



Silk Production in Australia

**A report for the Rural Industries Research
and Development Corporation**

by Dr J G Dingle

May 2000

RIRDC Publication No 00/56
RIRDC Project No UQ-77A

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ISBN 0 642 58086 3
ISSN 1440-6845

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Published in May 2000
Printed on environmentally friendly paper by Canprint

Foreword

The purpose of this report is to assess the potential for Australia to commercialise silk production. On the basis of that assessment, the report recommends a program for the introduction of moriculture, sericulture and post-cocoon processing in Australia.

Silk is a highly prized natural fibre with unique characteristics not matched by artificial fibres. The world silk trade needs to be analysed to assess the opportunities available to Australia to compete internationally.

Australia has stocks of silkworm and mulberry varieties that are well adapted to our climatic range. These stocks need to be assessed for their suitability for producing the type of silk required by world markets. Countries such as China, Japan, and India have amassed a large amount of information about moriculture, sericulture and post-cocoon technology which Australia needs to tap into to commence silk production at the most advanced stage possible.

This report briefly outlines the characteristics of silk and its production and consumption by various countries. It recommends that Australia should establish a Sericulture Research Centre and a silk market intelligence unit to facilitate the introduction and development of sericulture in Australia.

This project was funded from RIRDC Core Funds which are provided by the Federal Government.

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Peter Core

Managing Director

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Acknowledgements

I am grateful to the members of the International Centre for Training and Research in Tropical Sericulture and the Central Sericultural Research and Training Institute, Mysore, India, for their hospitality and for their information, instruction and discussions with me during a four week training program in November and December 1999.

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Executive Summary

Silk characteristics and production trends are compared with those of other international fibres. Raw silk fibre and silk fabric producing and consuming countries are identified and market trends noted.

Methods of moriculture, sericulture and post cocoon processing were investigated and instructional material prepared as written reports, webpages and videocassette tapes.

Supplies of stocks of mulberry and silkworm varieties available for importation into Australia have been identified as well as manufacturers of mulberry and silkworm growing and harvesting equipment and machinery, and post cocoon processing and fabric weaving equipment. Contacts have been established with sericulture research centres in other countries and current research interests noted. There has been a favourable response from overseas institutions to the concept of Australia becoming a silk producer.

Developing a silk industry in Australia will require the establishment of an Australian Sericultural Research Centre and a silk market intelligence unit to identify and develop products to take advantage of specialised opportunities in the international silk trade.

1. Silk in Comparison with Other Fibres

World wide silk production totals about a hundred thousand tonnes. The other natural fibres (cotton, wool) and synthetic fibres (nylon etc) total in the tens of millions of tonnes. Being a natural product and relatively rare enables silk to maintain its value, however it must also have characteristics that create a demand. Silk's physical characteristics are listed in table 1. The totality of these has not been duplicated by any synthetic fibre, but even if they are in the future, the natural product will remain in demand while there is consumer preference for natural over synthetic.

Silk production is divided into two major phases: Cocoon production and fabric production. The majority of silk in the world is produced by hand on a small scale. Silk cocoon reeling is by hand with or without the aid of machines, but the rest of the process of fabric making may be largely mechanical. Australian silk cocoon production could be introduced at two levels, as multiple small scale home units and/or as a few large scale mechanised units.

Australia imports a large amount of silk fabric and clothing each year. It may be possible to set up an independent silk industry in Australia to supply all our needs. However for a number of reasons, not the least being considerations of international free-trade agreements, the establishments of a silk industry in Australia would need to be integrated with world production.

TABLE 1 - PROPERTIES OF SILK FABRICS

Property	Definition	Benefits and Users
abrasion resistance	Ability of fabric to withstand the rubbing inherent in everyday use.	durability, resistance to splitting.
absorbency	The amount of moisture a dry fibre will absorb from the air	comfort, warmth, water repellence, wrinkle resistance
draping	Ability to hang delicately.	Is more appealing to the eye than other materials.
durability	Ability to withstand wear and decay.	Seemingly delicate but very strong. Used for suture material.
dyability	The fibres' receptivity to coloration by dyes.	Able to attach to and hold colour better than any other fabric.
elasticity	The ability of the fabric to stretch over its length without breaking.	Able to stretch up to 20% and mould itself over any shape. Used for silk stockings.
flame resistance	Burns slowly in an open flame and is self-extinguishing once flame is removed.	Excellent fabric for wall coverings and upholstery.
insulation	Does not conduct electricity	Used to insulate electric wires.
lustre	The light reflected from the surface.	Prism-shaped fibre makes silk very lustrous.
mildew/mould resistance	Mould is a white or greyish coating formed by fungi.	Resistant to mildew, moulds, and rots that attack other fibres, unless left in damp conditions for long periods.
resilience	Ability to resume an original shape after being stretched.	Tends to hang out and has good shape retention.
size reduction	Ability to bundle or fold into a small size.	Can carry in a small space. Silk maps were hidden in clothing during the war.
strength	Ability to resist stress.	Strong, but slightly weaker when wet. Tougher than cotton or fine wools.
weight	Silk is one of the lightest natural fibres.	Preferred for dresses in Asia (sari, kimono) and jockey riding jackets.
warmth	Silk feels warm on the skin.	Used to line snow jackets.

