm's growth and development call for a certain optimum temperature. Generally, in the young larval stage when the worm begins to develop, the minimum temperature should be 7°C and the maximum temperature 40°C. The temperature suitable for the normal and development ranges from 20°C to 30°C. The rearing temperature is highest in the first and second instars, but it gradually decreases about 0.5°C to 1°C for each instar as the instar advances. At the beginning of each instar, the rearing temperature should be raised in the poor-appetite stage and lowered to some extent in the good-appetite and gluttonous stages, and then raised again in the premoulting stage. The rearing temperature must be lowered during moulting, but raised in the pre-maturing stage. In silkworm production, the rearing temperature should vary according to species, stage of development, nutritional conditions and rearing seasons. In the southern provinces of China, the rearing temperature provided is shown in Table 2-1.

Table 2-1

Standard rearing temperature in South China

Crops	Varieties	First-third instars	Fourth-fifth instars
1	Bivoltine x bivoltine	27-26°C	26-24°C
2	Bivoltine x bivoltine Bivoltine x polyvoltine	28-27°C	27-26°C
3-6	Polyvoltine x bivoltine Polyvoltine x polyvoltine	30-28°C	28-27°C
7	Bivoltine x bivoltine Bivoltine x polyvoltine	29-27°C	27-26°C

Humidity: Humidity has the effects on the growth and development of the worm in two respects. It exerts a direct effect on water evaporation in the worm's body, regulation of the body temperature and metabolism. It also influences the withering rate of mulberry leaves, the worm's appetite and the sanitation of the rearing beds.

In a very humid environment, the body temperature of the worm rises, blood circulation quickens, pulse rate increases and depth of respiration depth heightens. In the meantime, the leaf intake by the worm and the digestion and digestibility tend to increase accordingly. Rearing duration is shortened, which is more evident in the young ages than in the late ages. The mounting and pupating periods are longer in humid conditions than in dry conditions.

Humid air helps to keep the mulberry leaves fresh. With a sufficient supply of fresh leaves, silkworms can be well fed and grow rapidly. However, the water evaporation in the body will be restricted and the worm's resistance to diseases weakened. Particularly in hot weather, high humidity will facilitate propagation of pathogens on the rearing beds, which increases the incidence of diseases. When the air is dry, the mulberry leaves wither rapidly, which reduces the worm's leaf intake. Under dry air conditions, the water evaporation in the worm's body increases considerably. Hence, the water supply in the body may not meet the demands affecting the metabolism, digestion, absorption and utilization of the nutrients by the worms. In this case, the silkworms become smaller and weaker and the cocoons are smaller.

The optimum humidity for rearing silkworms varies with stage of development, breed, toughness or tenderness of the mulberry leaves and water content. Since the worm obtains water mainly from mulberry leaves, when the leaves are high in water content, the worm has more water in its body. Fresh leaves contain about 75 percent water. During the time from the first feeding stage to the first moulting stage, the water content gradually increases from 70 percent to 85-90 percent in the newly hatched worms.

The water content rate in the body remains almost the same between the second and fourth instars. Contrary to the first instar, the fifth instar attains its highest water content rate at the newly moulted stage. Later, it gradually comes down. In the maturing stage, the water content rate descends to the level of the newly hatched worm. Regarding the water required for physiological functions of the worm, the proportion of accumulated water in the body of the first instar exceeds that of the mulberry leaves, whereas for the fifth instar, particularly in the late stage, the water content rate of the body drops below that of the mulberry leaves. Hence silkworms absorb more water from mulberry leaves in the young ages than in the late ages, showing a higher humidity tollerance when they are young. More fresh leaves at a high water content rate should be provided for the young worms. In the same instar, higher humidity is needed in the earlier stages than in the late stage. The optimum humidity should be in the range of 80-90 percent at the onset of the first instar, with a reduction rate of 50 percent for each instar. The optimum humidity for the late ages is in the range of 60-70 percent, which should be further adjusted according to breeds, atmospheric conditions and nutrition. In general, pure lines and monovoltines require lower temperatures than bivoltines at the same stage. Therefore, the optimum humidity should be adjusted in accordance with concrete conditions (Table 2-2).

Table 2-2

Relationship of the rearing humidity to larval duration and health

Rearing humidity (%)	Rearing temperature (°C)	Larval duration (day:hour)	Mortality (%)
60	25	25:1	20.1
75	25	21:23	14.5
90	25	20:11	25.3

Air and Airflow

Air: The freshness of the air can be determined by the CO_2 content. In addition to the existing 0.03-0.04 percent CO_2 in the air, CO_2 in the rearing room comes from the following sources: the burning of charcoal to raise the temperature; the expiration of workers and silkworms; the fermentation and breakdown of the leaves; and the worms' excrements. All of these cause CO_2 concentration in the room to increase continuously.

If the CO_2 is too dense and remains for too long, it will harm the growth and development of the worm. Generally, the harmful effects are less for the young ages than for the late ages. In the same instar, the resistance of the worm to diseases is the highest after moulting, and is then gradually reduced until the gluttonous stage, which is the least resistant stage. Resistance increases again when the worm reaches the moulting or maturing stage. When the CO_2 in the air exceeds 2 percent and remains so for more than two hours, it will exert adverse effects on the worm. The worm will vomit its intestinal juice when in contact with 12-13 percent CO_2 in the air and will die from continuous contact with CO_2 of 15 percent. Under normal conditions, the CO_2 cannot exceed 1 percent due to the exchange of air from indoors to outdoors. In the late ages, harm from CO_2 can be avoided by adopting the openside rearing system.

Besides CO_2 and water vapour, such toxic gases as CO, SO_2, NH_3, and HF, can also harm the worm when amounts pass their permissible limit. Oils, odours, smoke from burning firewood and other chemicals (DDT, HCH, SYSTOX), which produce sporadic gases are also harmful to the worm.

Airflow: Airflow helps to exchange air from indoors to outdoors or from outdoors to indoors. It also regulates temperature and humidity and has a particular effect on the evaporation of water in the silkworm's body, indirectly affecting the body temperature, the metabolic balance of the water in the body and the feeding value of the leaves.

Optimum airflow helps to evaporate the water in the body, promotes the drop in body temperature and assists in eliminating humid air. In high temperatures (over 28°C) and high humidity (85 percent), an airflow of 0.02-0.03 m/s in the room will help to eliminate the evaporating heat, lessening the damage caused by high temperatures and humidity. In low temperatures (below 20°C) and dry environments (50 percent), an airflow is harmful to the worm. Therefore, it is necessary to maintain a weak airflow in the young ages, and a somewhat stronger airflow in the late ages. Airflow is especially needed for the fifth instar. The ideal velocity is 0.1-0.3 m/s. When the room temperature and the humidity are too high, the velocity of airflow can be controlled within a range of 0.3-0.5 m/s.

Light: The newly hatched and first instar worms are phototactic. In the larval period, the worm's phototaxis decreases as it grows up. In the same instar, phototaxis is stronger after moulting and weaker at the gluttonous and premoulting stages. Mature worms are negative phototactic. The silkworm's phototaxis varies with different kinds of light.

Light can influence the development of the silkworm when the temperature is above 25°C. This effect is more obvious in the first through fourth instars than in the fifth instar, in which light can promote the worm's growth. At low temperatures, light does not inhibit the worm's growth; instead, it promotes its growth. In order to have a uniform development of the silkworms, direct or one-sided light on the rearing bed should be avoided. Diffused light and natural light, dim during the day and dark at night, are preferable.

2.3 Silkworm Feeds

Elements of the mulberry leaf and changes in quality: Mulberry leaves are good for the silkworm, which through digestion and absorption, takes nutrients from them for its normal growth and development. From the view point of chemical analysis, the principal elements of mulberry leaves are water and dry matter, the latter consisting of protein, carbohydrate (including soluble carbohydrate and cellulose), fat, inorganic salt and vitamins. All these elements are essential nutrients for the physiological functions of the worm. However, their contents vary greatly with the effects of external and internal factors, such as variety of mulberry trees, the position and maturity of the leaves, soil texture, fertilization conditions, photoperiod and seasons. Sometimes, even the type of training of mulberry leaves, the time for plucking leaves and conditions of storage, cause variation.

Varieties of mulberry trees: Early budding mulberry varieties mature earlier than middle budding or late budding varieties. Early matured leaves contain fewer nutrients but more water. For instance, the "Lun 40" variety in Guangdong contains more water but less carbohydrate, matures faster and is more easily hardened than the common "Jing" variety. Hence it is suitable for rearing worms of young age.

Cultivating conditions: By cultivating conditions for mulberry trees, we mean soil conditions, planting density, training patterns, fertilization conditions and management. These conditions have a complex effect on changes in leaf quality.

Soil conditions: When mulberry trees are grown in loam, the leaves contain more water and protein but less carbohydrate, and they mature slowly. The opposite occurs in sandy loam, which is preferable.

Planting density: In South China, mulberry trees are usually planted at densities of 6 000-10 000 trees/mu (1 hectare = 15 mu). If over planted, they will have more branches, which reduces photosynthesis. As a result, the leaves will contain too much water and mature late. The leaf blades will be soft and thin, the leaf quality degraded. Silkworms fed with this kind of leaf have low vitality. The cocoon yield and cocoon shell weight of 10 000 larvae will decrease.

Fertilizer application and management: Mulberry trees planted with insufficient fertilizers grow badly. The leaves contain less moisture and nutrients, mature early and are easily hardened. In a mulberry tree field where nitrogenous fertilizer is over applied (especially when fast working nitrogen is applied), the leaves contain much moisture and protein and mature late, and the leaf quality is soft and thin. Worms fed on these leaves have low vitality, contact diseases easily and their cocoon layers are thin. In extended cloudy and rainy periods, the leaf quality becomes still worse because photosynthesis is insufficient.

Training patterns: Low-trunk trees contain more moisture and protein but less carbohydrate than medium-trunk and high-trunk trees. However, the low-trunk mulberry trees mature more slowly. High-trunk trees and arboreous mulberry trees contain less moisture but more minerals.

In South China, there are various training patterns, for example, top clipping (Dai Shu Mei), summer cutting and winter cutting. The leaves grown on top clipped trees are better than those on other trained trees, as they have more time for growth, more nutrients accumulated and less water content. They are especially suitable for feeding silkworms in a high humidity region.

Leaf position and changes in quality: The chemical elements of the mulberry leaves vary with the position of the leaf on the tree. The tender leaves at the upper position are more suitable for feeding the young age silkworms, but they would cause high mortality in the grown silkworms. Those grown on the lower part are harsh and hard, with low nutritive value. For silkworm rearing, optimum matured leaves at the middle position are best.

Seasonal climate and changes in leaf quality: During the four seasons of a year, temperature, humidity, rainfall and photoperiod change constantly. These climatic conditions influence the growth and development of mulberry trees as well as their chemical elements and physical properties. In summer, when the temperature is high, sufficient rainfall and long days make the leaves grow efficiently, resulting in good leaf quality. In the rainy season, however, the leaves tend to grow too abundantly. Due to insufficient photoperiod, these leaves are soft, tender and immature. They contain more moisture and little protein, carbohydrate, mineral salt and vitamins. Silkworms fed on these leaves do not grow as well as when they are fed on the normal leaves. In autumn, mulberry growth is retarded by high temperatures, less rainfall and a shortage of water in the soil. The leaves are easily hardened and withered, presenting malnutrition problems. Of course, with different management, there may be some exceptions and variations to these general rules.

There are different ways to evaluate the leaf quality. Apart from chemical analysis, the physical properties of the leaves can be a criterion of the leaf quality. Also, the breeding results may serve as a criterion for biological evaluation.

In production, perceptive ability is needed to observe the softness, hardness, thinness, thickness, colour and strength of the leaves and to determine their feeding values.

The utilization of mulberry leaf nutrients in the silkworm's body: After eating mulberry leaves, the silkworm can utilize different nutrients in the leaves through digestion and absorption. Part of the nutrients are used to build up body weight and to produce silk and eggs. The rest are used to release energy to maintain the life of the worm.

Normally, the dry matter in the silkworm's body consists of the following elements: proteins 63 percent, soluble nitrogen-free substances 16.8 percent, fats 12.7 percent. The distribution of the required amount of the main leaf elements absorbed and utilized by the worm building up the body weight are shown in Table 2-3.

Table 2-3

Absorption and utilization of the leaves

	Dry matter	In the dry matter			
		Protein	Fat	Soluble N-free substances	Ash
Elements of leaves needed to build up 100 g dry matter of worms	156.7	68.8	6.0	74.6	7.3
Elements in 100 g of dry matter of worms	100.00	63.0	12.0	16.8	7.6
Residual rate of various elements	63.7	91.5	212.8	12.6	100.0

One-third of the digested and absorbed nutrients is used for energy consumption, the consumption rate being greatest for carbohydrate and least for protein. Half the protein absorbed from the mulberry leaves is used to produce silk substances, particularly after the fifth instar, in which most leaves eaten by the worms are used to produce silk. The body tissue of newly moulted silkworms of the fith instar is 93.64 percent of the total body weight, while the substances in the silk gland is only 4.35 percent of the total body weight. At the maturing stage, the body tissue is 58.03 percent of the total weight, while the silk gland is 41.97 percent.

From this it can be seen that in the late stage of the fifth instar, an abundant supply of the most nutritive mulberry leaves play an important role in the formation of silk. In addition, a certain amount of nutritive matter should be accumulated in the larval stage for consumption in the pupal and moth stages.

The substances that silkworms are unable to digest or absorb (such as leaf cell membranes, leaf veins or leaf blades), are gradually forced into the hind intestine by the rhythmical contraction of the muscles of the intestinal wall. The water in the undigested substances is reabsorbed in the small intestine before the residual substances come to the colon. Under the forceful action of the muscles of the hind intestine, fluid is pressed out and faeces are formed. When the faeces enter the rectum, they are further compressed into hexagonal grains and discharged from the anal aperture. Most fluid pressed out from the colon flows back into the middle intestine for redigestion and reabsorption due to the muscle contractions of the hind intestinal wall.

Mulberry leaf selection: The quality and suitability of the foliage have a direct effect on both the vitality of the silkworm and the yield and quality of cocoons and silk. Therefore, care must be taken to choose the best quality leaves to meet th requirements of different growing stages, particularly in the young ages. At the same time, attention should be given to providing the worm with enough leaves.

Mulberry leaves for young silkworms: The selection of mulberry leaves is an important technique in the rearing of young silkworms. In production, the selection of mulberry leaves for the first to third instars is usually conducted in a special mulberry field. Leaf selection varies with different leaf harvesting methods, breeds, rearing seasons and climatic conditions. Generally speaking, it is preferable to choose leaf blades for the first and second instars and leaf shoots for the third instar. Leaf colour and position can be taken as criteria for selection. For the first instar, the colour should be light green; for the second instar, it should be about to turn dark green. Leaves should be thick, smooth, tender, oily and fragrant, with a highly viscous mulberry fluid. Good leaves are the fourth, fifth and sixth blades respectively, counting from the top leaf downward. For the third instar, dark green mature leaves should be plucked from the lower part of the twigs, the leaf position being below the sixth. Leaves on the lateral twigs (without top shoots) can also be used. If the new shoots are budding, it is better to pick the leaves from the lateral twigs or mature slant twigs of the lower part of the main branches for worms of young ages. In rearing young worms, care must be taken to pluck the leaves of the same maturity to ensure a uniform moulting date.

Where conditions permit, the best plots of the field should be mapped out to ensure a supply of good quality leaves for the young worms.

Mulberry leaves for grown silkworms: A large quantity of mulberry leaves are needed in the late ages. Arrangements should be made to pluck the leaves from different plots at different times, using leaf maturity as the criterion. In the rearing area of South China - Guangdong Province - the vegetative period of the "Jing" mulberry variety is 28-30 days in the first half of the year and 35-40 days in the second half. When the leaves are mature, they can be plucked in batches. Topping can be done in spring in order to make the leaves grow larger and thicker, to promote early maturing and to ensure a uniform maturing stage for the new shoots. In this way, improvement of both leaf quality and silk output can be achieved.

Artificial feed: The use of artificial feed is an important breakthrough in silkworm rearing. This method has paved the way for the mechanization and industrialization of silkworm production in years to come. It also provides favourable conditions for research on silkworm physiology and pathology. Nowadays, silkworms can be reared with artificial feed without affecting the normal development of the whole generation. Problems, however, remain. Silkworms fed on artificial feed grow more slowly and gain less weight than silkworms fed on mulberry leaves. Artificial feed contains large amounts of water and rots easily by fermentation. Silkworms fed on this feed are weaker and contact diseases more easily. The cocoon shell and cocoon shell ratio are lower when the worms are fed on artificial feed.

There are formulas for artificial feed: with powdered mulberry leaves and without powdered mulberry leaves. The former can achieve a better result in rearing worms than the latter.

To prepare artificial feed, the content of powdered mulberry leaves should be 75 percent at the beginning, then gradually reduced to 50 percent and finally 25 percent at the end. Sub-artificial feed contains no powdered mulberry leaves at all.

A starch, such as potato starch or defatted soybean powder and corn powder, is used in large quantities as an additive. The less powdered mulberry leaves put into the feed, the more starch additives are required. Other nutritive substances include phosphate, vitamin B complex, vitamin C, citric acid, sorbic acid, etc. Agar powder and distilled water are added and the ingredients thoroughly mixed. The mixture is steamed and pressed into small pieces for easy feeding to the worms. In order to stimulate the worms' appetite, cellulose powder, B-sitosterol, and inorganic salts are added. For feeds without powdered mulberry leaves, mulberry pigment is required. Finally, a little preservative is needed.

The use of artificial feed is quite popular now in Japan. At present, it is widely used to feed the first and second instars. In 1981, 12.3 percent of the worms were fed with artificial feed from the first to the second instar, while only 0.3 percent were fed with artificial feed from the first to the third instar. Silkworms fed with artificial feed for all the instars are rare.

2.4 Cleaning and Disinfection of Rearing Environment

To prevent and control silkworm diseases, great attention should be paid to the cleaning and disinfection of the silkworms' environment in the course of rearing. The following are the common methods.

Pre-rearing cleaning and disinfection: The rearing rooms, aids and the surrounding environment must be cleaned and washed before rearing begins. Sick worms and litter adhering to the room and appliances should be removed before disinfection. The rearing operation should begin only after the disinfection is finished and the pathogens are killed. The common methods for disinfection are classified as follows:

Physical disinfection

(1) **Sunlight:** The bacterial effect of sunlight derives from ultraviolet rays, which denature the protein of the pathogen and kill the pathogen. Infrared rays and visible rays heat and dry the pathogen, enhancing the bactericidal effect of the ultraviolet rays and accelerating the death of the pathogen. Although sunlight has some disinfectant effect, its usefulness is greatly influenced by climate and its intensity is hard to control. Sunlight can only disinfect the surface of objects; it cannot penetrate to the inside, making it suitable only as a supplementary measure.

(2) **Boiling:** In this simple but effective method, small rearing tools are put into boiling water in order to kill the pathogens by making them coagulated and denatured. After the small nets, rearing chopsticks and other aids have been washed, they are put into a boiler and submerged in water. After being boiled for at least 30 minutes, they can be taken out and dried for use.

(3) **Steaming:** Steaming has proved very economical and effective in disinfecting rearing tools. Proteins of the pathogens can be denatured, thus causing the pathogens to die under the conditions of steam and high pressure. A special type of steaming cabinet should be

set up, and rearing tools packed in it in piles. Pour in water, close the cabinet, and raise the temperature to 100°C for half an hour, or 88°C for 40 minutes, if formalin (12.5 ml to a cubic metre of water) is added to the water.

Chemical disinfection

In chemical disinfection, various kinds of chemicals with varying effects are used as disinfectants. Some chemicals make the protein in the pathogen denature and precipitate. Others can hinder the metabolism of the pathogen, oxidizing the enzymes of the plasma to achieve the bacterial effects. Before applying chemicals, it is necessary to measure the exact size or volume of the rearing house and aids and to determine the required dosage. Below, are some commonly used chemicals and how they are applied.

(1) Bleaching Powder

Properties and disinfecting effects: Bleaching powder is a white powder that contains chlorine and has an irritating odour. Its capacity to bleach and disinfect is determined by the content of available chlorine (by percentage). Rearing rooms and appliances can be disinfected with bleaching powder containing 1 percent available chlorine, which exerts a strong bactericidal effect upon many pathogens, including pholyhedrosis virus, flacherie virus, muscardine, aspergillus, bacterial spores and pebrine spores.

Bleaching powder easily becomes moist upon exposure to air, releasing chlorine gas and gradually losings its effects. Since it is easy for the available chlorine in the bleaching powder to escape, the content of available chlorine should be determined before use. Preparations can be made on the basis of the calculated result so as to ensure a satisfactory disinfecting effect.

Calculation and preparation of bleaching powder solution: For disinfection, bleaching powder solution containing 1 percent available chlorine is used at the rate of 225 cc/sq. m. Required dosage of the diluted solution can be calculated in accordance with the size of the rearing room. Required concentration of the diluted solution should be prepared according to the available chlorine contained in the bleaching powder (the original concentration). When preparing the diluted solution, put the weighed bleaching powder into the vat, mix it with a little water and stir it until it becomes pasty. Add water to the required volume and stir it evenly. Let it stand, covered, for two or three hours, then take the clarified solution for use.

Method of disinfection: A sprayer can be used to disinfect rearing rooms and appliances. Spraying should be done evenly and thoroughly. The sprayed area should be kept wet for half an hour to achieve the disinfecting effect. Disinfecting should not be done in sunlight. Diluted solution should be used immediately after being prepared to prevent the solution from evaporating upon exposure to air.

(2) Formalin

Properties and disinfecting mechanism: The disinfecting capacity of formalin depends on how much formaldehyde (HCHO) it contains. Formalin has a very strong reduction effect, which can kill pathogens by depriving them of their body oxygen. Formaldehyde has a very strong killing effect on nuclear polyhedrosis virus, flacherie virus, muscardine, bacterial spores and pebrine spores; its effect is weaker on cytoplasmic polyhedrosis virus.

Calculation and preparation: Formalin containing 2 percent formaldehyde can be used to disinfect the rearing room and appliances at a rate of 18 cc/sq. m. The dilution factor required can be calculated according to the purpose of the disinfection and the size of the rearing room. The ratio of water and the original solution can be worked out according to the concentration of the original solution.

Method of disinfection: Formalin disinfection should be conducted in airtight rooms. Before disinfection, all window and door crevices should be sealed with paper strips. Spraying should be conducted evenly and thoroughly in the rearing rooms. After spraying, the room temperature must be raised to about 24°C for at least five hours. Sprayed rooms should be closed for 24 hours. If the appliances in the room are disinfected at the same time, the dosage of formalin should be increased proportionally. The appliances should be disinfected before spraying the rearing rooms.

Points for attention:

- Formalin disinfection should be completed 10 days before the rearing operation begins, otherwise the remaining odour of formaldehyde will exert an unfavourable effect on the growth of the worm.

- Put the heat source for raising temperatures in a safe place. When the stove is lit, it should be covered with an iron sheet cap to prevent accidental fires.

- Since formalin has a strong and irritating odour, the operator must wear a gas mask or cover his mouth and nose with a wet towel while working. Disinfecting work should be done in rotation.

- Undiluted formalin solution should be sealed and stored in a cool, dry place to prevent it from being exposed to high temperatures, strong sunlight and cold. In this way, the loss of medicinal effect due to evaporation and sedimentation can be avoided.

(3) Mixture of Formalin and Lime Water

Formalin solution cannot kill all cytoplasmic polyhedrosis virus. However, with the addition of fresh lime powder, its disinfecting effect can be increased remarkably. This mixture can make the cytoplasmic polyhedrosis virus lose its pathogenic ability in 20 minutes. It also has a strong killing effect on some other pathogens.

Preparation of the mixture: This mixture can be prepared by adding 0.5 percent fresh lime powder to previously prepared formalin solution, the concentration of which is 2 percent. After mixing thoroughly, use the turbid fluid as the disinfectant. The mixture should be used immediately as it will lose its effect in 24 hours.

Method of disinfection: The required dosage and the points for attention in application of the mixture are the same as those for applying the formalin solution, with the exception that less strict measures for sealing the doors and windows are needed. That is to say, when the door and windows are well built, there is no need to seal the crevices with paper strips.

Apart from the disinfectants mentioned above, sulphur or some other specific fumigants can also be used in disinfecting silkworm diseases.

Hygiene in rearing: Hygienic work is an important element in rearing silkworms. This work consists in keeping the rearing room, appliances and beds clean and disinfected.

Disinfection and disease prevention in the rearing season: When rearing rooms and appliances are disinfected during the pre-rearing time, pathogens can be reduced considerably or even eliminated. However, in the course of rearing silkworms, pathogens can be re-introduced to the rearing room through many channels, and disinfection should, therefore, be repeated.

- Spray the floor, corridor, entrance and exit of the rearing room and mulberry storehouse with a bleaching powder solution of 1 percent effective chlorine at three-to-four day intervals.

- Wash hands before entering the rearing rooms and the mulberry storehouse. Put a lime powder mat at the entrance to the rearing room. People who enter and leave the room should be required to step on the mat or to change their shoes.

- After cleaning away the litter, wash hands before feeding worms.

- Use mulberry containers and litter containers separately. These appliances should be constantly disinfected with bleaching powder.

- Throw sick worms into a lime jar. Do not throw the sick worm away randomly as it could become a source of infection.

- Clean used nets and mats and dry them in the sun. Do not use them again unless they are disinfected.

Disinfection of the beds during rearing: In silkworm rearing, the outbreak of diseases is closely related to the hygienic conditions of the rearing beds. Pathogens are usually excreted by worm's droppings, which will contaminate the mulberry. If healthy worms eat the faeces, they can contact diseases. Since rearing beds are the main source for the propagation of pathogens, disinfection of the beds is essential. In production, lime powder is generally used to disinfect the worm's body and the rearing beds. Fresh lime powder has a strong disinfecting effect on many diseases. It also has an antidotal effect on chemically polluted leaves. Fresh lime powder can isolate pathogens and keep the rearing beds dry.

Cleaning and disinfecting after rearing: When the rearing time comes to an end, the remaining dead worms, waste matter, etc., must be cleaned away, collected and buried under the earth with some lime powder thrown on top. Rearing rooms, mounting rooms, mulberry storehouses, environments outside and inside and appliances, should be disinfected by spraying bleaching powder solution of 1 percent available chlorine to prevent the spread of pathogens. Another disinfection is needed before a new crop begins.

CHAPTER 3

INCUBATION

3.1 Preparatory Work for Incubation of Silkworm Eggs

Incubation is an important step in protecting the activated silkworm eggs before rearing. After the eggs have been laid or taken from storage, the environment under which they are protected has a great influence upon the development of their embryos, the uniformity of the hatching of the ants (newly hatched silkworm larvae), the health of the larvae, the mortality of the silkworms, the yield of the cocoons and so on.

Definition of incubation: Incubation is also known as "seed warming", by which the activated silk eggs are protected in proper temperature and environmental conditions so that the embryos can develop normally and the eggs hatch uniformly. The time for incubation for the Chinese bivoltine species at 20-25°C is 10-11 days or 9-10 days at 25-26°C; for the multivoltine species it takes 8-9 days at 25-26°C.

By activated silkworm eggs is meant non-hibernating eggs or hibernating eggs that have undergone an artificial hatching treatment or overwintering. Under natural conditions, the silk eggs will develop and hatch by themselves. But as the atmospheric temperature and humidity change all the time, this is likely to cause uneven and low percentage of hatching, the young larvae will become weak, yield of cocoons is low and of bad quality, making it difficult to control the proper time for larvae collection. Incubation will help the egg embryos to develop properly and the larvae to hatch at the designated time, with a high hatching percentage, a uniform hatching time and great strength. Incubation is thus one of the best ways to secure high yield and good quality cocoons.

Determination of incubation time for spring silkworms: It is very important to choose the proper time for incubation of the spring silkworms, to ensure that the growth and production of the mulberry leaves coincides with the growth and development of the silkworm. Secondly, proper timing means the silkworms can be fed with sufficient well developed leaves. Moreover, variation in incubation time influences the disposition of different crops in a year as well as quantity and quality of mulberry leaves.

Determining the incubation day will depend upon when the mulberry trees sprout and on local climate. It is also closely related to the duration of the larval period and the time required for incubation. The mulberry begins to grow in spring, but sprouting will vary with different varieties.

The rate of growth of the mulberry leaves varies too according to temperature and rainfall in different places. They grow very slowly below 10°C, normally at temperatures warmer than 17°C, and vigorously above 20°C. Therefore, they will grow rapidly where winter is short and comparatively slowly in regions where winter is long.

Preparation for incubation: Preparation for incubation is quite different according to the conditions prevailing in different places. Incubation may be undertaken individually or collectively. The former may be undertaken in an incubation chamber or by the farmer; the latter may be undertaken in the rearing regions or in the breeding farm. Collective incubation requires first of all that an incubation centre be established, after which the incubation room and tools are prepared. The tools should be disinfected thoroughly; the disinfectants and the fuel for keeping the room warm shuld be made ready. If disinfection is not carried out thoroughly, some bacteria or other microorganisms could be left behind, threatening the entire silkworm rearing industry.

Ten days before the operation begins, the chamber and tools must be thoroughly disinfected; after that the room temperature must be raised to 27°C and the windows opened to let out the bad smell of the disinfectant. Incubation is a delicate and important job, and whoever is chosen to be in charge needs considerable experience.

Incubation room and incubation chamber: The choice between an incubation chamber and an incubation room depends on the scale of the industry.

(1) **Incubation room:** If a large number of eggs are to be incubated, an incubation room is used. It should be built in regions with a large production of eggs and in places where transport is convenient so that the eggs can be shipped.

The incubation room must maintain a uniform temperature and humidity, and have even and sufficient illumination and good ventilation. It must have a ceiling and tile floor and indoor and outdoor verandas. It must have ventilators and a space of at least 100 cubic meters to hold 4 000-5 000 boxes (or sheets) of eggs.

(2) **Incubation chamber:** This is made of an iron sheet with a double-layered wall, into which hot water can be poured to keep it warm. It has a ventilator on top and an electric heater or coal furnace at the bottom to maintain the optimum temperature inside; sometimes even an electric lamp may be put inside for heat; in order to control the humidity inside some water or a piece of moist cloth may be stored in the bottom.

Electric auto-heating incubation chambers have been invented, and these can help the embryo of the silkworm to develop well, hatch uniformly and facilitate the work.

3.2 Development of the Silkworm Embryo

The speed of the growth and development of the embryo is different in hibernating and non-hibernating varieties, but the morphology of the eggs at various developing stages is more or less the same for both. The changes of the morphological characters of the developing embryos are a series of processes that cannot be divided sharply from one another, but for the sake of convenience, they are arbitrarily divided into fifteen stages according to those of the hibernating silkworm (Table 3-1).

Table 3-1

Characteristics of different developmental stages of silkworm embryos

Stages	Characteristics
A Late period of diapause	Short body; the cephalic lobe is bigger than the caudal lobe; somewhat round and rather smooth; segments inconspicuous.
B_1 Period after the diapause stage	The body begins to develop and lengthen; the cephalic and caudal lobes grow larger; segments gradually become pronounced.
B_2 Elongation	The body gradually elongates; the cephalic and caudal lobes grow even larger; a primitive groove appears in the mid-portion of the cephalic lobe; segments become pronounced; the body is ladder-shaped.
C_1 Period before the longest embryo stage	The body further elongates; the cephalic and caudal lobe become bigger; 18 segments can be seen.
C_2 Longest embryo	The body lengthens; the cephalic lobe is well developed; the 18 segments are conspicuous; a longitudinal groove appears from the 2nd to the 4th segments, and the 5th to 7th segments become swollen; the caudal lobe is oblong.
D_1 Embryo grows in thickness	The body matures and fattens; the edge of the cephalic lobe is square; the groove deepens; the 18 segments become more conspicuous; the longitudinal groove is most distinct.

Table 3-1 (continued)

Stages	Characteristics
D_2 Appendages develop	The body becomes longer; the groove becomes even deeper in the cephalic lobe; appendages appear from the 2nd to the 7th segments
E_1 Early development of appendages	A pair of labra lobe develop from the anterior end of the cephalic lobe; antennae appendages develop and protrude prominently; a stomodaeum is found in the central part of the cephalic lobe; the appendages from the 2nd to the 7th segment develop further
E_2 Late development of appendages	The body shortens, its width increases: the last two segments become contracted and fused together; the proctodaeum appears in the posterior end; the cephalic lobe and the appendages of the 2nd to the 7th segmentations become more developed; the segments from the 8th backward have a pair of round appendages, one on each side; a pair of depressed spiracle openings appears on each lateral side of the 5th to the 17th segments
E_3 Shortening	The body is greatly shortened and enlarges; the anterior four segments fuse together to form the head and the posterior two segments the tail; the appendages on the 10th to the 13th segments develop into prolegs; the other appendages on the abdomen disappear
F_1 Involution	The body of the embryo forms an S-shape; the posterior segments turn round; there is a navel on the dorsal side of the 2nd segment; the embryo starts to move to and fro, first at the abdomen, then at the head and the thorax; it them moves to the opposite side and forms an S-shape when it reaches the centre of the egg
F_2 Final stage of involution	The embryo that was in supine position with its abdomen facing the outer side of the egg turns round and moves to the opposite side of the egg with its abdomen facing the inner side; its navel is now closed and the alimentary canal is formed

Table 3-1 (continued)

Stages	**Characteristics**
F_3 Appearance of the trachea	The trachea is coloured; ocelli appear pink in colour; the embryo swallows the yolk through its mouth; the digestive guts and openings all communicate with each other; setal hairs begin to grow on the surface of the body; those on the tail grow out like jets; ant-like body appears
F_4 'Eye-spot'	The head turns deep brown; black spots may be seen through the eggshell; amnion, serosa and vitelline membrane are separated from one another; they are all swallowed by the embryo itself together with the yolk, hence there is some pigment of the serosa in the fore-gut; but the embryo surface is not yet coloured
F_5 'Blue egg'	The ant is formed; the whole body of the embryo is coloured; the surface of the shell looks greenish gray

At the beginning of the incubation, the hibernating or non-hibernating eggs taken out from cold storage (or cold-stored after acid treatment) are first kept at 14-16°C for half a day, and subjected to high temperature for incubation. During the process, special attention should be paid to the C_2, E_3, F_3 and F_4 stages of the embryo. C_2 is the stage at which the temperature begins to be raised; at E_3, an important stage, a comparatively high temperature is needed to protect the embryos; if the temperature is raised too early during the incubation period, the embryos do not develop uniformly in later stages; if the temperature is raised too late, the voltinism of the eggs is affected. If the eggs have attained the F_3 stage already, the date for the distribution of eggs should be fixed first. Special attention should be paid to the stage F_4 ('eye-spot'stage), during which the eggs should be kept in darkness for a certain period of time.