2. Production of Raw Silk and Fabrics

2.1 World silk production in comparison with other textile fibres.

Silk production is only about 0.2% of the total textile fibre production in the world. Even though the production of silk together with other natural fibres doubled in the 20 years from 1975 to 1995, the production of synthetic fibres increased three fold (Table 2).

TABLE 2 - WORLD SILK PRODUCTION IN COMPARISON WITH OTHER TEXTILE FIBRES (THOUSAND TONNES)

YEAR	SYNTHETICS	COTTON	CELLULOSE C FIBRES	WOOL	SILK	% OF TOTAL	TOTAL
1975	7346	11809	2959	1502	49	0.21	23,665
1985	12515	17540	2999	1672	59	0.17	34,786
1995	20200	19200	3000	1600	100	0.23	44,100

2.2 Silk production in different countries

For most silk producing countries, silk production is non-mechanised and family based. Production increases are therefore slow but production falls may be sudden due to population changes such as developments and urbanisation that cause population shifts. For example, while most silk producing countries doubled production between 1975 to 1995, Japan's silk production halved (Table 3).

TABLE 3 - WORLD SILK PRODUCTION BY COUNTRY (TONNES)

YEAR	CHINA	INDIA	CIS	BRAZIL	OTHERS	JAPAN	TOTAL
1978	19,000	3475	3240	1250	2200	15960	49,360
1985	32,000	7029	3990	1458	2748	9582	58,914
1993	71,845	14000	4000	2326	3750	4254	100,175
1996	59,000	13000	2600	2360	2500	2250	82,660

The other trend to note in Table 3 is the general down turn in silk production between 1993 and 1996. The main reasons for the down turn were the increased price of labour and over production of cocoons. If it is possible to mechanise production a number of countries may be looking for this development because the demand for silk is increasing while production is falling.

2.3 Coarse and fine silk production

Another factor to take into account is that different types of silk are produced in different countries. Indian silk, 95% of which is multivoltine (tropical), is coarser and is generally woven into fabrics as a cottage industry. None or almost none of India's silk is sold in the raw form internationally. On the other hand, China's silk is bivoltine and is the finer silk required by the international trade.

Australian production should aim at producing fine silk for international trade but this is more difficult and more technical than producing coarser silk and may require substantial development work under Australian conditions.

2.4 Production of silk fabrics

Silk is woven in China and in raw silk importing countries by power looms. In Thailand and India fabrics are woven on hand-looms, however power looms are increasing in India. Almost all silk weaving is done on power looms in Vietnam, Brazil and Korea.

There is a difference in the size of export orders and hence the specification of fabric runs for different countries. For example, China and Korea are very dependent on large export orders to cover the cost of factory production, whereas Thailand and India are more flexible and can produce smaller orders for highly specific markets such as in Germany. Because hand looming produces more natural variation in the fabric, buyers and consumers need to be educated about the differences between hand loomed and power loomed silk fabrics.

2.5 Future trends in silk and silk fabric production

It is extremely difficult to predict future production trends and also difficult to obtain current production figures quickly. All silk producing countries would like to increase production. However, as well as occupational changes and labour costs mentioned previously, a number of technical problems also affect potential production figures, for example, silkworm diseases and mulberry leaf production problems.

3. Silk Consumption and Silk Trade

3.1 The Market

Japan and China are the world's largest consumers of their own and imported raw silk, thrown-silk yarns and grey fabrics. India and CIS process all their own silk production. Western Europe, USA, Canada and Australia produce virtually no silk and import all their requirements.

For a silk producing country, the form of the product marketed may be any or all of the following:

- cocoons
- raw silk
- grey (undyed) fabrics
- dyed fabrics
- manufactured goods

Because China is such a large producer and exporter, world prices are dependent on the silk prices set by China.

3.2 Exporting and importing countries

- Cocoons: Exporting countries: China, Brazil
 Importing countries: Japan, Republic of Korea
- Raw silk (yarn): Exporting countries: China, Brazil, Vietnam
 Importing countries: India, Italy, Japan, Republic of Korea

3.3 Managing the market

The small range of countries involved in the silk trade means that silk marketing is fragile and haphazard. It would be necessary to have good intelligence from each of the above seven or so countries to manage the entry into and participation in the world silk market. Contribution to the International Sericultural Commission (ISC) and the International Silk Association (ISA) could provide the necessary intelligence on the world silk trade.

4. Results

4.1 Report of a visit to India to investigate sericulture methods

A training program was undertaken at the International Centre for Training and Research in Tropical Sericulture (ICTRTS) at Mysore, India, from 17th November to 18th December, 1999. The program consisted of hands-on rearing of a batch of silkworms and interviews with the heads of each of the fifteen research and training sections. Visits were undertaken to rearing farms and associated research and service establishments in and around Mysore and Bangalore. A report on the information provided during the interviews “Silk Production in Southern India” is given in Appendix 1.