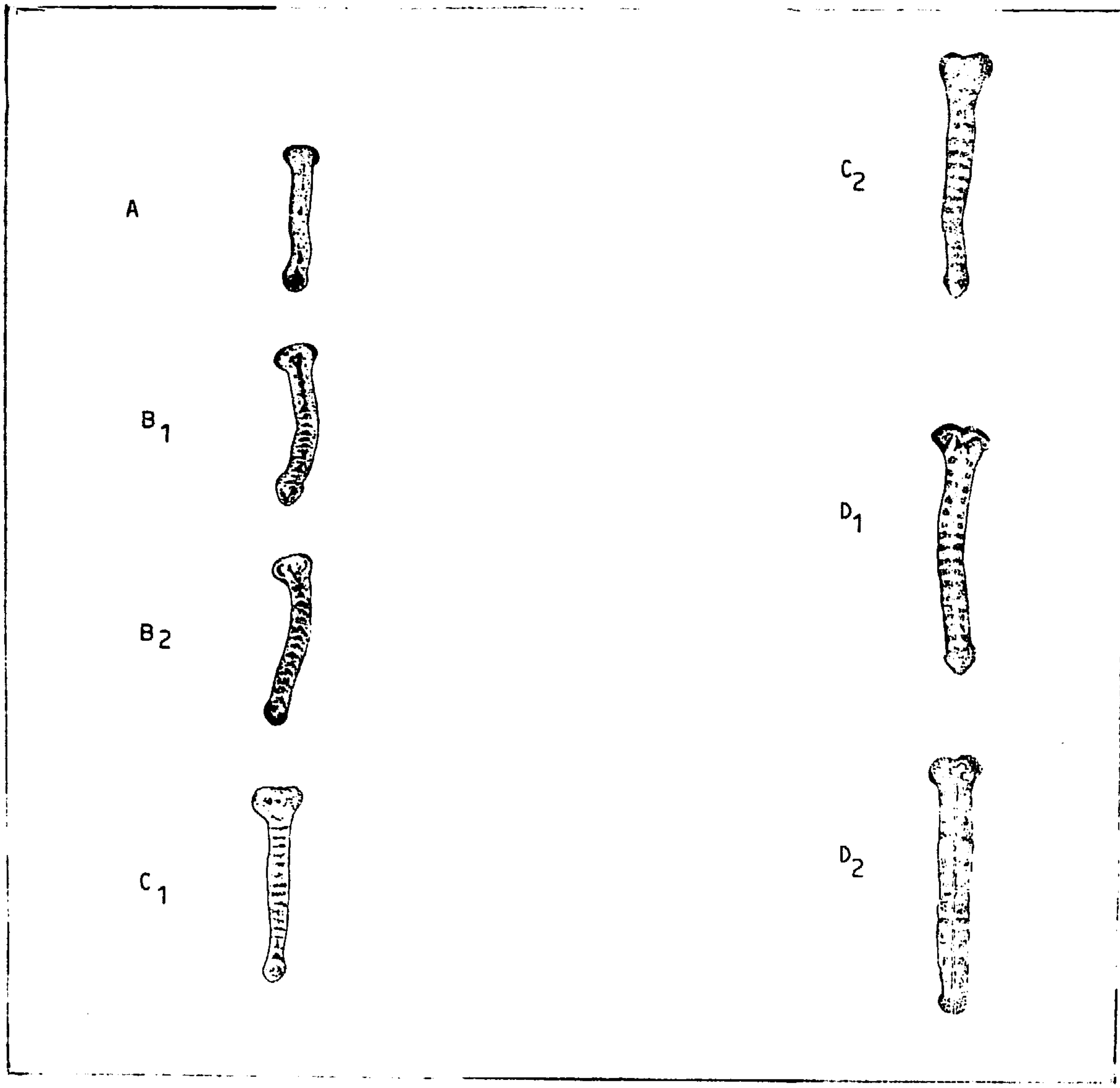


Figure 3-1 Embryonic development - 15 stages

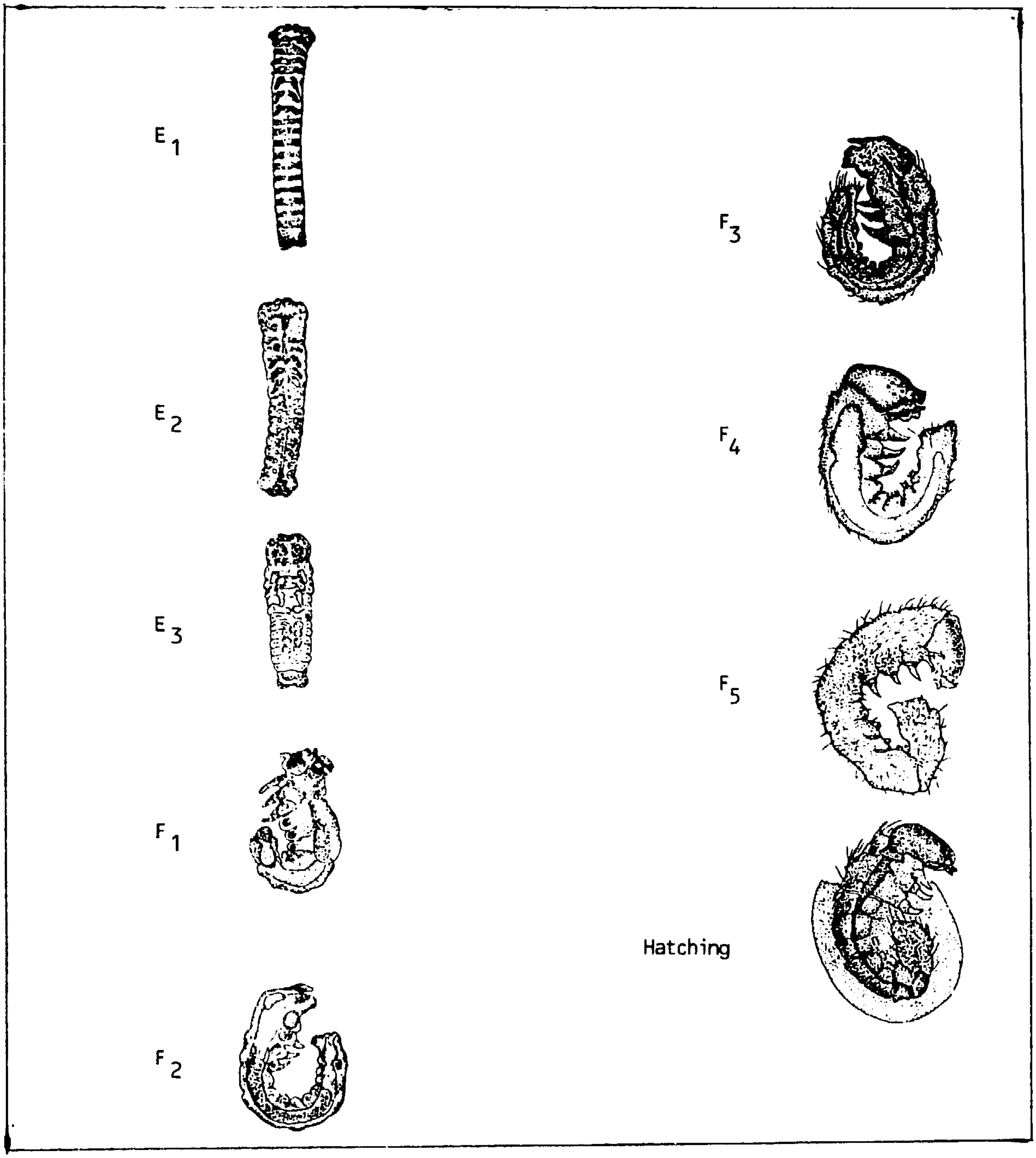


Figure 3-1 (continued) Embryonic development - 15 stages

3.3 Environmental Conditions for Incubation

Influence of environmental conditions on embryo development

Temperature: The temperature during incubation closely affects embryo development with respect to duration of incubation, uniformity of the hatching of the ants, percentage of hatching, vigour of the silkworms, voltinism and quality of the cocoons.

Temperature also affects the speed of embryonic development at different stages: at the C_1 stage, the optimum temperature is 15°C, at which the embryo develops rapidly; above 20°C, it develops slowly. At the C_2 stage, the optimum temperature is 20°C, at which the embryo develops rapidly, at 15°C it develops slowly. If unevenly developed eggs are kept at 20°C just after they are removed from cold storage, or if they have encountered temperatures higher than 20°C while in transit, then those at the C_2 stage will develop faster while those at C_1 will develop slowly, causing a great irregularity in the development of the embryos. However, if the eggs taken out from the cold storage are kept at 15°C right away for two or three days, during that period the fast developing embryos would slow down allowing the slow developing ones to catch up. Therefore, it is best to keep the eggs of the spring silkworms at 15°C, until all the embryos have reached the C_2 stage i.e., the starting point of the embryo development. Afterwards, the temperature is raised to 20°C in order that the development of all the egg embryos is uniform. Thus, it is advisable to transport the silkworm eggs five days after they are removed from storage. High temperatures during transportation should be avoided, and if the temperature is too high in the day time, they should be transported at night.

Immediately after the longest embryo stage (C_2), organs and tissues rapidly form. These are very sensitive to environmental conditions. Especially after involution, morphology and physiology change greatly and the embryos are most sensitive, but after the ants are formed (at F_5), their resistance to lower temperature is much increased. Thus in incubation, "Blue-eye" eggs can be stored at a low temperature for a short time to delay the time needed to collect the ants.

Humidity: The influence of humidity on the hatching and vigour of the silkworm is great, but less than that of temperature. Too dry or too wet air is harmful to the eggs' physiologically. The embryos have the least resistance to dryness from the E_3 stage to hatching. During this period the embryos has developed into an ant, and the serosa surrounding it has already been digested. Under this dry condition, the eggs lose their water easily and dead eggs increase. If, on the other hand, the humidity increases to more than 90 percent, the eggs hatch uniformly and the ants grow larger, but they are very weak. The optimum humidity for incubation ranges from 70 to 75 percent prior to E_3 and 75 to 85 percent after E_3.

Illumination: From the very beginning of the incubation up to the "eye-spot" stage, light hastens the embryo development, but from the "eye-spot" up to the later stages, darkness hastens embryo development. However, during the final hatching stage, darkness inhibits development. Making use of the law of light and darkness in relation to embryo development, the uniformity of the hatching of the ants may be controlled by keeping the eggs in complete darkness when 20 to 30 percent of the eggs are in the "eye-spot" stage. In this way, late developing embryos of the early stages would speed up their development in complete darkness, and while the faster developing embryos of the early stage would be inhibited from hatching. Until the very morning of ant collection comes, eggs should be exposed to light so as to make them hatch at the same moment. In darkness, the eggs can be inhibited from hatching for up to only nine hours. After nine hours, they will begin to hatch regardless of darkness. Those eggs waiting to hatch in the darkness are very sensitive to light. Once they are in contact with dim light for a short time, e.g., 5 m candle power for 30 seconds, they will start to hatch at once: after the lights have been cut off, the eggs must be kept in complete darkness.

Air: The eggs are more resistant to CO_2 in the early stages, than in the later stages, especially two or three days before collection of the ants, at which time the embryos' resistance to CO_2 is weakest. In fact, it does no harm to the eggs if the CO_2 content is less than 0.5 percent, but if it is any higher, more eggs would die, hatching would be uneven, and the ants would become quite weak. Therefore, fresh air must be maintained constantly in the incubation room, particularly in the later stages of incubation. In practice, in the early stages, the incubation room can be ventilated for ten minutes twice a day (in the morning and afternoon), or four times in the final stages. Each time, large amounts of outside fresh air should be circulated to the whole room and the CO_2 and other harmful gases pushed out.

Change of voltinism and environmental conditions in incubation: The temperature in incubation has a great influence upon the voltinism of silkworms. If the temperature is maintained at 15°C in incubation, the bivoltine variety would tend to acquire non-hibernating characteristics. If 25°C or higher temperatures is maintained, they will tend to become hibernating. If it is within the range of 17-20°C, a part of the eggs of the next generation would become non-hibernating, but most of them would become hibernating (the percentage varies with variety).

Humidity has no influence upon voltinism at temperatures higher than 25°C or lowever than 15°C. In temperatures of medium range, high humidity favours production of the non-hibernating variety. Humidity has its greatest effect upon voltinism right after the involution stage. Thus, it is important to maintain the optimum himidity for incubation in the later stages.

Light is next after temperature in affecting changes of voltinism. At 20°C, the bivoltine variety would become a hibernating variety in light; while a small number of them become the hibernating variety, the majority become non-hibernating if kept in complete darkness. It has been observed that light has its greatest effect on voltinism between the shortening and the "Eye-spot" stage. For industrial cocoons, high temperature of 25°C is sufficient to change voltinism and raise the quality of silk, regardless of light conditions.

Incubation conditions: In accordance with the needed environmental practical conditions in Chinese silkworm rearing regions, the industrial varieties of silkworm are divided into: bivoltine, multivoltine and bivoltine-multivoltine hybrids. Based on experience, the criteria for incubation techniques is laid out in Table 3-2.

Table 3-2

Incubation conditions

	Bivoltine hybrid		**Multivoltine hybrid**
Stages	**Early stage** C_2-E_2	**Late stage** E_3-F_5	**Incubating period** C_2-hatching
Optimum temperature (°C)	22-22.5	25.5-26.5	28-29
Optimum humidity (%)	75-76	79-84	80-85
Light	Natural	Natural or artificial, 18 hours/day (darkening from F_5 to hatching)	Natural (darkening from F_5 to hatching)

3.4 Some Technical Management in Incubation

Management after receipt of the eggs: After receiving the eggs, put them in order into the incubation chamber according to variety, production farms, batch number, and date of egg collection. Record the number of egg sheets. Then take samples from each variety and dissect some embryos to investigate the developing condition of the embryos and determine the optimum temperature to be maintained. Then put the eggs into the incubation shelves (some loose eggs are put into wooden framed incubation, while the egg sheets are put into a wire frame). Label each frame with farm name, collection date, variety and batch number.

Egg dissection: During incubation, dissect some eggs every morning to observe the embryo development and determine the room temperature to be maintained.

Method of dissection: Caustic potash (or caustic soda) is usually used to separate the eggshell from the content. Prepare a 20 percent caustic potash solution in advance, heat the solution until it boils, and remove the alcohol lamp. As soon as the bubbles disappear, put some loose eggs (about 30) onto a small spoon and put the spoon into the solution. Notice that the eggs do not float on the surface but sink into the soluiton, so that the eggshells can be dissolved evenly. For egg cards, take a small piece (about 20 eggs) and soak them in the solution for about 10 seconds until they turn the colour of a red bean. Remove them at once and wash them with clean water to get rid of the caustic solution. Then put the eggs into a petri dish containing some clean water, suck out some water with a pipette and blow the water on the eggs several times to make the embryos separate from the shell. If they have soaked in solution too short a time, and the embryo cannot separate from the eggshell, some warm water may be used to blow on the eggs until the embryos are completely separated. Use the pipette to put some of the embryos on glass slides and observe their development stage under a low-power microscope. Every morning, choose some samples from each of the different varieties, different farms, batches and collection dates and dissect them. From stage E_2 onward, embryos may be dissected twice a day, in the morning and afternoon, so that the time for the E_2 stage may be ascertained and the temperature may be raised in time.

Maintenance of temperature and humidity: Room temperature may be raised according to the daily development of the embryos. Usually the day's temperature and humidity may be decided before 10:00 hrs.

The humidity of the incubation room may be maintained by an automatic electric humidity system or by heating a basin or trough containing water, or even by hanging some moist cloths in the corner of the room or by some other means.

Changing the position of eggs and shaking of eggs: In order that the eggs be warmed evenly during incubation, their position must be changed twice a day in all directions - forwards, backwards, upwards, downwards, right and left alternatively. The position of egg sheets is changed by hanging one side up or down. In addition, the loose eggs in the container must be shaken simultaneously, so that they can receive heat and moisture evenly and can all develop normally.

Ventilation: In order to keep the air in the incubation room fresh, the room must be ventilated often. Prior to the E_3 stage, when the eggs' positions are changed in the morning and afternoon, the room could be ventilated at the same time. After E_3, ventilation could be conducted twice before noon and twice after. After ventilation, optimum temperature and humidity must be maintained.

Exposure of silkworm eggs to light: Eggs need to be exposed to light, especially after E_3. Electric light is preferable. The source of light should be about 70-100 cm away from the eggs and should illuminate uniformly. A photoperiod of 18 hours is needed every day. Once the embryos reach the blue-eye stage (F_5) when some newly hatched worms appear (i.e. the night before hatching), the light must be cut off and the eggs put in complete darkness until 02:00-05:00 hours the next morning. Afterwards, they can be put in contact with light, so that the ants can hatch uniformly.

Predicting hatching date: The hatching date is determined by the embryo development with reference to the colour of the eggs and the distinctness of the egg dimple on them. When black spots are observed on the eggs, the embryos are said to be in the eye-spot stage. The following day, they will turn green or grayish brown, which is called the blue-spot stage. Some worms will hatch the following day, and ants are collected a day later.

The hatching day of the eggs can be calculated according to the accumulated temperature necessary for the different varieties. The accumulated temperature equals the incubation temperature minus the initial temperature for embryo development (i.e. 10°C effective temperature). The accumulated temperature varies for different varieties and must be determined before its accurate value could be obtained.

Delay in ant collection: If the climate should suddenly change at the beginning of incubation, or the mulberry should grow very slowly, or for some other reasons, ant collection has to be delayed. Then, in accordance with the development stages of the embryos, measures must be taken to make the eggs develop normally.

Changing the incubation temperature: When the embryos have not yet reached the shortening stage, the room temperature should not be risen but retained at the same grade. The hatching date will thus be later than originally planned. If the egg embryos have already reached the shortening stage, raise the room temperature as usual to keep the incubation procedure going or the voltinism of the eggs will be affected.

Cold storage of the blue-eye stage eggs: If the eggs have reached the blue-eye stage, when some newly hatched silkworms can be seen, incubation could be delayed by cold storage. If the embryos have all developed well, they are physiologically safe for cold storage. The temperature for cold storage should be maintained at 3-5°C; the time limit seven days, but a shorter time is preferable. The humidity for storage should not be less than 75 percent.

Cold storage of ants: If the eggs have already hatched into ants, they may be placed in cold storage. The length of storage time differs with the storage temperature offered. If the temperature is 15.5°C, it should be less than two days. If the temperature is 10°C, it should not exceed three days.

Despatch of silk eggs

The rearing units must give several days' advance notice in order to prepare to receive the eggs, which should be despatched at the blue-eye stage. It is advisable to arrange the eggs of the same variety and of the same stage in one rearing unit. Two to three hours before the despatch of eggs, the temperature of the incubation room should be raised or lowered to coincide approximately with the outdoor atmospheric temperature. The eggs must be well packed. To distribute a small number of eggs, roll up each egg card into a cylinder with the eggs inside. Wrap several rolls together with clean paper. To transport a large number of cards, put them in egg-card frames and wrap the frames with paper or cloth. Loose eggs should not be piled in heaps.

The silk eggs should be transported when the fluctuation of the daytime temperature is not great. They should be sent in the cool of the morning or night, not at noon. In transit, the parcels of eggs should be protected from rain, scorching sun, dryness, chemical insecticides, gasoline, harmful gas, etc. Do not shake the eggs too vigorously, or let them suffocate in high temperatures. Finally, let them be kept in complete darkness.

Make-up incubation: After the eggs have been received by the rearing house, the optimum temperature and humidity should be maintained and other protective measures should be carried out continuously. One day before the arrival of the eggs, the room temperature of the rearing house should be raised to 21°C and its relative humidity to 85 percent (a difference of 1.5°C between the dry and wet bulb of a psychromster.) Once the eggs are put into the house, the room temperature must be raised by 0.5-1.0°C per hour while the relative humidity remains at a difference of 1.5°C between the dry and wet bulb. The egg sheets are put into the trays in the larvae rearing room, while the loose eggs are taken out from the boxes and poured into the trays in which the bottom is covered with some egg collecting paper. The four sides of the trays are surrounded by bamboo strips or wooden strips, and a small red net is spread over the eggs so as to prevent them from rolling. Cover the tray with another tray and put them in complete darkness until the morning of ant collection. Then remove the cover, and expose them to light evenly, and the ants will hatch uniformly.

CHAPTER 4

METHODS OF SILKWORM REARING

4.1 Mode and Method of Rearing Young Larvae

Modes of rearing young larvae: The modes of rearing the young larvae vary according to the equipment and the climatic conditions in various regions. In China's silkworm rearing region, the following rearing methods are used: cover (lid) rearing, plastic-tent rearing, ditch rearing and electric hot-bed rearing.

(1) **Cover rearing:** This methods entails covering the rearing bed of the young larvae with either paraffin paper or a plastic membrane. The aim is to lower the rate of transpiration of the mulberry leaves, which would keep them fresh longer and allow larvae more time and better conditions to feed them. At the same time, it would decrease the environmental micro-climatic changes in the beds, making the larvae develop normally. The rate of water lost from the leaves is significantly lower under cover rearing than under open rearing. The results are as follows:

Table 4-1

The influence of cover and open rearing upon the rate of water loss in mulberry leaves (%)

Size of leaf	Mode	After 3 hours	After 6 hours	After 9 hours	After 12 hours
Large ($3\ cm^2$)	Covered	3.5	8.0	12.0	15.0
	Open	7.0	10.4	21.0	30.0
Small ($1\ cm^2$)	Covered	4.5	9.5	13.5	17.5
	Open	8.5	21.5	32.0	43.5

Note: During the time of investigation, the room temperature was 29°C and the relative humidity 91 percent.

For summer silkworms or third instar larvae, the rearing beds must be covered with paraffin paper. For the spring and autumn rearing, when the climate is very dry, or for the first and second instars, one sheet of paraffin paper or plastic membrane is put on the bottom of the bed, and another is used as the cover.

The silkworms are fed three to four times a day. Remove the cover 30 minutes before feeding and replace it afterwards. When the larvae moults, the leaves and cover are no longer needed, and the beds must be kept dry.

(2) **Plastic-tent rearing:** To prevent loss of moisture in the rearing bed, the rearing stands can be covered with plastic membrane. The cover method allows optimum humidity to be maintained in a larger space than under the paraffin method. When the mulberry leaves are thus kept fresh, they provide a more healthy diet to the larvae. Besides, the plastic-tent can help protect the larvae from bad environmental conditions outside. The inside environment is very stable. This method also allows the rearing beds to be isolated from pathogens and dust, with the result that infectious diseases rearly occur during rearing. It is also a good method for rearing the early-stage larvae, especially during rainstorm seasons.

The silkworms are fed three to five times daily under this method, which is usually used in the first and second instars. If it is too dry inside the tend, the rearing beds inside the tent are also covered with plastic membrane. During the third instar, part of the top tent can be taken off.

(3) **Hot-bed rearing:** A hot bed is used for the first and second instar larvae during cold seasons. It has two parts: the rearing room above ground and the installation of heat sources underground. Its size depends upon the number of silkworms to be fed and the size of the rearing trays.

The underground portion is subdivided into three parts: the stove, the heating pipe and the chimney. Heat is conducted through the pipe to the rearing room and optimum temperature may be maintained inside the room. Wood or coal are usually used as fuel. Whenever the temperature falls one degree below the optimum temperature, a fire should be lit. If the room temperature fluctuates greatly, sand may be used to cover the base of the beds to help control the temperature; the control plank in the middle part of the chimney may be turned. To raise humidity, water is sprayed onto the sand.

(4) **Electric hot-bed rearing:** The principle of the construction of the electirc hot bed is fundamentally the same as that of the ordinary hot bed; the sources of heat are different. The former uses electricity as a heat source, such as an ultra-red lamp and electric heater buried in the sand of the rearing bed, or an electric furnace installed in the room. An electrothermal regulator can be installed outdoors.

To increase the humidity inside the room, some moist mats are put over the sand or water is boiled in the rearing room. If possible, the room should be equipped with an electrothermal humidifier.

Methods of rearing the young-stage silkworms

(1) **Ant collection:** The newly hatched silkworms, called ants, are collected and transferred to the trays and fed with mulberry leaves.

Ant collection is the beginning of silkworm rearing. Prior to this operation, mulberry leaves should be prepared for feeding, the room temperature and humidity should be adjusted and rearing tools should be assembled.

There are four methods of ant collection: by mulberry leaves; striking down; inverting egg sheets onto the mulberry leaves; and netting.

Ant collection by mulberry leaves: Chop the leaves into fine pieces and sprinkle them directly onto the egg sheets. When the ants have crawled into the leaves, turn the egg sheet with the eggs facing the rearing bed paper and use a feather to brush the ants evenly onto the beds. This method is very simple, but the correct weight of the ants cannot be obtained.

Striking down method: Use chopsticks to strike the back of the egg sheets to shake the ants onto the beds. This method is good for collecting uniformly hatched ants. If 80-90 percent of the silkworm eggs have been hatched within one day, this simple method can be used. Its advantage is that the ants can be collected in a short time, and an accurate weight can be obtained simultaneously.

Inverting the egg sheets onto the mulberry leaves: First chop the leaves into fine pieces and spread them evenly on the bed, then weigh the ants together with the egg sheets. Turn the sheets upside down onto the leaves in the beds, and let the ants be in contact with the leaves for 15-20 minutes. Then remove the egg sheets and weigh them again. The difference between the two weights is the net weight of the ants collected.

The above three methods are often used in brushing ants on egg cards.

Net collection: This method is good for both loose eggs and egg sheets. Put a little red net with a mesh of about 0.16 cm^2 onto the egg sheets or loose eggs, spread some mulberry leaves on the net to attract the larvae, and then raise the net and put it onto another tray. After that, arrange the larvae evenly in the beds. This method is simple, but no correct weight of the ants can be obtained.

(2) **Good quality mulberry leaves:** The amount of good quality mulberry leaves fed to the young worms is small. It is only about 5-6 percent of the total amount fed for all the instars. To make a good start, and to set a sound basis for healthy and strong bodies, the larvae must be supplied with sufficient good quality mulberry leaves.

Good quality mulberry leaves mean fine, nutritious, well grown leaves, and that depends on the conditions of cultivation and upon selection, harvesting, transport and storage.

The quality of mulberry leaves is closely related to harvest time. Generally speaking, leaves harvested in the evening contain more sugar and starch but less water, while those harvested in the morning are the opposite. The comparative contents of sugar, starch and water in mulberry leaves harvested in the morning and evening are shown in Table 4-2.

Table 4-2

Comparative contents of sugar, starch and water in mulberry leaves

CONTENTS	TIME 06:00	TIME 18:00
	CONTENTS (%)	
Water	82.11	74.01
Sugar	0.490	0.921
Starch	0.707	2.043

If the climate is dry, the leaves should be harvested in the cool of the morning, when their water content is high, so that they will keep fresh. If the climate is moist, they should be harvested in the afternoon. During the rainy seasons, they should be picked as soon as they are dry.

Harvested leaves should be kept out of direct sunlight and protected from rain. They should be transferred to the storage room as soon as possible. There are several storage methods:

Storage in a pot: Lay the leaves to be used by worms of the first and second instars flat in layers in such a way that they spiral upwards. The petioles should face toward the outside of the pot, the leaf tips toward the inside. Leave a space in the centre. Cover the mouth of the pot with a damp cloth or damp tray. If the climate is moist, leaves can be stored in a basket.

Storage in water tank: Build a water tank in the leaf storage room. Pour some water in the bottom to a depth of 10-20 cm, and put a wooden frame above the water. Put some bamboo mats on the frame and spread the leaves on them. Cover the top of the tank with some moist trays or moist cloth, so as to keep the tank moist inside.

Storage in a plastic membrane tent: In this simple and easy-to-learn method, the leaves are stored in a plastic membrane tent hung indoors, with its top being about a metre above the floor and its bottom touching the floor. Large amounts leaves can be stored in this way and the effect satisfactory.

With any of these methods the longer the storage time, the more nutritive substances are lost. Therefore, if possible, storage should be limited to one-half to one day. In order to keep the leaves fresh and preserve the nutritive substances, the temperature during storage should be kept low and the humidity high, with little air current. Leaves should also be kept in darkness.

Well fed larvae: Since the young larvae grow and develop rapidly, sufficient fresh mulberry leaves must be provided so that they will have enough to eat. In order to keep the larvae well fed, the following operations have to be undertaken:

(1) **Chopping mulberry leaves:** The purpose of chopping mulberry leaves is to facilitate the feeding of the worms. If the leaves are evenly fed, little refuse remains in beds, and the larvae develop evenly. But the leaves lose a great deal of moisture when they are chopped and wilt very easily. The finer they are chopped, the higher the rate of moisture loss and the faster they wilt. How they should be chopped will vary. For example, the more feedings a day, the smaller the leaves are chopped. In cover rearing, as fewer feedings are required, the leaf fragments should be larger. During the hot and dry season, large chopped leaves are preferable, while in the cold and damp season, small chopped leaves are desired. During the gluttonous stage, the leaves can be chopped larger than those for feeding the premoulting worms. The chopping methods are as follows:

Square shape: This is suitable for the larvae of the first and second instar. Generally, one side of the square should be 1.5 to 2 times the length of the worms, the size on which it is easiest for them to feed.

Rectangular shape: This method is best suited for premoulting worms in moist regions. Rectangularly cut leaves lose water easily by evaporation. When the leaves are sprinkled on the beds spaced fairly apart, the beds will become drier. For the larvae of the first instar, the leaf should be 0.1 cm wide and 4 cm long. The leaf fragments must be longer and wider as the larvae grow larger in the late stages. Normally, the length of the leaf strips should be about three times as long as the larvae and about twice as wide.

Larger fragments: Once the silkworm larvae reach the third instar, the mulberry leaves should be chopped into bigger fragments. The leaves (blades or shoots) are cut into squares or triangles or strips as long as 10-15 cm.

An electric cutter for mulberry leaves may be used. If used, different sizes for different instars may be obtained by adjusting the machine. This is the most efficient way to chop mulberry leaves.

(2) **Feeding times:** Silkworms feed on mulberry leaves at regular intervals. Before feeding on the leaves, both young and late age larvae need a short time to rest. The ant silkworms begin to eat 40 minutes after hatching and at each instar they begin to eat 100-170 minutes after moulting. When they have eaten enough, they remain motionless until part of the food has been digested, after their appetite resumes and they will begin to crawl about to find food. As they grow, especially in the late stage, they will eat more and more and the time needed for feeding is longer and longer.

Whether the larvae are hungry or full can be observed from the shape of their bodies and from their motion:

- If the worm's thorax is swollen and if it raises its head and thorax, its body elongates motionlessly, and its skin is very tense and pale, it is full.

- If its thorax is transparent, its body elongates, and it crawls about, it is still hungry.

- If the worm's thorax is transparent, its skin is rather loose, and silk comes out from its mouth, these are the symptoms of hunger and fatigue. Mulberry leaves must be supplied at once.

It is important to know the right time to feed the larvae or the worms will starve. When the mulberry leaves of the preceding feed in the beds are no longer fit to eat, it is time to feed the worms with fresh leaves. Since the cover-rearing method was introduced in feeding the young worms, mulberry leaves can be kept fresh for a longer time than before. The silkworms can be fed three times a day instead of many times, as in the past. In a dry climate, four feedings per day is preferable.

(3) **Amount of feeding:** The amount of feed must be just right. Supplying too much would be wasteful since the refuse leaves would be increased. Moreover, too many refuse leaves would make the beds cold and damp. During the rearing of the young stage worms, an accumulation of refuse leaves can often make many weak worms very inactive. They would develop unevenly and damage production. On the other hand, if too little leaves are fed, the worms do not have enough to eat and their health is placed at risk.

Generally, the standards for feeding are: for the first instar, 1.5 to 2 layers of mulberry leaves are required; for the second instar, 2 to 2.5 layers; for the third instar, 2.5 to 3 layers. Each time fresh leaves are added, beware that about one-fourth to one-fifth of the refuse leaves remain in the beds. At the same time, the quantity of leaves fed each time is closely related to the number of feedings per day, the quality of the leaves and the temperature and humidity. The young stage larvae reared under cover and in high teperature and high humidity will grow and develop rapidly. Therefore, at this stage, the quantity of leaves fed each time should be increased and the number of feedings per day decreased. The amount of leaves fed also varies with the different stage of growth and development. The later the stage, the more leaves are required. Within the same instar, the amount of mulberry leaves fed also depends upon whether the worms are in a poor appetite stage, good appetite stage, gluttonous stage, or premoulting stage. It should be noted that from the poor appetite stage up to the gluttonous stage, the amount of feeding should be gradually increased, and from the gluttonous stage up to the moulting stage, the amount of feeding should be gradually decreased.

The poor appetite stage: This stage begins with ant collection or the first feeding of an instar and lasts about a quarter of the time of an instar. For the first instar, it last until the "sparse bristle" period. For the second instar, it begins with the first feeding and lasts until the skin colour of the larvae becomes green and the wrinkles of the skin extend. At this stage, the digestive system of the larvae is not so good. Therefore, the amount of the first feed is usually equal to the largest amount of the previous instar or 80 percent for one feed. As time goes on, the amount of feed is increased step by step. Each time before feeding, there must be some refuse leaves remaining in the beds.

The good appetite stage: This stage comes after the poor appetite stage. It occupies about one-fourth of the whole feeding period. In this period, the silkworms become more slender and green in colour, the wrinkles in the skin disappear gradually, and their skin becomes smooth. The quantity of mulberry leaves fed should not be excessive. Each time fresh leaves are added, there must be some refuse leaves remaining in the beds.

The gluttonous stage: This period occupies three-eighths of the total feeding period. At this time, the silkworms become big and long and slightly green in colour. Their skin is tense and lustrous. Their appetite is the best for the whole feeding period. Sufficient mulberry leaves must be provided, so that the worms can accumulate nutrients in their bodies. For every successive feeding, there must be some refuse leaves remaining in the beds, or when there are none then fresh leaves can be supplied at an interval of about one hour.

The premoulting stage: This period occupies about one-eighth of the total feeding period. During this period, the worms become fat, their skin lustrous, and their segments quite distinct. They hold up their heads and thorax and remain motionless for a long time. Because their appetite is reduced and they eat very little, the dosage of mulberry leaves should be small and the quantity of the refuse leaves should be maintained at a low level.

To guarantee that the worms have enough leaves to eat, the time and dosage of feeding should be determined in accordance with the atmospheric temperature, relative humidity, silkworm variety and the quality of the mulberry leaves. Generally, under high atmospheric temperatures, the worms always have a good appetite, so more feedings and feed must be given. If the climate is dry, the mulberry leaves will wilt easily, and larger dosages should be offered. Since the fast-eating silkworm variety consumes larger amounts of leaves within a short time, larger dosages should be offered. The slow-eating variety consumes less and takes longer to consume its feed, then a lower dosage is needed.

(4) **How to preserve mulberry leaves in the rearing beds:** Besides completing the delicate work of leaf harvest, leaf transport, and storage, technical management must be provided to preserve the mulberry leaves in the rearing beds. If the leaves do not keep well, they will wilt, spoiling the worms' appetite. If the leaves lose more than 10 percent of their water content, the appetite of the worms would be significantly reduced. If it is reduced to more than 30 percent, the consumption of leaves would be decreased to less than half the quantity fed under ordinary conditions. Sometimes, they even refuse to eat. See Table 4-3.

Table 4-3

Relationship between quality and consumption of leaves

Leaves	Weight of fresh leaves	Dry weight	Refuse leaves (dry matter)	Consumption		Rate of Consumption (%)	
				Actual amount	Index (%)	Acutal amount	Index (%)
Fresh	100 g	22.1 g	14.1 g	8.0 g	100	36.20	100
Wilting 10%	100 g	22.1 g	15.3 g	6.8 g	85	30.70	85
Wilting 20%	100 g	22.1 g	15.7 g	6.4 g	80	28.26	80
Wilting 30%	100 g	22.1 g	18.7 g	3.4 g	42.5	15.38	42.5

Note: Based on tests using fourth-instar silkworms, 300 worms in each treatment.

The degree of wilting in the rearing beds is closely related to temperature, air current, and size of the rearing beds. If the temperature is high, the air dry, the air current fast and the size large, the leaves wilt very rapidly. If there are several feedings a day at short intervals, the leaves will keep fresh longer; if the number of daily feedings is fewer, more leaves will wilt. This means that the number of feedings is determined by the degree of wilting. The cover methods in young silkworm rearing help to reduce the number of feedings per day and permit the mulberry leaves to be kept fresh.

Bed cleaning and spacing

Bed cleaning: The purpose of bed cleaning is to eliminate the refuse leaves and excreta of the worms in the rearing bed. Bed cleaning may be done before moulting, after moulting and at an intermediate period during an instar. See Table 4-4.

Table 4-4

Frequency of bed cleaning

Instar	Before moulting	Intermediate period	After moulting
1	1		
2	1		1
3	1	1	1
4	1	1-2	1
5		Once a day	

Bed cleaning is done by hand or by net. Injury to worms should be avoided, and diseased and weak worms should be eliminated. Silkworm litter is removed from the rearing room and the rearing tools should be cleaned.

Spacing: As the silkworm grows and develops, the size of the rearing bed should be enlarged accordingly. The worms should be arranged evenly, neither too crowded nor spaced too far apart, as either would cause insufficient feeding and irregularity in development or waste of leaves and rearing appliances.

This work can be carried out together with bed cleaning or feeding. Feathers are used to enlarge the bed for the young worms and hand or net for the grown worms.

Management of the moulting process: Moulting is a transition from one instar to another. The moulting worms seem to be motionless in outward appearance, but in fact the moulting activities are going on inside their bodies. The worms are very sensitive to the environmental conditions, and the management of moulting worms is a rearing technique of primary importance. In addition, if it is not adequately handled, it would result in abnormal development of the worms.

The management of the process of moulting involves the following processes: use of rearing bed net at suitable time; bed cleaning before moulting; selection and separation of moulting worms from premoulting worms; protection of the moulting worms after the feeding stops; the first feeding of the newly moulted silkworms; and the bed cleaning after moulting.

Management before moulting

Application of bed cleaning net: In order to keep the rearing beds clean and dry before the moulting stage, bed cleaning nets are used to clear away the faeces and to improve the environmental conditions. If the nets are laid down too early, the refuse leaves are excessive, the rearing beds are too cold and damp and the worms will not moult regularly. Their health would be greatly affected. If the nets are applied too late, many moulting worms would remain in the faeces under the nets, thus making the operation inconvenient and causing many worms to be lost. The right time to lay down the nets depends upon the observation of the change in the colour and shape of the worms' bodies, their eating behaviour, and so on. After the gluttonous stage comes the premoulting stage, during which the body becomes lustrous; the posterior gradually turns pale white (or waxy yellow for the multivoltine); the body becomes shortened and fat; the segments stand out; the appetite is weak; the worm eats only a small quantity; it moves very slowly and holds up its head and thorax. The worms always crowd together. If the worms are beginning to moult individually and not uniformly, it is time to apply nets to the beds. But it is still necessary to consider the variety of silkworms, the instar, the temperature of the moulting period, and the mode of rearing.

Bed cleaning before moulting: Some lime powder is spread on the bed before the nets are applied. After the nets have been applied, feed the worms once or twice with some small fragments of leaves, then clean the beds. The premoulting worms are taken out onto the clean trays to moult.

Separation of moulting from premoulting worms: In a mass of larvae, there are some males and females, some well-fed some ill-fed. Since the quality of the mulberry leaves is not uniform, some are tender and some are tough, the individual worms cannot develop uniformly and the larvae would not begin to moult at the same time. In that case, the moulting worms should be separated from the premoulting ones. The process of dividing the larvae into two batches actually means to divide the larvae from one rearing bed into two. The purpose is to clean the beds to make the larvae grow uniformly and develop evenly. Generally, these processes should be carried out 8-10 hours after the application of the nets. Before dividing the larvae into two groups, spread some lime powder or other moisture absorbing substances on the bottom of the beds. Then lay the net on it, and on the net put some long and slender mulberry leaf fragments. After the worms have crawled to the net, take it up and put it in a warmer place to induce them to moult faster. Generally speaking, the late moulting larvae are always the malnourished ones or of those which are infected by diseases at their early stage. Therefore, if some of the weak larvae still do not moult after the division of the rearing bed, they should be discarded.

__Arrangement of daytime moulting for the silkworms:__ In order to facilitate work in production, some measures have to be taken to arrange the larvae to moult in daytime. The merits of daytime moulting are that it is uniform and fast and convenient for work. The operational techniques are; first, one must be familiar with the regular moulting habits of the variety, i.e., the time of feeding and moulting for the early stage larvae at different instars. Then one should decide on the time for ant collection and try to control the room temperature, humidity and quality and quantity of mulberry leaves, so that the period of instars may be regulated. As a consequence, the worms would be forced to moult in the daytime. Besides controlling daytime moulting for the first instar, measures should be taken to ensure the capability of the larvae of the second and third instar to moult in daytime.

__Management during moulting:__ Moulting lasts 20-24 hours, but this varies with variety, instar, temperature and humdity. The bivoltine variety takes longer to moult than the multivoltine. The spring variety takes longer than the summer one, the late stage larvae longer than the young ones. Those reared at a lower temperature take longer to moult than those reared at a high temperature.

__Stopping feeding and collecting late-moulting silkworms:__ When most of the larvae have gone to moult, except some individuals, feeding should then be stopped. The late-moulting silkworms should be gathered together to be fed again or to be discarded. After all the late-moulting ones have been picked out, sprinkle some lime powder or cereal husk charcoal onto the beds to keep them dry.

__Protection of worms during moulting__

__Temperature:__ At the beginning of moulting, the room temperature should be maintained 0.5°C higher than the objective temperature in rearing. When all of the worms have gone to moult, the room temperature should be adjusted to 0.5-1°C lower than the objective one.

__Humidity:__ At the beginning of moulting, the air in the rearing room should be rather dry, but in the final stage, it should be kept somewhat moist, within the range of 75-80 percent.

When the air is too dry, it is hard for the silkworms to moult. They become very weak and half-moult or do not moult at all. If the humidity is too high, the worms cannot control their body temperature and moisture content. They become quite weak and vulnerable to diseases. To reduce this defect, some drying substances should be sprinkled on the rearing beds.

__Light and air:__ During the moulting period, the light should be moderate and even, avoiding direct sun on the rearing beds. Air current should circulate gently, avoiding strong wind blowing toward the rearing beds.

First feeding

Suitable time for feeding: The first feeding of the larvae means the first feeding of the ant silkworms or the newly moulted larvae. Choosing when to carry out the first feeding of those newly moulted larvae depends upon their characteristics. If too early, it would make them poor in digestion. They could not absorb the nutrients well and would develop unevenly. If it is too late, they would be hungry and weak, which is obvious at high temperatures.

Two or three hours after moulting, the larvae build up an appetite. They hold up their heads and thorax, and crawl about to find the mulberry leaves. In order to make the larvae develop uniformly, it is advisable to feed them when all larvae are out of moult.

Mulberry leaves for the first feeding: After the larvae have moulted, their mouth pieces and the new interior membrane of the digestive tract are very tender. They should be fed with fresh and tender leaves, about half of the maximum quantity of one of the feedings of the preceding instar.

Feeding temperature: In order to stimulate the larvae's appetite raise the feeding temperature to about 0.5-1°C over the temperature during moulting.

Disinfection of larvae bodies: Before feeding, sprinkle some lime powder or powder to prevent muscardine on the bodies of the larvae. Then lay down the net and feed them the mulberry leaves.

Bed cleaning and enlargement: Generally, after the larvae have been fed twice (including the first feeding) with leaves, the rearing nets should be raised and the beds cleaned. The beds should be enlarged properly at the same time.

The micro-climate in the rearing room: In silkworm rearing, the temperature, humidity, air and illumination are integral parts that influence the life of the worms. Of these, temperature and humidity are the most closely related to their growth and development.

Hot and dry climatic conditions: Usually, hot and dry weather occurs in autumn, especially when there is a west wind blowing, or before a typhoon. The following measures should be taken to lower temperature and raise humdity.

- Use an air blower to blow in cold air to lower the room temperature. Make use of the underground tunnel to send the cool current of air from the ground. At the same time, hang with some green leaves or moist cloth to the doors and windows.

- If it is too hot at midday, close the windward doors and windows and open leeward ones. Use electric fans to ventilate the room. In the cool of the evening, open wide all the doors and windows to let the cool air current in.

- Sprinkle well water onto the wall or on the floor. When the water evaporates, it will absorb some of the heat, lowering the room temperature and increasing the humidity.

- Feed the larvae with fresh, moist leaves. For the first instars, the fragments should be cut larger. From the second instar on, whole leaves are used to feed the worms. Cover the beds after feeding.

- The rearing trays should be put low in the stand with wider space apart. Shallow ditch rearing is recommended.

(2) **High temperature and high humidity:** Such weather often occurs in rainy seasons in the summer or rainstorms in autumn or during a typhoon. High humidity is the main problem.

- Open the leeward windows and shut the windward windows. Hasten free circulation of air to discharge heat and moisture.

- Raise the temperature to decrease the humidity. During the period between evening and the following morning, when the room temperature is lower and the humidity is still high, a weak fire is made in a stove to expel humidity. The stove should be put under the exhaust window, with all the windows open side. When the room temperature is too high or the humidity has decreased indoors, put out the fire.

- Equip the rearing room with a dehumidifer. Sprinkle the floor with lime powder and the rearing beds with drying materials to lower the humidity. The rearing rooms, tools and beds should be kept dry.

- When it is very hot at noon, the amount of mulberry leaves fed should be decreased. The mulberry leaves that have less water content should be supplied. Faeces in the bed should be cleaned frequently to keep the beds clean and dry and to prevent hot moist air forming. During the night, the larvae have a good appetite, so the amount of mulberry leaves should be increased.

- Increase spacing between trays and enlarge rearing beds to decrease density of the silkworms.

- In a rainy season, feed the worms with stored and surface-dried leaves rather than wet leaves.

- It would be better to rear the grown worms on the floor or in a shallow ditch. Sprinkle lime powder or burned husk to absorb moisture in the rearing beds.

(3) **Cold and dry climatic conditions:**

- Raise the room temperature and put a basin containing some water over the fire. The water evaporation will increase the humidity in the room. An electro-humidifier can also be used.

- Close the doors and windows. Arrange free circulation of air at intervals. Raise the room temperature before opening the windows for ventilation.

- Sprinkle some clean water onto the mulberry leaves in storage to keep them fresh. Before feeding, scatter the leaves to get rid of surface water.

- Use cover rearing for the young worms. Keep the leaves fresh. Raise the temperature and humidity in the rearing beds.

(4) **Colu and wet climatic conditions:**

First raise the room temperature; eventually the humidity will fall. The methods are as follows:

- After the room temperature has been raised, open some of the doors or windows to allow free circulation of air and to lower the humidity.

- Decrease an adequate amount of mulberry leaves so as to make fewer refuse leaves to maintain the rearing beds in a drier state.

- Sprinkle more moisture-absorbing substances and clean away the faeces often to keep the beds dry.

- After they have been stored, the leaves must be chopped into fine fragments. A smaller quantity of leaves needs to be fed. Moist leaves are not desirable. Keep the indoor air fresh and the light even.

(5) **Ventilation:** The rate of respiration of the young larvae is low. Ventilation may be undertaken by air diffusion or natural ventilation. In cover rearing, remove the cover about half an hour before feeding to permit ventilation before the mulberry leaves are supplied. Ventilation should last longer for third instar worms. For the grown worms in particular, free circulation of air is of primary importance, and is especially needed under high temperature and humidity.

(6) **Illumination:** To avoid overcrowding of the silkworms, beds must be illuminated moderately and evenly. Direct sunlight should be avoided, for it will cause a sudden rise of temperature, which will make the leaves wilt easily, with consequences for the feeding and the growth of the larvae.

Cooperative rearing and exclusive mulberry plantation

To ens ire that the young age larvae grow and develop well, in addition to t e technical measures mentioned above, facilities favourable to the productive organization are needed.

(1) **Cooperative rearing:** Since the young worms' resistance to diseases is weak, their rearing space is small and their consumption of mulberry leaves is also small, it is desirable to rear them in cooperation. Cooperative rearing means gathering together a certain quantity of young worms from the townships, villages or individual farmers and rearing the worms in a cooperative rearing house. The feeds are chosen from the mulberry leaves of superior quality most suitable to the needs of the young worms. The operations are entrusted to the peasants with high technical training. They are responsible for rearing the larvae from ant collection to the second or third instar. After that, the worms are despatched to the individual rearing farmers. Cooperative rearing allows the thorough disinfection of the tools and rooms to prevent diseases, and the micro-climatic environment can be well controlled, so that the larvae can grow up healthy and strong under a disease free environment. It will increase the number of silkworms reared by the individual farmers; eventually, labour and production costs can be saved. Furthermore, artificial feeds and rearing mechanization can be practised. This rearing method has been extended far and wide in Japan, China and many countries. It is effective in obtaining a stable and high yield of silk.

(2) **Running exclusive mulberry plantation for the young stage larvae:** In order to ensure the health of the larvae during the rearing period, the mulberry leaves chosen as feed must be of high quality. An exclusive mulberry plantation is therefore needed. All the expenses including the cost of leaves, are paid by the individual farmers who take part in the cooperative rearing. The size of the plantation depends upon the quantity of larvae reared. It should be situated on fertile land with good irrigation drainage. The plant and row spacing of the trees must be wide enough. The location chosen must be in a sunny spot with good ventilation. Finally, potash, phosphoric fertilizers and organic fertilizers should always be applied to the trees.

4.2 Mode and Method of Rearing Grown Larvae

Just as there are differences in the physiological features between grown worms and young ones, there are differences in the environmental conditions and nutrition they require. One must know well the rules of their growth and development in the light of the physiological features and adopt the appropriate modes of rearing and the technical measures. For example, the late stage larvae eat a large amount of leaves, and their metabolism is vigorous. Their body weight increases rapidly and they prefer a cool, dry and well-ventilated environment. Their resistance to diseases is stronger than that of the young worms. As a result, more space and labour are needed.

Mode of rearing grown worms: There are several modes of rearing the grown worms:

(1) **Rearing by trays:** This is a traditional mode of rearing. In the rearing room are placed some rectangular or triangular stands, each with 8-10 shelves on which are placed some square or round rearing trays. This method uses space efficiently. Four to six daily feedings are required. For the fifth instar, a daily cleaning is required.

The defects of the method are that much labour is spent in feeding and in bed cleaning and the capital investment needed is large.

(2) **Floor rearing:** The worms of the fourth and fifth instar are reared on the floor indoors or on the ground under the shed. The site should be on high and dry land. Wooden floors are preferable. The floor space must be cleaned thoroughly and disinfected with a solution of bleaching powder. Before the larvae are put onto the floor, it should be sprinkled with a layer of quicklime (CaO) powder or a layer of straw cut into short pieces. Then, as part of bed cleaning at the fourth or fifth instars, the refuse leaves are cleared off and the worms are put on the floor for further rearing.

There are two types of floor rearing. Trays 1.3-1.6 m. wide are used; length depending upon the size of the floor space. There is a corridor 0.6 m wide between beds. The other type is rearing on the floor at random; a springboard or several earthen pavements are laid down on the beds to facilitate work. Some extra space serves for the enlargement of beds later on, as they are growing and developing. Ordinarily, during the end of fourth instar moulting, bed cleaning has to be carried out once and the worms are then removed to the floor for rearing. After that, just before they moult again, another bed cleaning has to be undertaken.

If the worms are removed to the floor during their fifth instar, no bed cleaning is needed. For feeding, the whole leaf of the shoots of the mulberry trees are used. The daily dosage is four or five feedings, similar to that of the tray rearing. Since floor rearing entails only one layer, the air in the room is sufficient, labour is saved and the operation is quite convenient. For all these merits, however, one of its major defects is that the utilization of room space is not economical.

(3) **Shallow ditch rearing:** A shallow ditch sheltered by a thatched shed made of bamboo or wood is dug on the ground at a high and dry site with good drainage. It may be built under the trees or the bamboo trees (see Figure 4-1).

Under the shed, one of the following three types of ditches are dug: single ditches, double ditches and multi-ditches. There is always a path between two ditches. The length and width of the ditch depends upon the shape of the land and the construction materials used. Ordinarily, a ditch should be 10-12 m long. If it is too long, ventilation is poor. The width of the upper side is 1.3-1.6 m and the bottom about one metre; the depth is about 0.3-0.4 m. The walls of the ditch slant. When the worms grow up, the rearing beds can be enlarged naturally. Since the ditch is so deep, there is little change in the inside temperature. In hot rearing seasons, it has the functions of protecting the worms from the heat and maintaining humidity. Generally, when the moulting period of the larvae of the fourth or the fifth instar has just finished, and after they have been fed once or twice in the tray, they should be removed to the ditch, preferably in the morning or afternoon. Before the worms are put into the ditch, the inside of it together with the corridors must be fully cleaned and disinfected with quicklime powder. The larvae must be sprinkled thinly and evenly at the centre of the ditch so that they can crawl to either side of it gradually. After that, the temperature and humidity inside are maintained under natural conditions in accordance with that outside. No further bed cleaning is needed. Four or five daily feedings are needed. The mulberry leaves must be sprinkled evenly on the beds. During rearing, beware of ants, rats, toads, poultry and flies.

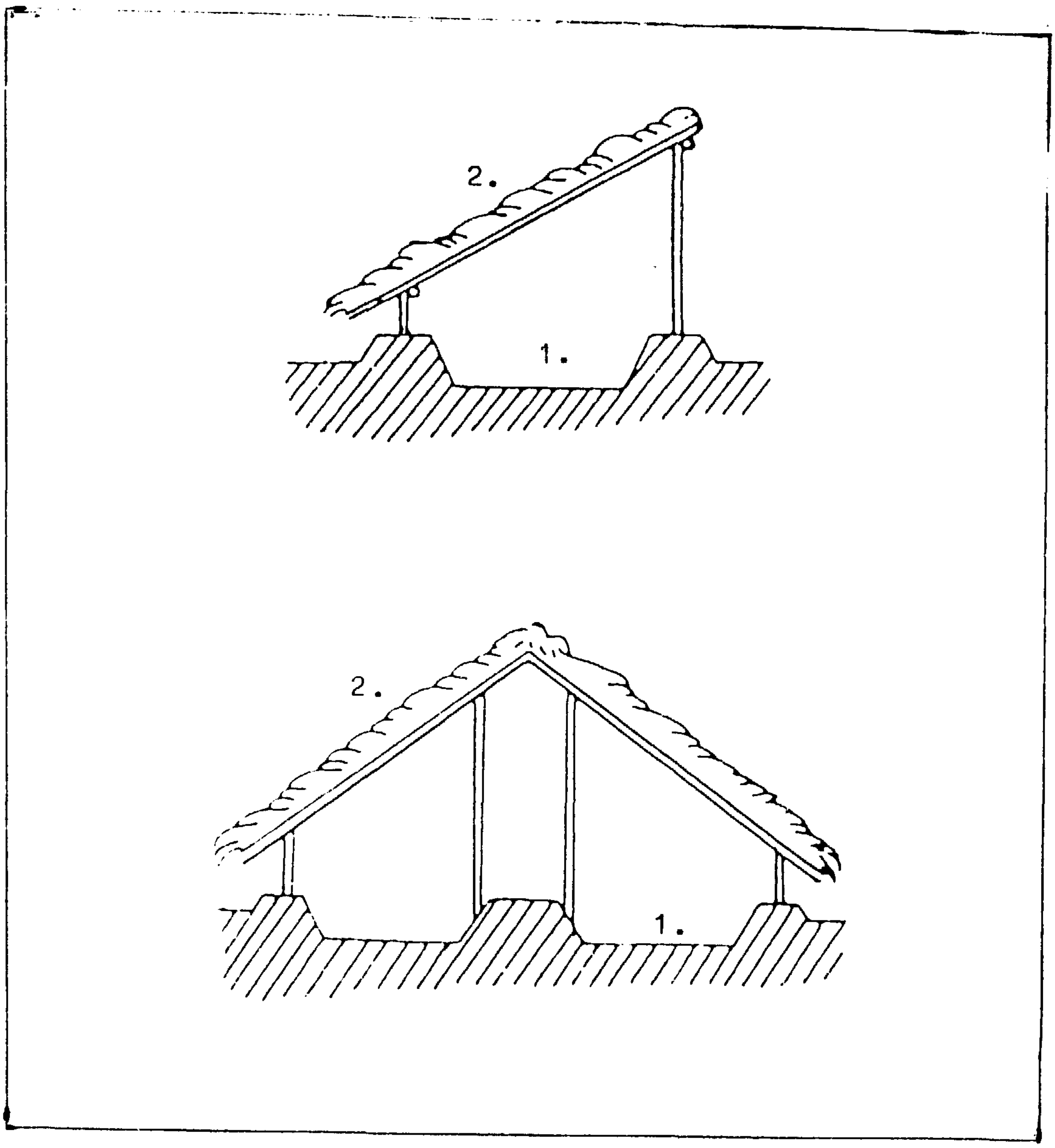


Figure 4-1 Types of thatched cottages with shallow ditches
1. Shallow ditches 2. Thatches

(4) **Outdoor rearing:** This method is the rearing of silkworms in the open air on the ground or in a ditch covered with some simple materials. This type of rearing is most suitable to dry regions or seasons. Its merit is that it economizes the utilization of rearing house, rearing tools and labour. If ventilation is good, the silkworms will grow and develop normally. But its defects are that rearing is greatly influenced by the climatic conditions. Besides, the worms might encounter many natural enemies, which must be carefully guarded against.

(5) **Open air rearing:** The site should be chosen on elevated flat land, slanting toward the west. It must have a drainage ditch, and must be set under a wood or bamboo tree. On sunny days, the mulberry leaves wilt easily, in which case mulberry shoots should be used in feeding instead of the leaves. Sometimes, the leaves or the rearing beds may be sprinkled with some water; but during a moist night, cloudy or rainy days, moist leaves should not be used.

Direct sun on the grown worms should be avoided as the worms will crowd to the shady side. At each feeding time, the worms must be rearranged uniformly in the bed, to avoid some of the worms crowding together and spinning cocoons in the bed.

(6) **Ground rearing:** Choose some land, under wood or between the rows of medium or tall-trunk mulberry trees and dig some ditches. If rearing is undertaken between the rows of the mulberry trees, the branches of those trees must be bent like an arch and pruned in advance during the previous winter, so that in the following spring the leaves can grow out and form a shady cover over the rearing ditches.

A drainage furrow must be dug on one side of the bottom of the ditch. The management of rearing for this method is similar to that of the open-air rearing.

Rearing technique for grown silkworms: The growth, development, and physiological characteristics of the grown larvae are quite different from those of the young ones. The rearing methods are also different. Ordinarily, cover rearing is adopted for young larvae and open rearing for the grown worms. In production, the following points have to be considered in particular:

(1) **Ventilation:** The silkworms eat more and more as they progress from instar to instar. Metabolism is vigorous and the quantity of heat produced, the moisture evaporated and the CO_2 exhausted, increase. Gases are diffused from the spiracles, skin and faeces. If the circulation of air in the rearing beds is weak, there will be a layer of gases of high temperature, high humidity and acid smell surrounding the bodies of the larvae. This can hinder the continuous loss of moisture and CO_2 from the bodies of the larvae, thus raising their body temperature, decreasing the activities of various kinds of enzymes and affecting normal metabolism. In consequence, the larvae will become very weak and vulnerable to diseases.

Under such environmental conditions, the ventilation in the rearing room must be strengthened, so that the harmful gases and moisture can be expelled and currents of fresh and dry air can be circulated in exchange. This can help the transpiration of the moisture of the larvae's bodies, which lowers their body temperature and permits them to develop normally.

If the grown larvae are reared indoors, the doors and windows should be opened wide so that free current of air can circulate through the south and north sides of the room. The speed of the current should be held under 0.5 m/sec. - a mild breeze. If there is no circulation of air inside the room, an exhaust fan, electro-air pump, and blower should be used. During the hot season, when the temperature outdoors is higher than the room temperature, the windward windows should be closed and the leeward windows opened. The windows should be opened for air circulation only in the morning or evening. If the humidity is high, (e.g. on a rainy night with an east wind blowing; or due to the high humidity in the morning and in the evening), the room temperature must be raised to eliminate the moisture inside the room. Furthermore, the dry west wind should be prevented from blowing into the room directly.

When the grown larvae are reared in ditches on ground covered by a shed, the soil temperature is usually lower than the atmospheric temperature. Since the air inside the shed communicates with the outside air, ventilation is better with this method of rearing. Although fresh air comes from all sides, usually only the south and north sides of the shed are opened for free circulation of air. If the wind is too strong, making mulberry leaves wilt easily, then the windows on the windward side should be closed.

Efficient utilization of mulberry leaves: The quantity of leaves consumed in the fifth instar accounts for 80 percent of the total for the whole rearing period. One catty (0.5 kg) of cocoon yield to one dan (100 catties or 50 kg) of leaves consumed is considered efficient use. Rational use means making the larvae eat as much as possible so that the nutrients are fully absorbed and converted into silk substances.

Supply an adequate quantity of mulberry leaves for feeding, and secure the smallest amount of refuse leaves. The quantity of feeds of the larvae varies with variety and development stage. A feeder must know well the rule of feeding. The right quantity of mulberry leaves to be supplied to the worms means the least quantity of refuse leaves remaining in the rearing beds. According to the investigation of the larvae of the fifth instar, the relationships between the different quantity of mulberry leaves to be fed, the quantity of refuse leaves, the quantity of leaves eaten by the worms and the percentage of mulberry leaves eaten by the worms are shown in Table 4-5.

As can be seen from the table, the fifth instar larvae eat only 50-60 percent of the mulberry leaves fed; the other 40-50 percent is wasted as refuse leaves. The more leaves you feed, the more remnants you will have and the lower the rate of ingestion. When the larvae have eaten enough leaves at the first feeding, they stop eating for a long time, during which they will consume only a small quantity of leaves, even if there are plenty of leaves on the bed.

Table 4-5

Feeds, ingestion, and ingestion rate at the fifth instar

Amount of feed (kg)	Refuse (kg)	Ingestion (kg)	Ingestion rate (%)
2.08	0.83	1.25	60.10
2.55	1.03	1.52	59.61
2.83	1.37	1.46	51.59
2.93	1.52	1.41	48.12

Note: The silkworms used are bivoltines, 100 worms for each treatment.

It is reported that the percentage of feed eaten by the larvae in the third hour after the first feeding is 2-10 percent higher than that of the second hour, and 2-5 percent higher in the fourth hour after the first feeding than that of the third hour. That is to say, as time goes by, the quantity of feed eaten per unit of time diminishes; sometimes the larvae almost stop eating, in which case the leaves wilt and are trod upon by the worms and wasted. Therefore, the worms should be well fed and as few refuse leaves as possible left.

The porportional utilization of mulberry leaves of each instar and the specified amount of mulberry leaves used: With a view to economical utilization of mulberry leaves in sericulture, the approximate proportion of the feeding of mulberry leaves in different instars must be specified gradually, so that the larvae will be well fed without waste. This is particularly needed in the fifth instar of the larvae.

There are some rules for the fixation of the dosage for the larvae of different instars and for the daily dosage of the fifth instar. These amounts vary with the varieties of silkworms, rearing conditions, and the quality of mulberry leaves, so that the rearrangement of each dosage depends upon some practical circumstance. It must be determined delicately and rationally.

(3) **Leaf selection:** Mulberry leaves are the only source of nutrition for the silkworms. The amount of mulberry leaves consumed by the fourth and fifth instars is 90 percent of the total amount consumed in all instars. The silk substance of the silkworms is synthesized mostly in the fifth instar. In order to produce 100 parts of silk substance, 170 parts of protein, 200 parts of sugar, 23 parts of fats, and 7 parts of inorganic salts are needed. Since all these substances come from the mulberry leaves, quality is as important as quantity. Therefore, in the rearing of grown larvae, the following inadequate mulberry leaves should be avoided and good, mature leaves used instead.

Tender leaves: Tender leaves are those premature leaves born on the shoots of the tree. They wilt easily and contain much water but little dry matter (carbohydrate, fatty substance, fibre and ash). The absolute content of protein is also less than that in mature leaves. But these have much organic acid. If the larvae of the fifth instar are continuously fed with tender leaves, they will become malnourished. Since the worms have taken much water and organic acid from the tender leaves, the pH of their digestive tracts is low. The activity of enzymes will be lowered and the digestion and absorption of nutrients by the worms will be hindered. The larvae will be very weak and easily infected by bacterial flacherie. Therefore, it is particularly important not to feed them with tender leaves in rainy seasons. If the leaves on the trees have not yet matured, the harvest season should be delayed to obtain more mature leaves, or the tender leaves should be mixed with the mature leaves for feeding.

Over-mature leaves: Leaves with water content of less than 70 percent or which are easily broken by crushing between fingers are called over-mature. They contain little protein; the useful ingredients (nutrients) are reduced, while the worthless ingredients, such as fibre, are increased. Since the leaves are tough, hard and difficult to digest, the quantity eaten and digested and the rate of digestion are all decreased. If fed on these leaves, the larvae will grow slowly. Their body weight would decrease and their life cycle would be lengthened. During a drought, leaves should be harvested before the early dew becomes dry in the morning, not at midday. Leaves should be stored for as short a time as possible, so that they will not wilt easily. The amount of feed and numbers of feedings should be increased adequately, and the temperature and humidity for the feeding should be raised a little.

Sunlight deficient leaves: If it has been raining for a long time, or if the mulberry trees are planted too close together, the leaves have insufficient exposure to sunlight, often shading each other. The photosynthesis of the leaves is thus hindered. As a result, the amount of the protein and carbohydrate assimilated will be decreased conspicuously. At the same time, their transpiration will be slow, so they will have a higher water content. If such leaves are used as feed, the larvae will grow and develop slowly. Their life cycle will be lengthened and their bodies will be weak. Mortality will be high. The worms will be vulnerable to diseases. If there is no alternative but to choose these leaves in feeding, they should be stored for 24 hours before use. In this way, the moisture content of the leaves will be decreased by transpiration and part of the starch will change into sugar, improving leaf quality. The temperature and humidity should be raised, attention should be paid to ventilation, and more moisture-absorbent material should be sprinkled on the rearing beds.

Muddy leaves: If the larvae are fed with leaves stained with mud, they will not eat the leaves or will eat less. After feeding on dirty leaves, the larvae will develop indigestion.

Chemically stained leaves: Due to the spraying of chemicals in the mulberry plantations or nearby rice fields, mulberry leaves can be stained with chemicals which remain effective for some time. If the larvae eat or come into contact with such leaves, they are poisoned. In case of doubt as to the presence of poisonous substance in the leaves, a small part of them should be fed to some larvae to verify the toxicity. If they prove to be non poisonous, they can be used on a larger scale.

Leaves stained with pollutant gas from a factory: A mulberry plantation must not be located in the vicinity of a factory and never be leeward of it, because chimney smoke contains large quantities of SO_2, HF and other harmful gases that can penetrate into the tissues of the leaves. After eating the polluted leaves, the larvae would be poisoned and die. If polluted leaves are discovered, wash them at once, or soak them in 2-3 percent quicklime solution, before feeding, thus reducing their toxicity. The best way is, of course, not to use them at all.

Diseased or pest infected leaves: Mulberry tree pests, such as mulberry white caterpillar, mulberry snout moth's larvae, wild silkworm and mulberry caterpillar, all suffer from the same diseases as the silkworms. If the silkworms eat the leaves stained with the faeces of these pests, or if they are in contact with the dead worms' bodies, they themselves would be infected with the diseases. Sometimes, if the rice fields and forest are sprinkled with the Bacillus thuringiensis var. sotto Ishiwata or the muscardine fungus for biological control, the nearby mulberry plantations would be polluted. These leaves should not be harvested for feeding.

(4) **Use of hormones:** Some chemicals analogous to insect hormone, such as the synthesized juvenile hormone and moulting hormone (ecdysone), which is extracted from some plants, have been used in silkworm rearing.

Juvenile hormone: There are many substances analogous to the "juvenile hormone"; amongst those which are produced and used in China are "734", "738", "512", and "515".

The use of these substances in sericulture production results in physiological changes in the worms, chiefly the lengthening of period of the fifth instar. That is to say, the time required for eating and the amount of mulberry leaves eaten would be both increased. Since the amount of nutrients accumulated and assimilated would be increased, body weight would increase, and the weight of silk substances would increase as well. Thus the final goal of raising the production of silk could be attained. Practical operation proves that the production of silk can be increased by 8-10 percent for the bivoltine variety and 10-15 percent for the multivoltine variety if this kind of hormone is used. The technical skill needed to use juvenile hormone is as follows:

Dosage and concentration: In using this hormone, it is important to choose the dosage that is safe to the larvae and that will increase silk production at the same time.

Time for spraying: The time to spray juvenile hormone is a bit earlier than the middle stage of the fifth instar. It must be determined delicately according to the variety of the silkworm and the temperature and humidity. Since the fifth instar last longer in the bivoltine than in the multivoltine, the spring and late autumn crop is longer than the summer and early autumn crop, spraying the hormone should be done late. If the atmospheric temperature is too high, spraying should be done earlier. If the temperature is too low, it should be later. In Guangdong Province, during the hot season, it is favourable to spray the hormone 42-60 hours after the first feeding of the multivoltines at the fifth instar.

Preparation of the hormone and method of spraying: One ampoule of 734 No. II (5 ml) and 4-5 litres of water may be used for the spraying of 4-5 egg cards of bivoltines, or one ampoule of hormone and 6-8 kg of water for 6-8 egg cards of multivoltines. When the chemical is used, break the ampoule, pour the solution into a vessel, mix it with a small amount of water and stir it well, then add water to the appropriate amount and stir it for several minutes. The solution is now ready for use.

Since the juvenile hormone is sprayed directly onto the larvae so that it can be absorbed through their skins, it is necessary for the larvae to eat up all the mulberry leaves before spraying, so that their bodies can be fully exposed. Now spray the hormone in the form of mist by the sprayer at a moderate speed, neither too fast nor too slowly. Make sure that every larva is in contact with the hormone evenly. About a quarter of an hour later, when it is not so moist, the larvae may be fed with mulberry leaves again.

Points for attention:

- When there is not a sufficient quantity of mulberry leaves for feeding, or when the larvae are infected by disease, do not spray the worms with the hormone. The period of the instar would be prolonged, and the injurious effect would be more serious.

- The accurate dosage of hormone should be strictly followed. Do not change the dosage or change the time for spraying.

- After the bodies of the larvae are sprayed, they will eat more slowly for two days; during this time less feed should be supplied. Later, when their appetite returns, more mulberry leaves should be supplied again, to let them have enough to eat before mounting. The waste of feeds should, however, be avoided.

- Be well aware of the ripening stage of the larvae ready for mounting, place the worms properly in mounting. After being sprayed with juvenile hormone, the pupating time fo the silkworms would be delayed, in which case, do not harvest cocoons too early.

Moulting hormone (ecdysone): Moulting hormone can shorten the larval period of the fifth instar silkworms by half a day if it is sprayed on the worms by the time when 5 percent of the whole batch of silkworms are in maturity. Larvae sprayed with moulting hormone will mature uniformly and quicken the speed of spinning cocoons. Therefore, it can be used to hasten the maturity of the larvae and help to save mulberry leaves and labour during rearing. If it is used together with juvenile hormone, the defects of irregularity in maturity and delay in spinning and in mounting of the larvae, which always occur when the latter is used alone, can be avoided. Under some critical circumstances, such as shortage of mulberry leaves or the occurence of disease in the later part of the fifth instar, it can also shorten the time for maturity and mounting and thus decrease the loss in production to some extent.

For the polyvoltines one ampoule of the hormone (40 mg) and 1 kg of water are mixed to sprinkle 10 kg of mulberry leaves for feeding one egg card of worms; for bivoltines one ampoule of the hormone and 0.6 kg of water are used to sprinkle 6 kg of leaves. The solution must be mixed thoroughly before use. Since the larvae may be repelled by the odour of the moulting hormone, 50 g of rice wine is mixed with one ampoule of the hormone before feeding. As the larvae will mature ten hours after the feeding of the moulting hormone, they are usually fed with the leaves when about 5 percent of the worms are in maturity.

Prevention and control of the enemies of the silkworm: The deadly enemies of the silkworms are ordinary insects like flies and ants. Some bowls containing water should be put under the legs of the rearing stands or some lime powder should be sprinkled on the rearing beds. Sometimes, the mixture of one part chlordane oil emulsion with 12 parts of talc or fine sands, or 5 percent powder can be used to spray the surroundings of the legs of the stands or ditch. This method is very effective with ants, but be careful not to let the silkworms come into contact with the powder or they will be poisoned.

CHAPTER 5

MOUNTING AND COCOON HARVESTING

5.1 Mounting

When the fifth instar silkworms have taken sufficient mulberry leaves, they stop eating and begin to excrete the silk bave for spinning cocoons. At this point, they are considered mature and are put into the mountages for spinning cocoons. This process, called mounting, is the final stage in silkworm rearing and is also considered critical with regard to obtaining a bumper harvest and good quality cocoons. During mounting, the provision of good mountages, rational management and preservation must be ensured.

Mountages (Mounting aids or cocooning aids): The mountage is where cocoons are spun. A good mountage has the following characteristics:

- It is convenient for spinning cocoons; there is abundant space for spinning, so that double cocoons will be kept to a minimum.

- The branches of the mountages should be uniformly distributed and stand firmly.

- There is free circulation of air between the mountages, and moisture is easily dispelled.

- It is capable of enhancing the quality of the cocoons and their reelability percentage.

- It can afford a high percentage of horizontal cocoons and superior cocoons.

- The investment is low and the mountages may be used again and again.

The mountages may be made of bamboo, wood, rice straw or paper, and come in many types. So long as they meet the criteria listed above, they can be of different types, such as the "centipede" type, the folded type, the square-frame type and the "umbrella" type, the bamboo "floral" type, the bamboo slip type or others. The square-frame type which can produce 90 percent good quality cocoons, is superior to the others. In Southern China, where the humidity is rather high, the bamboo "floral" type is preferable because it is easy to raise the temperature and dispel the moisture in the mountages. It is also durable.

Arrangement of the mounting

(1) **Suitable time for mounting:** After the active eating stage (gluttonous stage), the silkworms gradually lose their appetite. Their

bodies shorten and they excrete soft faeces and begin to show signs of maturity. Later, their appetite suddenly decreases, their faeces are greenish and their thorax becomes translucent, as does the abdomen. Finally, they stop feeding. They raise their heads and thorax. They excrete some silk bave in their mouth parts and they crawl about in the rearing beds to find a site for cocooning. All these are the characteristics of maturity.

When the mounting period is arranged either too early or too late, the quality and quantity of the cocoons are affected. If too early, the premature silkworms will craw about without cocooning. This not only is troublesome for mounting management, but also causes a low raw silk percentage of cocoons later on. Besides, the insufficient feeding increases the number of dead larvae. On the other hand, if it is too late, part of the silk excrete will be wasted, hence double cocoons, thin layered cocoons, scaffold-pressed cocoons, and stained cocoons are formed, seriously influencing quality and quantity.

(2) **Methods of mounting:**

Hand picking: The mature larvae is picked up by hand and put into a small bamboo tray and immediately transferred onto the mountages. If "floral" mountages are used, mature larvae are sprinkled on the floral mountage evenly. The mountages are held up in a "/\" shape and turned about later. While this method is convenient for mature larvae, it is labour consuming.

Self-mounting by the worms: The method is as follows: First, the early-matured larvae are picked out and put on some mountages; when most of the worms are maturing (in the early stage of maturity, some moulting hormones or maturity-hastening chemicals are fed to the larvae), the larvae are first fed with a small quantity of mulberry leaves, then the mountages are put down on the rearing beds. Since the silkworms have the habit of moving upwards, they will crawl up to the mountage. As soon as a sufficient number of larvae reach the mountage, it should be removed and replaced with a new one. This method saves much labour, but is hard to use if the larvae are not uniformly mature. It is also difficult to determine the appropriate density of the larvae.

Density of the silkworm larvae in mounting: The density of mounting varies with the size of the mountage. Generally, with the centipede mountage, the density is about 350-400 mature larvae/m^2; for the square-frame type, about 150 larvae per mountage. For the floral mountage, it is about 1 m x 0.6 m for 1.5-2 kg mature larvae or about 500-600 larvae for the bivoltine varieity and 800-900 larvae for the polyvoltine. Usually, for the large cocoon variety, the higher the temperature the thinner the density should be, and vice versa.

Preservation in mounting: The excretion of silk bave lasts about three to four days. During this period, the reelabiity of the cocoons and the quality and quantity of the silk produced, are closely linked to the preservation of the environmental conditions of the mounting.

Temperature: Once mounting begins, temperature influences the speed of the worms' cocoon spinning and the quality of cocoon silk. Generally, the higher the temperature, the more rapid the excretion of silk bave, and vice versa. However, if the temperature rises too high, the cocoon shell will become very loose and folded with wrinkles and knots. Moreover, it will induce a change of character in the sericin protein, thus increasing the cohesive power of the silk filaments, causing more difficulty in reeling and increasing the number of dropped-end cocoons. If the temperature is too low, the larvae will excrete the silk bave slowly, the cocoon will be large, and the spinning will take longer. Because of the humid conditions in South China, the optimum temperature range there for cocoon spinning is 27-28°C for bivoltines and 31-33°C for polyvoltines.

Humidity: After mounting begins, the mature larvae will excrete more urine than ever before, creating a humid environment in the mountage. If the humidity is too high, more larvae and pupae will die. At the same time, the silkworms become very fatigued and excrete bave slowly. The number of head vibrations gradually decreases and longer rest periods are needed. There are more knots in the bave, and a larger area is needed. It is not easy for the silk to dry. Since the filaments of fibron adhere tightly to one another, it is hard to dissolve the sericin, making reeling more difficult. If the atmosphere is too dry the cocoons will be defective (multi-layered cocoons, loose-knit cocoons, etc.). If the cocoon layer is loose knit, the filaments will break easily, making it unfavourable for reeling and lowering the neatness of the silk. The optimum relative humidity for mounting is 70-75 percent. In highly humid areas, it is extremely important to expell excessive moisture during the mounting period.

Table 5-1 shows the influence of temperature and humidity on the reelability of the silkworm cocoon.

Table 5-1

Influence of temperature and humidity on reelability of silkworm cocoons

Temperature (°C)	Humidity (%)	Reelability (%)	Reelable length of the bave (m)	Total length of the bave (m)
24	70	90.09	1 007	1 118
	80	80.05	958	1 088
	90	78.74	837	1 063
26.5	70	91.32	978	1 071
	80	85.05	937	1 104
	90	68.68	726	1 057

Air and air current: Mature silkworm larvae excrete large quantities of faeces and urine, releasing such harmful gases as ammonia into the mounting room. If these gases are not expelled, they will increase the humidity in the mountages and damage the reelability, humidity and lustre of the silk. It is important to speed up the room's ventilation by removing excessive moisture and harmful gases. This will improve the sanitary conditions for the mature larvae so they can excrete bave for cocooning normally. If the air current in the room is too fast, a strong wind will blow directly on the mature larvae, causing them to crowd together and form many double cocoons. If the wind is even stronger, multi-layered cocoons will be formed. Air current speed in the mounting room should be less than 1 metre per second. In practice, it has proved that under high temperature and humidity, air current can increase the reelability of cocoons significantly.

Illumination: Mature silkworm larvae have a tendency to turn away from light. When a strong light or side light enters the mounting room, the larvae will crowd to one side, forming many double cocoons or cocoons of uneven thickness. A mounting room should have moderate, even rays of light, with no strong direct sun or side light. If the mounting is kept in darkness, spinning will slow down and the quality of the cocoons will decline.

In the delta of the Pearl River in South China, the local silkworm rearers have developed preservation measures in mounting adaptable to the local situation.

As soon as the shape of cocoon is formed by the mature larvae, the mountages are put together, in the shape of a lantern, to facilitate ventilation and elimination of humidity in the mountages.

Ordinarily, five floral mountages are arranged vertically to form a pentagon, or six of them to form a hexagon. The floral mountages are fastened together, side by side, with some small bamboo rings. Another four to six $\wedge$ shaped mountages are placed horizontally in the top of the hexagon or pentagon (9 to 12 mountages are needed for each group). A coal burning stove is placed in the centre of the mountages, the top of the stove covered with some ashes of rice straw. The temperature and time required depend upon different silkworm varieties and different seasons of the year. For the bivoltine, the temperature should be maintained at about 28°C in spring and autumn for two or three days until the larvae excrete silk bave. For the polyvoltine, the temperature should be 30 to 33°C in summer for more than 36 hours. The humidity in the mountages should be 65 to 75 percent relative humidity.

In other sericulture regions of China, centipede, folded and square-frame mountages are often used. Their methods of arrangements vary from one another. Nevertheless, an overall plan for the whole mounting room is arranged.

"Baking": "Baking" means heating the cocoons in the mountages to a half-dried state. This process is adopted to prevent fly maggots in summer. The operation is completed on the basis that all the silkworm pupae and the fly maggots have been killed inside the cocoons. According to one method, the room temperature is raised to about 80°C

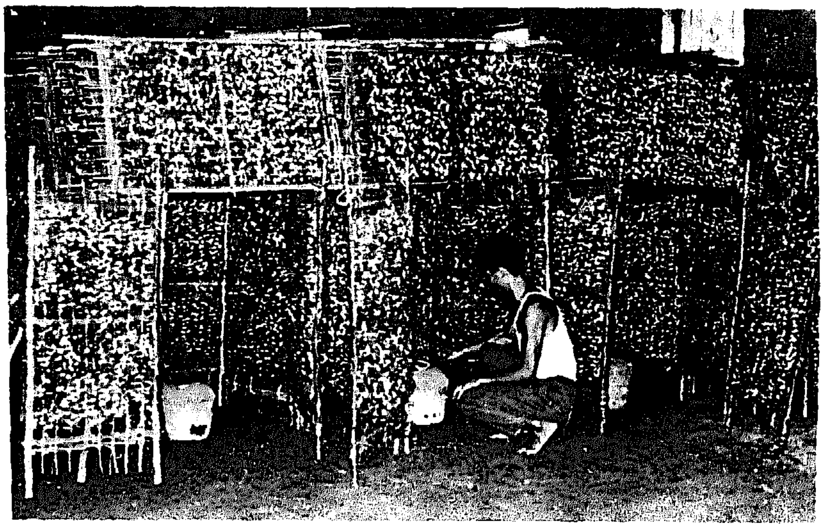


Figure 5-1 "Floral" bamboo mountages

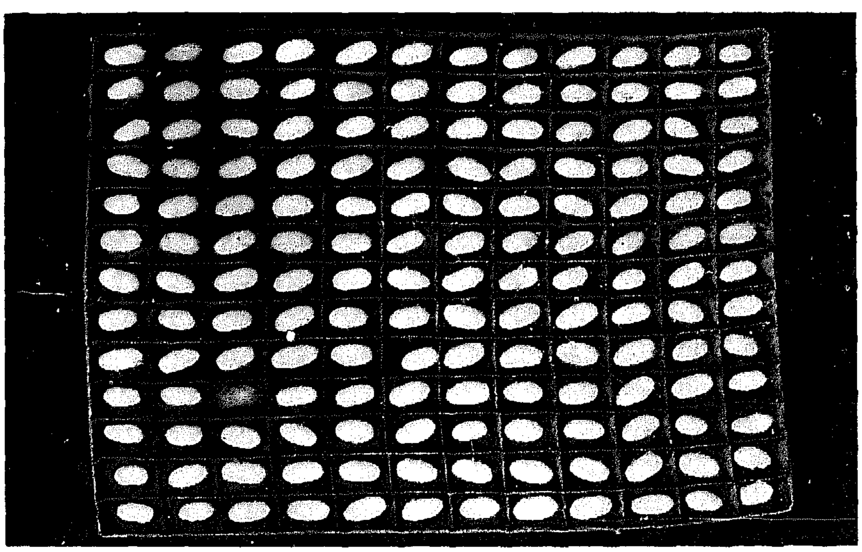


Figure 5-2 Square-frame mountages

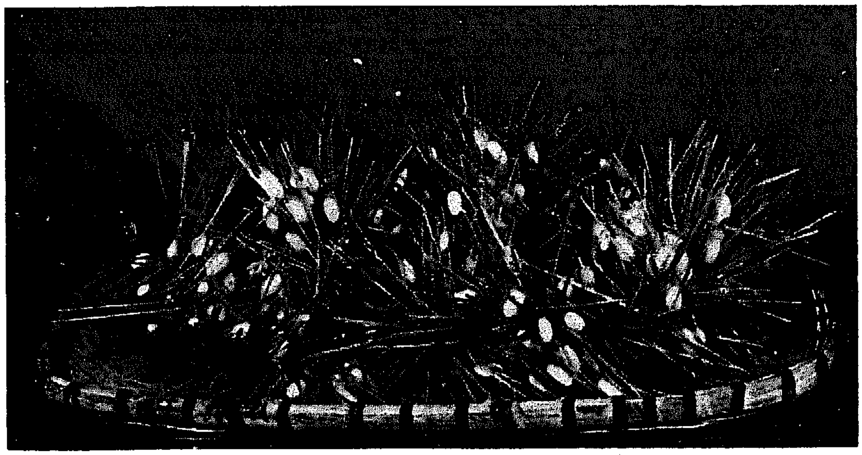


Figure 5-3 Centipede-shaped mountages

Figure 5-4 Bamboo slip mountages

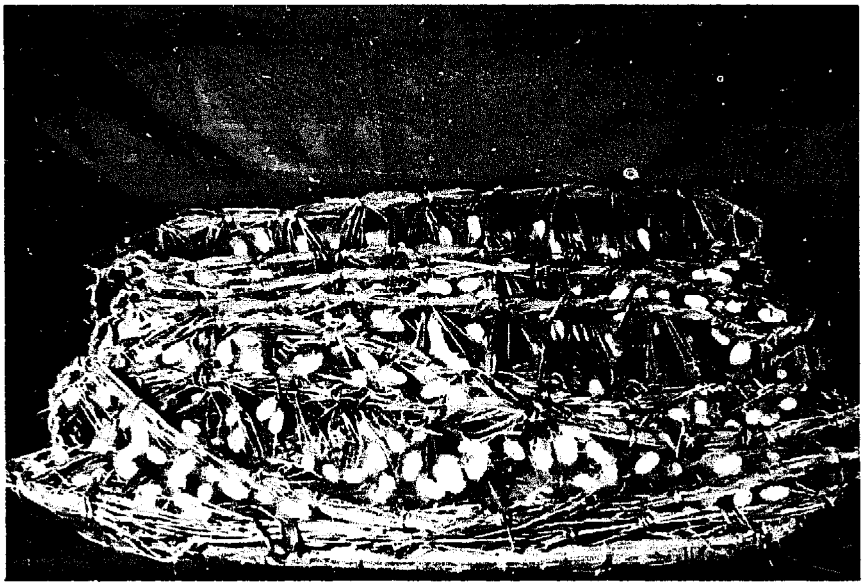


Figure 5-5 Folded mountages

for three hours, then the mountages are turned over and heated again for another two hours until the fire of the stove extinguishes itself. In the second method, the temperature for "baking" should be maintained at 70°C for about 5 to 6 hours. Be sure to make an outlet for the expulsion of the damp at the beginning of the process.

The formation of poor-quality cocoons and measures for prevention: Poor-quality cocoons means light defective cocoons or inferior cocoons. The former have a slight defect and are still reelable, but their reelability is bad and only low-quality silk can be produced. The latter have a major defect on the surface of the cocoon shell. They are not reelable. This is mainly due to inappropriate treatment and inadequate preservation during cocooning.

Double cocoons: Double cocoons are so called because they are spun by two or three silkworms whose pupae remain in the same shell. Their silk baves interwind with each other. They are larger and have a thicker layer of shell. They are made not into silk of superior quality but into floss or spun threads. The reasons for doubling are that the worms have not been given adequate space for spinning or they are arranged too late for mounting, or the temperature is too high in the preservation of mounting. Other reasons may depend on the characteristics of certain silkworm varieties. Measures for preservation are as follows:

- Let the silkworms have adequate space for spinning of cocoons.

- Too high a temperature should not be maintained during the mounting period and the worms should not be too late in cocooning.

- Before cocooning of the silkworms, always change the positions of the mountages, so that the mature worms can crawl to a wider space to spin the cocoons.

- Do not let the sun shine directly on the mountages.

Dead silkworm cocoons (mutes): During mounting, some pupae are dead inside the cocoons. The decaying pupae release a putrid fluid which also stains the silk shell. These cocoons are called "dead" or "mute" cocoons. This is due to the polyhedrosis and flacherie diseases, or unsuitable environmental conditions in mounting (especially high temperature and humidity). If the air is dry and the temperature is high, dead pupae or unmounted pupae easily occur. Disinfection and other protective measures should be carried out.

Scaffold-pressed cocoons: These have a non-uniform texture of the silk shell. Some portion of it appears especially compact and is hard to separate during reeling. The baves are easily broken. They are formed because the space for the spinning of cocoons is too narrow. For prevention, improvement of the mountages is needed and sufficient space should be allowed for spinning.

Stained cocoons: These cocoons are stained by the mature worms' intestinal fluids which drop on them, or by the fluids of the putrifying worms, or the fluids from the mountages. For prevention, mature worms should not be mixed with premature ones during mounting; the mountages should be kept dry by provision of good ventilation. Floral mountages must be placed at a suitable inclining angle, so that excretions will not drop on the cocoons. Finally, all the late-mounting worms should be picked out and put together onto another mountage for spinning.

Broken-end cocoons (thin end or weak points): The defect of the cocoon generally occurs at one end, which may be too thin or even broken. Sometimes, it is due to the characteristics of some silkworm varieties or to uneven illumination or too high a temperature or humidity during mounting. Improved environmental conditions for mounting are needed.

Usi fly maggot cocoons: These are so called because their cocoons are always pierced on the ends by the maggots of usi flies. These cocoons are unreelable. For prevention, bake and dry the cocoons to kill the usi fly maggots at the earliest possible time, before they can pierce the cocoons.

Malformed cocoons: Those that do not possess the definite characteristics of cocoons of certain silkworm varieties are classified as malformed. This category includes all cocoons with pointed or flat ends, or those of irregular shape. They easily become dropped-end cocoons during reeling. Their silk is of bad quality. This occurs largely because of the irrational structure of the mountages, where the space for spinning is too small, the time is too late for mounting, or the larvae are too weak during cocooning. All these factors should be noted and preventative measures should be taken.

Loose knit cocoons: These cocoons are flossy, not compact, and have conspicuous wrinkles on them. They feel soft and are difficult to reel. There are many dropped ends and much silk is wasted during reeling. They occur for reasons connected with the characteristics of the silkworm varieity, but sometimes because of the weakness of the worms. For this reason, they excrete silk bave very slowly. Sometimes, they occur because conditions in mounting are too dry.

Multi-layered cocoons: These cocoons are so called because each of them contains several layers of shell that are not gummed together. This occurs because the worms when mounted are incorrectly handled. During the mounting period when the temperature is high in daytime, the worms excrete bave and spin it into cocoon shells, while at night, when the temperature is lower, the worms would stop excreting bave. When the temperature rises again the next day, they resume spinning. In so doing, the worms produce alternatively several layers of shell within a cocoon whose silk does not interwind tightly together. For prevention, optimum temperature and humidity should be maintained throughout the mounting period. Abrupt fluctuations of temperature and humidity should be avoided.

Thin-layered cocoons: These are so called because the layer of the cocoon shells is very thin, i.e., less than one-third of the cocoon layer ratio of the superior-quality cocoons. They occur because the silkworms are fed insufficient amounts or are fed leaves of inferior quality, thus making them grow weak or late in mounting. These cocoons possess scant silk and are hard to reel. It is therefore of primary importance to feed the fifth instar larvae well, to make them grow and develop soundly, and to mount them at the appropriate time.

The occurrence of non-cocooning silkworms and preventative measures: Different factors can cause non-cocooning larvae. The chief ones are the minor toxicity of chemical insecticides, some silkworm diseases (such as polyhedrosis, flacherie, or pebrine diseases), some physiological abnormality or poor environmental conditions (e.g., the fluctuation of temperature or too high temperature or humidity during the mounting period), the characteristics of some silkworm varieties, and mechanical injuries. An overdose of the juvenile hormone also can cause such an occurrence. In short, the reasons for non-cocooning must be determined according to the different conditions and equivalent effective measures must be taken to prevent them.

5.2 Harvesting of Cocoons

The harvesting of silkworm cocoons is the final stage of the process of silkworm rearing; and must be carefully carried out.

When to harvest: The best time for harvesting cocoons of silkworms must be decided correctly. If it is too early, the larvae have not yet pupated, the skin of the pupa is still tender and easily wounded, and blood will come out, staining the cocoon shell and affecting the quality and colour of the silk. If it is too late, the polyvoltine maggots of the usi flies that parasitize the silkworm will pierce the ends of the cocoons. The appropriate time for harvesting cocoons varies according to the mounting temperature. Generally speaking, it is most suitable to harvest when the larvae have already pupated and their skin has turned yellow. For the bivoltine variety, the suitable time is five to seven days after mounting begins. For the polyvoltine, it is four to five days after. However, climatic conditions have to be considered simultaneously.

__Method of harvesting:__ The dead and decaying pupated cocoons should be removed to avoid staining the good ones. The early mounting cocoons should be harvested first, the late mounting ones afterwards. The cocoons should be handled carefully and lightly; they should not be thrown or the pupae will be wounded inside. When harvesting is finished, they should not be piled densely or the respiration of the pupae will be obstructed and heat and moisture will be formed affecting the quality of the cocoons.

The cocoons should be picked up by hand in the centipede mountages, with forceps in the floral type and machines should be used in the square-frame type, in order to save labour.

Cocoons must be placed according to quality (e.g. superior quality, inferior quality and double cocooons). Attention should be paid to the decaying cocoons, which must be discarded at once or they will affect the quality of the good ones during the process. The double and inferior cocoons should be sorted out from the superior ones. Classification of cocoons should be strictly adhered to and should be sold according to grades.

CHAPTER 6

THE DEVELOPMENT PROGRAMME AND PRODUCTION PLAN

The planning of silkworm rearing has two aspects. First, it is an overall plan worked out by the Government for the development of sericulture in a certain region, especially for a new region. It addresses the scope and speed of development, mulberry plantation, silkworm rearing, egg production and cocoon processing, together with the land, labour, housing, production materials and training of technical personnel concerned. Second, it is also a production plan worked out by each silkworm rearing unit itself for the layout of silkworm production for the whole year and detailed arrangement of production materials, including mulberry leaves, housing, rearing tools and labour.

6.1 The Development Programme of Silkworm Rearing

It is simple to develop silkworm rearing in traditional regions that already have a sound foundation than in a newly developing region. Nevertheless, a project has to be worked out in order to fulfil the production plan on schedule. The key points of a project to be considered are the scope of development, the expansion of the area of mulberry plantation, the speed of development, raising the level of scientific skill, and enriching scientific knowledge in sericulture. Moreover, in a new region a more detailed project has to be offered and followed, to achieve the production goal step by step. Prior to the development project, the overall features of the silkworm industry should be thoroughly studied in order to work out a practical plan.

The features of the silkworm industry

There are many links with agriculture, industry, commerce and trade. As to agriculture, the mulberry must be well planted, the silkworm well reared and bred in order to propagate good varieties. The links are similar to links in a chain, each one restricts one another and promotes one another and no single one is expendable. Anything lost or gained in each link affects the success or failure of the whole industry and the quality and quantity of cocoon silk and finally, its economic benefit.

High technologies are required. The aim in the development of the silkworm industry should be to obtain maximum quality and quantity of cocoons and raw silk in the most economical manner. Therefore, for mulberry planting, good quality and large quantities are both needed. At the same time, in silkworm rearing, strong and good healthy breeds of silkworms with fine quality of silk, are also needed. Also necessary is a good environment for rearing the worms and relatively advanced skill. Only with all this can worms grow and develop normally, especially in the changeable climatic condition of the Asia-Pacific region.

Good planning is essential. Mulberry leaves are the basis of silkworm rearing: no mulberry leaves no silkworms! Good-quality mulberry leaves can produce good worms. In order to better utilize the leaves and to rear as many worms as possible, a rational arrangement of rearing rooms, rearing tools and labour must be made. The amount of mulberry leaves and their harvesting seasons must be strictly arranged according to schedule, so that there will not be an excessive amount of leaves to feed only a few worms, making it necessary to discard the leaves, nor a limited amount of leaves to feed a large quantity of worms, so that the surplus worms would have to be discarded. When the harvesting or quality of leaves does not match the needs of the worms, they could become infected with diseases, and the industry could fail. In short, a detailed plan should be worked out for the supply of silk eggs, their time of distribution and on the coordination of different varieties of the silkworms used.

The pathogens of silkworm diseases are very complicated. There are many ways by which the silkworm can become infected by diseases; therefore the environmental conditions of the rearing houses are of primary importance. Atmospheric pollution would affect the growth of the mulberry and even affect the worm directly; insecticides could poison the worms. Many silkworm diseases are transmitted by contaminated mulberry leaves. Diseases can be infectious or non-infectious. The infectious diseases include the virus diseases, the bacteria diseases, the fungus diseases and the protozoa diseases. All these can cause a high fatality and ruin an industry. The non-infectious group includes diseases caused by injurious gases, pollution by insecticides and disease by usi flies.

The scale of the industry: The most important element is the planning of the mulberry plantation. The items to be considered are: area of the plantation, site of the planting, yearly planting schedule, estimated yearly output of leaves, total amount of silkworms reared yearly, total yearly output of cocoons in the following years. Consideration should also be given to technical management. It is advisable to have an overall picture of the local enconomy. The total amount of raw silk produced in the whole region should be able to meet the requirements of the raw material for the development of the sericulture industry in a country. It is advisable to have mulberry plantations of 350-400 hectares within a period of, at most, two to three years. From the third year onwards the cocoon yield per hectare of mulberry trees should reach 1.5 ton/year (i.e., there would be 500 tons of cocoons per year in the county). A reeling factory with 120 sets of 20-end reeling machines should be run, and it could produce 50-60 tons of raw silk per year. At the same time, a grainage may be provided, which can supply 30 000 egg sheets every year to the rearing units, so the supply and demand of silk eggs are balanced with each other. If the facilities in some counties are deficient, the scale should be reduced and the pace slowed down.

Labour: In the development of the silkworm industry, much labour force is required. In Japan, where the industry is now mechanized to a high level, the labour required to produce 100 kg of cocoons decreased from 900 work hours in 1949 to 219 work hours in 1979. According to investigations in Fukujima County in Japan, a farmer with a yearly output of 2 000 kg of cocoons needs only 155 work hours to produce 100 kg of cocoons. In other words, less manpower is needed in the Japanese silkworm industry than previously. In China, silkworm rearing farmers still depend mostly on manpower. To produce 100 kg of cocoons it takes about 600 work hours in the eastern part of China and about 450-500 work hours in South China.

According to investigations in Fukujima County, the percentage of labour consumed in different areas of work in the silkworm industry are as follows: fertilization and management in mulberry plantations - 10 percent; leaf harvesting - 34 percent; feeding worms - 37 percent; mounting - 5 percent; collection of cocoons - 7 percent, and others - 7 percent. In Guangdong Province, China, the labour consumed in the industry is as follows: mulberry fertilization and management - 35.5 percent; leaf harvesting - 30.86 percent; feeding worms - 14.83 percent; mounting - 8.01 percent; cocoon collection - 5.85 percent; and others - 5.73 percent. According to the division of labour, the main labour used in the industry is: 20-30 percent, and subsidiary labour 70-80 percent. The labour of the grainage, silkworm rearing, reeling factory and weaving factory, should also be included in the plan.

The labour force available in silkworm rearing should be adjusted to those available in the other fields; and those available in the busy season should be arranged with those in leisure seasons.

Rearing tools and rearing rooms: A special rearing house and a special set of rearing tools should be prepared in advance, with precautions taken to prevent the spread of silkworm diseases. In the non-production region, human dwellings should be separated from the rearing house.

The requirements for the construction of a rearing house have already been discussed. With regard to the planning of the rearing house, the following three points have to be considered: floor space, position and structure, and adequate layout.

The floor space of a rearing room: The size of the floor space depends upon the growing speed of silkworms of different instars and upon the structure of the building. As an example, the bivoltine in different instars takes 10 g of bivoltine eggs (equal to 90 percent of this amount for polyvoltine eggs). Each instar requires different space and sizes of rearing beds (see Table 6-1).

The standard space for the rearing beds (40 000 eggs) suggested by the Mysore Research and Training Institute, India, for the final stage in different instars are: 0.15 (I), 5 (II), 10 (III), 20 (IV) and 40 (V) m^2. These are much denser than those shown in Table 6-1.

The utilization of rearing rooms and rearing tools for 10 boxes of silk eggs (10 g of ants/box) for the bivoltine silkworms reared in Zhejiang Province, China, is described in Table 6-2.

The rearing tools and rearing house used are somewhat different in Guangdong Province, where several crops of silkworms are reared per year. Their items are listed in Table 6-3.

Table 6-1

Space required at different instars

Instar	At ant collection	First	Second	Third	Fourth	Fifth
Size of rearing beds (m^2)	0.17	0.84-1.17	2.51-2.84	5.84-6.60	11.67-14.00	23.34-27.84
Multiplication of preceding instar	-	6±	2.7±	2.5±	2.3±	2±

Table 6-2

Specifications and quantity of the rearing room and rearing tools

	Items	Quantity	Specifications	Remarks
Rearing House	Feeding room	3	4.7 x 9 x 4 m^3	If the young worms are reared in the hot bed and the grown worms are reared outdoors. Two feeding rooms may be spared. In floor rearing, 244-289 m^2 is required, and the grown worm rearing room is also used as a mounting room.
	Mounting room	1.5	4.7 x 9 x 4 m^3	
	Leaf chamber	1	4 x 8 x 2.6 m^3 (width x length x height)	
Rearing Tools	Rectangular tray or large circular tray	280-300 180-200	1.4 m in diameter	About 1.1 m^2 About 1.6 m^2
	Ladder-shaped stands or tripod rearing stand	30-36 22		To hold the large round trays

Table 6-2 (continued)

Rearing Tools	Young silk-worm net	200		
	Grown silk-worm net	600-700		
	Feeding stand	10-12		
	Mountage of reed mat	100 sheets	3.3 m in length 1.6 m in width	
	Plastic membrane	15 kg		Polyethene membrane

Table 6-3

Size of rearing rooms and quantity of rearing tools required for feeding ten egg cards of polyvoltines in Guangdong Province, China

Item	Quantity
Rearing room	40 m^2
Leaf chamber	20 m^2
Rearing stand	6 sets
Bamboos	120
Mountages	250
Rearing trays	120
Leaf baskets	8 pairs
Faeces baskets	3 pairs
Chopping knives	2
Stoves	4
Hygrometers	2
Nets	50
Polyethene bags	10 kg

The site of the silkworm rearing house and its structure: The silkworm rearing house is where the silkworms live and are raised. The building, structure of the house, materials used, and premises attached are all planned and arranged according to local circumstances and materials. An old building is either restructured or a new one built. Suitable environmental conditions should be provided so that a stable and high yield of cocoon silk is obtained. Therefore the site for the rearing house should be selected according to regional environmental conditions. In regions where rainfall is abundant, a dry, sunny, well-ventilated and well-drained highland should be selected. In regions where rainfall is scarce, wind is strong, climate dry and the temperature fluctuates violently, a leeward, warm, sunny and rather moist area should be selected. The climatic conditions of the Asian-Pacific region are characterized by high temperature and humdity and long-day zones. Therefore, the rearing house should be built on comparatively high land, with low level of underground water and good ventilation.

The direction in which the rearing house faces is important, since it affects room temperature and humdity. Since China is in the northern hemisphere, there is usually a south or southeastly wind during summer. Since the south wind is warm and mild, bringing a current of fresh air, it is especially suitable for the summer and autumn crop of silkworms. Therefore, in China, the rearing house always faces south, southeast or southwest, and no direct sun will reach the room inside. However, the direction of the rearing house varies with the rotation of the earth at different latitudes and longitudes. It should, however, be selected according to one principle: direct sun should be avoided. In order to obtain a cool, shady and well-ventilated environment in South China, farmers always plant some trees around the building. Until the trees grow, mat-shelters are built outside the windows and climbing plants such as melon or squash are planted, so as to resemble an outer verandah.

There are three types of buildings: single-storey, two-storey and three-storey type. With the three-storey type, the leaf chamber should be arranged on the ground floor, the rearing room on the first flour, and the mountage room on the top floor. However, this type of house is not convenient for regions in which silkworms are reared all year round, since it requires a high investment and is not suitable for individual farmers. In South China, a one-storey house is always used, since it is economical, simple, easy to construct, and has good ventilation. The most popular types of rearing houses are shown in Figures 6-1, 6-2 and 6-3.

Equipment in a rearing room: To ensure the free circulation of air, windows or doors and ventilators on the roof are used to provide ventilation; double-layered roof tiles and ceiling are used to keep out the sun's heat; a stove is used to keep the room temperature high in cold seasons; a slow-burning fire is used to keep down the inside humidity, but preventing too much moisture indoors depends chiefly upon the elevation of the foundation of the house and other factors. If possible, some electrical equipment, such as a fan, a furnace, autoregulating humidity devices, and air conditioning equipment, may be installed to control the micro-climatic conditions in the room.

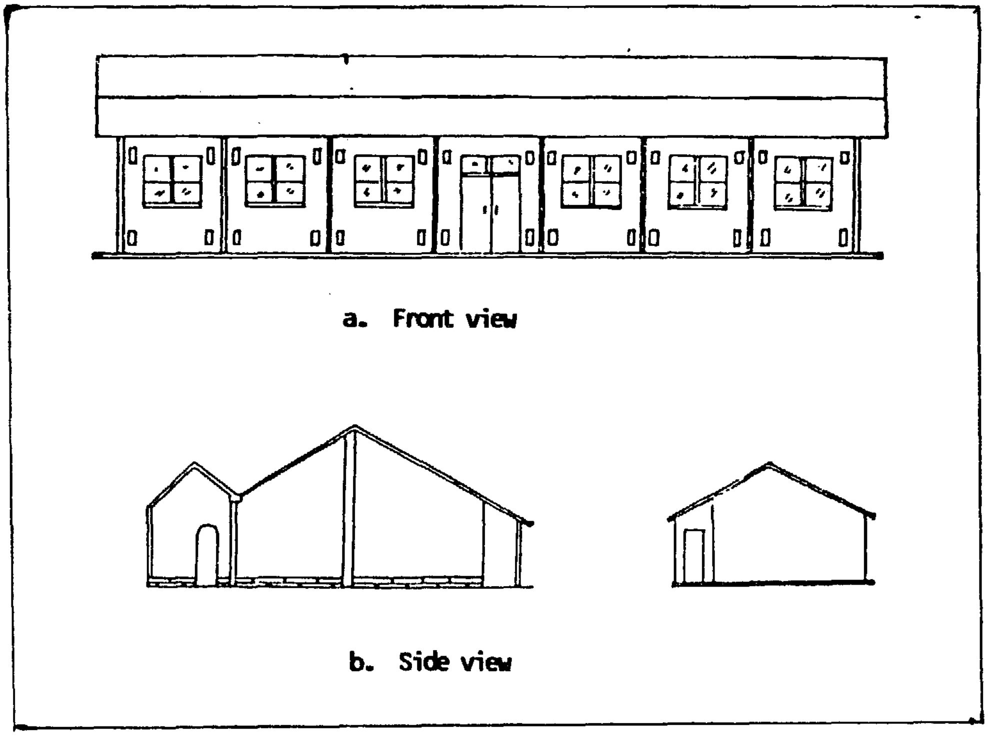


Figure 6-1 Design drawing of a one-storey house (Guangdong Province)

Figure 6-2 A two-storey rearing house in Shunde County, Guangdong Province

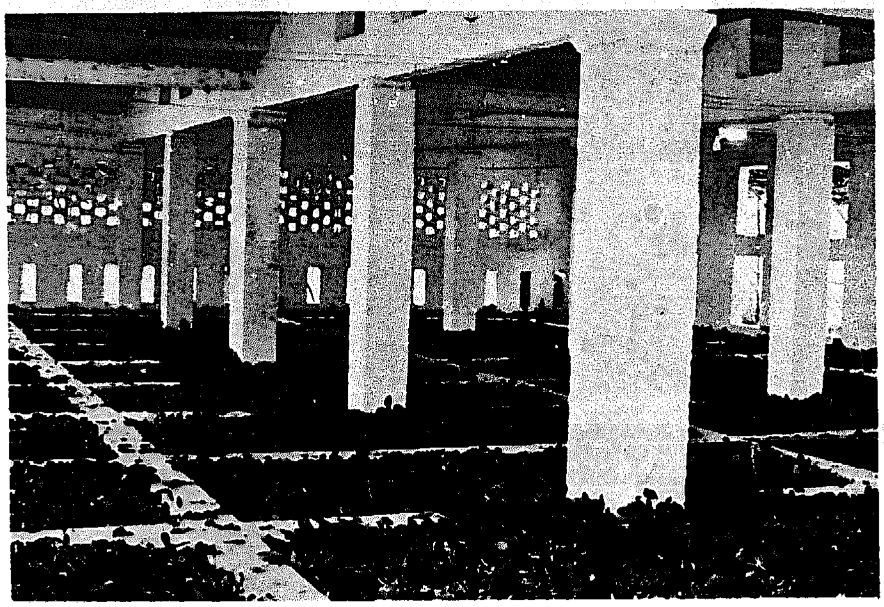
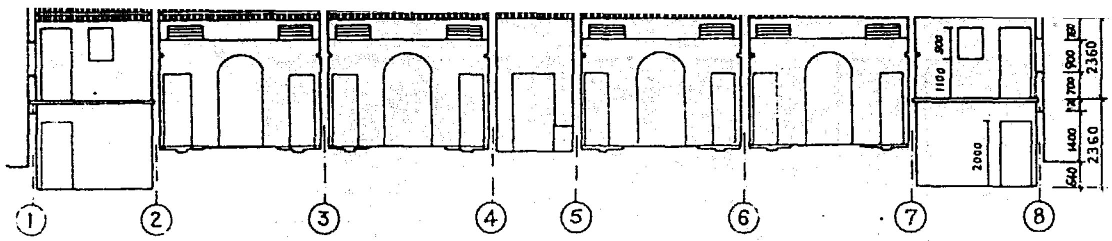


Figure 6-3 A shallow-ditch rearing house in Nanhai County, Guangdong Province

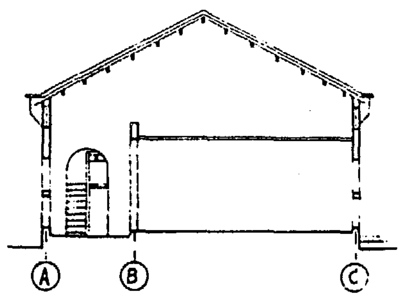
<u>**The rational layout of the rearing house**</u>: Whether the layout of the rearing room, mounting room, leaf chamber and other premises concerned is rational or irrational, depends chiefly upon two points: First, it must be favourable to disinfection, in order to break the transmission cycle. Second, it must facilitate work. These are particularly important for the production units that rear worms on a large scale all year round.

An example of the layout of a rearing house is given in Figure 6-5.

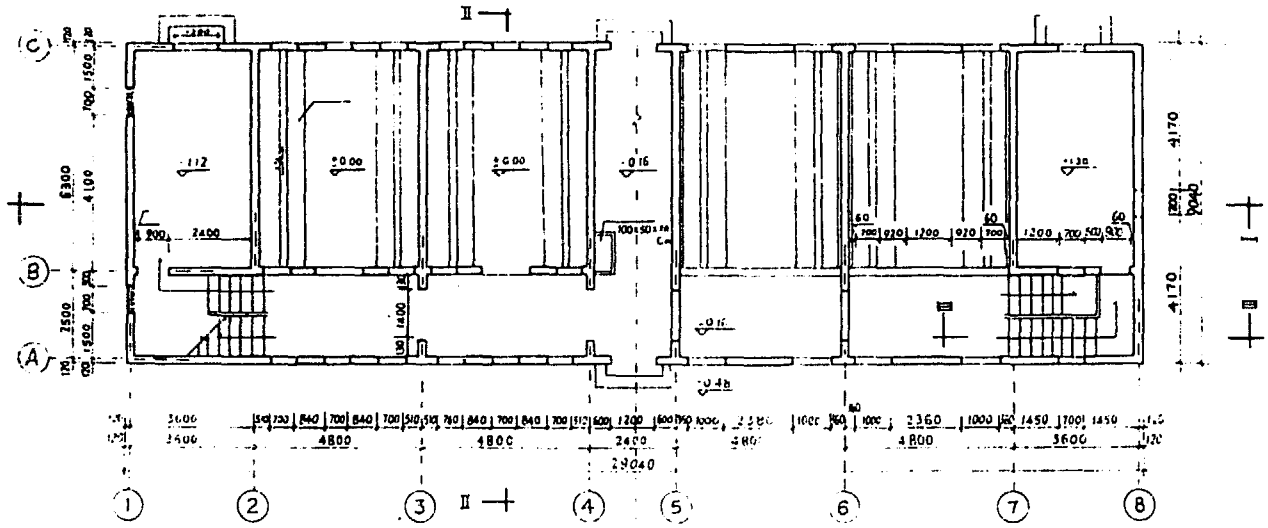
Figure 6-5 illustrates that: (a) the rearing room for the early-stage worm is built separately from that of the late-stage worms (a ditch with mat-shed); (b) the mounting room is behind or by the side of the late-stage rearing room; (d) the early-stage worms and the late-stage worms have leaf chambers of their own near the rearing room; (e) they also have separate passage-ways; when the mature worms are brought to mountage, or when the rools are taken out to be washed, it is not necessary to pass through the corridor of the early-stage worms room; (f) the piers for loading and unloading mulberry leaves should be upstream from the place where the rearing tools are being washed. This describes the longitudinal layout, but there is also a horizontal layout which is generally similar. The only difference is that the orientation



a. Front view

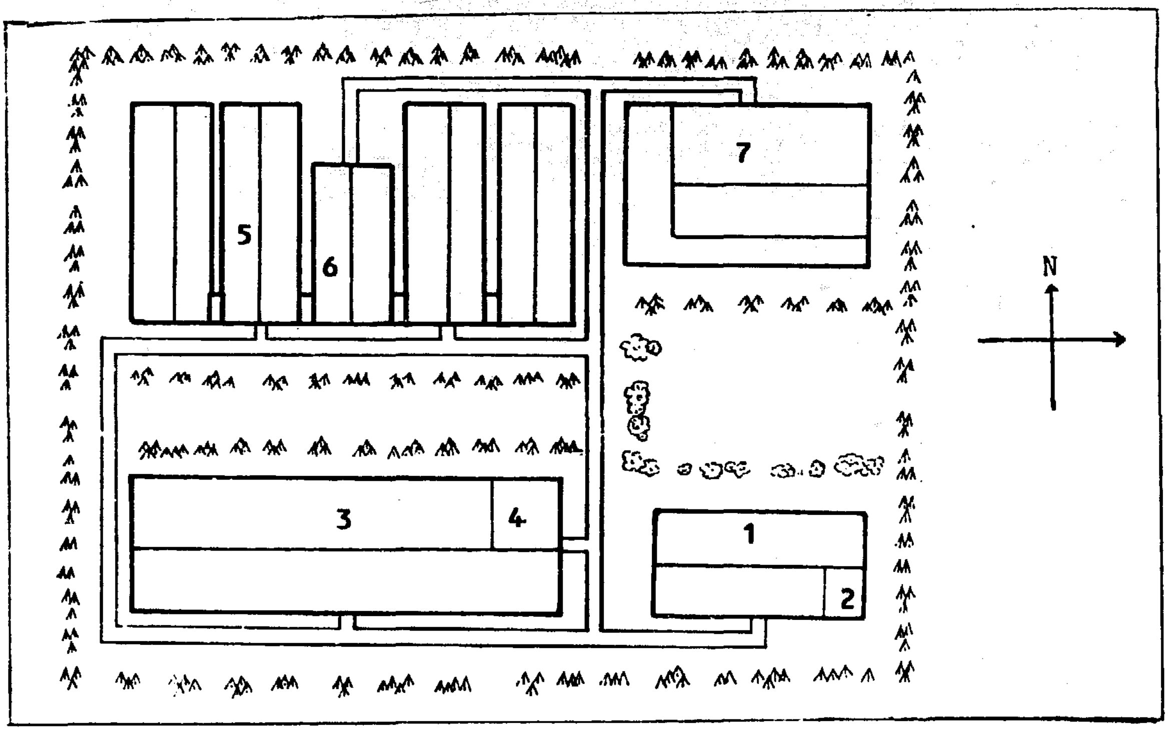


b. Side view



c. Layout

Figure 6-4 Design drawing of a rearing house in Shunde County, Guangdong Province



1. Rearing room for early age larvae
2. A small leaf chamber
3. Rearing room for middle age larvae
4. Half-underground room for storing leaves
5. Shallow ditches for rearing grown stage worms
6. Mulberry leaf chamber
7. Mounting room

Figure 6-5 The layout of the rearing house in a production team in Shunde County, Guangdong Province

is shifted from north-south to west, and the rooms are in the following order: the early-stage worms rearing room with leaf chamber, the late-stage worms rearing room with leaf chamber, mounting room, and cocoon drying chamber.

In Shunde County, for 10 000 catties of mulberry leaves (harvested in several crops), 8 m^2 of rearing room (in average), 12 m^2 of ditch, 5 m^2 of mountage room, 3 m^2 of leaf chamber - totalling 28 m^2 - are needed. In Zhejiang Province, the ratio of the space occupied by the rooms is: rearing room, mounting room, leaf chamber = 10: 10: 5.

<u>**Training of technical personnel:**</u> Silkworms grow and develop rapidly. They are very sensitive to ecological changes. If management is not carried out well, they are easily attacked by diseases. The

cocoon yield would then be greatly affected and the industry would eventually fail. Therefore, a new developing region should always be provided with technical consultation, training of technical personnel and a network of technical organization. Since the art of silkworm rearing is progressing continuously, new varieties with positive characteristics have been found from time to time. Therefore, the traditional regions, as well as new ones, need to be supervised by trained personnel. Two problems which have to be resolved during the planning stage of the project, are the number of technical manpower needed and the number to be trained. This, of course, depends on the circumstances prevailing in the various regions. Japan, which has a strong tradition in sericulture, has about 180 000 silkworm rearing farmer households, 264 technical consulting centres, 978 instructors, and 2 624 extension workers. In some counties of Guangdong Province, various levels of sericulture technology are practised; the county technicans, the district technical stations, the township technical assistants, and the village leaders who are in charge of this industry. All these persons are responsible for strengthening technical instruction and ensuring the safety of different crops of silkworms throughout the county.

6.2 The Plan of Silkworm Rearing Production

A silkworm rearing unit should work out its yearly production plan before commencing work.

The yearly layout of production of sericulture: The layout of the prodcution plan depends on the utilization of the mulberry leaves, labour force and equipment. It also influences the final product. The contents of the layout are determined by answering the following:

- What is the situation with regard to regional climatic conditions, mulberry planting and skill of harvesting?
- Is production the main activity or a side activity? If a side activity, how is it to be arranged with other crops?
- How many crops of silkworms are to be planned in a year?
- When will each crop begin?
- What is the amount of silk eggs required for each crop?
- What are the varieties to be used?

All these problems are related not only to production management, but also to the very complicated technical problems. For example, in southern India, where the climate is very hot, silkworms can be reared all year round. However, in northern China, the average temperature is lower and silkworm rearing can be carried out only from May to September, 3-4 crops per year. In Central China, the rearing season is from April to October, permitting 4-5 crops/year, the spring crop being the main one in the year in both cases. Recently, the summer variety and autumn variety are also gradually coming into use in both regions.

In South china, the rearing season is from March to November, allowing 7-9 crops/year. However, in order to breed certain varieties, rearing is carried out year round. The main rearing seasons in the past, were summer and autumn. Moreover, to raise the quality and quantity of the silk, the volume of early spring and late autumn rearings has, since the 1950's, been gradually increased.

Selection of variety of silkworms, their quantity and rearing time: When selecting a variety of silkworm consideration should be given to climatic conditions prevailing in different regions, mode of rearing and level of technology. The bivoltine variety, which has a large quantity and fine quality of silk is generally selected in some parts of China, since the spring is generally rather warm, the micro-climate is easily controlled and quality of mulberry leaves good. If the season is hot and humidity is high, then the polyvoltine variety should be selected, since it is more resistant to diseases and insect pests. The polyvoltine variety is mainly used in Guangdong Province, because it has a long summer with high temperatures and humidity. However, if rearing conditions are adequate, the bivoltine variety is sometimes used.

The quantity of silk eggs used and the time for rearing are determined by the growing condition of the mulberry, in addition to the characteristics and requirements of the silkworm variety. Hence, before the rearing season begins, it is very important to forecast the amount of leaf yield at different periods and the optimum time for leaf harvest. It is important therefore to plan very carefully, so as to ensure that the silkworms balance with the mulberry leaves. Calculation of the proportion of the quantity of mulberry leaves used to the quantity of silkworms reared, may be made according to the requirement of the leaves by the worms. However, this value varies with different varieties of silkworms and different instars. Generally, to produce 1 kg of cocoons requires 13-15 kg of leaves; for the bivoltine variety, 10 gm of eggs requires 650-750 kg of leaves in the spring crop and 450-500 kg of leaves in the autumn crop. For the polyvoltine variety, 300-350 kg of leaves is quite enough. As to the requirement at the different instars, for the first to third instars, 4-5 percent of the total amount of leaves in one cycle is used; for the fourth instar, 11-13 percent; in the fifth instar, 80-85 percent is used.

Organization of the labour force: The organization of the labour force varies with the conditions of rearing and the level of technology of the feeders. The amount of work in the early-stage is less than that for late-stage worms, so the burden of each feeder is quite different. Table 6-4 shows the number of egg sheets handled by a highly skilled technician.

Preparation of rearing tools and expendable goods: The installation of rearing tools has already been discussed. Here, some expendable items used in the rearing rooms will be discussed. The

Table 6-4

Number of egg sheets handled by skilled technicians

		First instar	Second instar	Third instar	Fourth instar	Fifth instar
Guangdong, China	Bivoltine Polyvoltine	5 7.5	5 7.5	3.5 5	2.5 4	2 3
Zhejiang, China	Bivoltine	4-5	4-5	3-4	1.5-2	1-2
Japan	(1) (2)	23 55	20 55	12 25	 5	 5

Note: In China, manpower is used mainly in silkworm rearing. If the silkworms of the first to third instars are reared in a cooperative rearing farm, the work capacity of each of the workers is double that of an individual farmer.

(1) In an ordinary cooperative young-larvae rearing room.
(2) In a mechanized cooperative young-larvae rearing room.

quantity and variety of expendable goods vary depending upon the method and time of rearing. Among these, the ones most needed are disinfectants used in treating the tools and the rooms. Bleaching powder, formalin (used mostly in the closed rooms), and quicklime powder, are items mostly used. If there is no electric heater, coal or charcoal may be used to maintain the temperature of the rearing room. Quicklime or cereal-husk charcoal should be spread over the faeces to separate the faeces from the worms. For mountages, cocooning frames are used in Japan; and bamboo mounting aids are used in Guangdong Province, straw mounting aids in Zhejiang Province. In the latter case, the mounting aids are folded and shaped into a centipede. Before the time of mounting, a large quanity of straw has to be stored.

Other items are goose feathers for collecting the ants and readjusting them in the rearing beds, seat paper, bamboo mats and reed mats.