4.2 Silk information web pages

Based on the extensive literature available at ICTRTS, a series of web pages has been prepared for anyone who wishes to view them on the internet. The objective of this initiative is to have introductory information available immediately for any potential silkworm producer and to generally promote the silkworm industry. References to more detailed descriptions in the literature are also provided for those who wish to become serious producers. The webpage address will be <http://www.animal.uq.edu.au/research/research.htm>

4.3 Videotape of sericulture in India

A videotape was made of the ICTRTS and associated silk research and service centres in southern India. Copies of the videotape are available from the author at the School of Animal Studies, University of Queensland.

4.4 Recommendation

Based on the review of world trends of the increasing demand for high quality silk and declining production of international grade silks, Australia’s favourable climate, our technological and scientific capability and the need to diversify farm production, it is recommended that research into and promotion of silk production in Australia be supported by a network of government and private agencies. Australia should establish a Sericulture Research Centre and a silk market intelligence unit to facilitate the introduction and development of sericulture, moriculture and silk processing.

5. Developing a Silk Industry in Australia

Failure of previous attempts at establishing a sericulture industry in Australia is given in Appendix 2.

Silk production is a complex agro-industrial system which uses advanced technologies. The following factors have to be considered before embarking on sericulture and/or silk processing.

5.1 Sericulture

5.1.1 Mulberry cultivation

Sufficient botanical and agronomic expertise exists in Australia to undertake mulberry development work and training. Black (*Morus nigra*) and white (*Morus alba*) mulberry species are grown in Australia and an initial project would be to compare the growth characteristics and leaf yield of mulberry varieties in Australia. Comparison with overseas yields would determine whether it would be an advantage to try to import overseas mulberry varieties.

5.1.2 Silkworm selection

Silkworms in Australia are kept in a univoltine system (ie. one generation per year) mainly because of the seasonal production of mulberry leaves. However it may be possible to create artificial conditions for the propagation and growth of mulberry leaves and silkworms all year with present Australian stocks. Preliminary trials should be conducted to determine the potential of Australian origin stock before (or at the same time as) importing overseas stock.

Whether using local or imported stocks of silkworms, parent stocks will have to be selected and maintained and crossed to produce commercial hybrids. This will entail the use of a substantial area in a building to store the silkworm eggs (grain), sort and sanitise the eggs, and incubate, hatch and grow the worms in separate batches.

5.1.3 Quarantine Requirements

Quarantine requirements to import silkworms and mulberry trees to Australia:

1. Charges for Importation

In addition to freight costs, the Australian Quarantine Inspection Service (AQIS) levies the following lodgement fees for applications to import plants, seeds and biological material such as laboratory animals and bees. \$60 per application.

2. Quarantine Conditions

The importation of some products is, by law, subject to certain quarantine conditions and restrictions, while other products cannot be imported without quarantine permit

Product Type	Sections to Complete on Application Form
Live Animals Laboratory animals, animals for scientific purposes, insects and arthropods	Sections: 6, 7 (a/b), 9
Live Plants Plants such as cuttings and tissue cultures (also seeds)	Sections: 6, 7 (b), 8, 9

Details of sections

Section 6. Details of Transport

For the importation of livestock (live animals) it is necessary to provide the date of export, part of export and intended airline or vessel to be used. It is also necessary to provide the route, country by country, that the animal will enter from departure until arrival into Australia. This will ensure the route to be taken is quarantine approved.

The intended date of arrival is required to be completed by those importing livestock and those importing live plants that will require post entry quarantine.

Section 7.

7(a) Biological Status

You are required to provide a list of ingredients that have been used to produce the final product, which you intend to import. For each ingredient you should specify the species of origin, country of origin and any treatments or tests applied which would decrease the quarantine risk.

The details of the period the animal has spent in official quarantine premises or under restrictions in the country of export must also be specified, along with the time the animal has been a resident in the country of export.

7(b) Genetically Manipulated Status

Certified Scheme/Accredited Source

Please indicate if the produce has been genetically manipulated or contains any genetically manipulated material.

Section 8. Product Details

Certified Scheme/Accredited Source

For live plants or seeds, please indicate if the material to be imported is from an AQIS accredited or approved source or is produced under a Certified Scheme.

Location grown/collected/manufactured collection team or collection centre

The information that this section requires relates to the location that the products were grown/prepared/manufactured/collection team or approved collection centre in the country of origin.

For all products except Animal Reproductive Material you are required to provide either the location where grown or the registered premises (please provide premises registration number) or the laboratory where prepared.

Section 9. Location details within Australia

The information that is required in this section relates to the location that the imported product/plant/animal will under go further processing or will be held for further direction or will undergo further Quarantine at an approved Quarantine premises. Approved Quarantine premises must be approved at time of import. If you intend to utilise more than one facility for the imported commodity, please provide summary of premises to be utilised.

For plants, seeds or plant propagative material requiring further growth in post entry quarantine please indicate if the material is to be grown at a Government Post Entry Quarantine Facility or at an Approved Private Post Entry Quarantine Facility. (Please provide the premises registration number). **It is also the importer's responsibility to ensure that space is available in the Post Entry Quarantine Facility for their material and for live animals.**

Application

Applications to Import Quarantine Material are obtainable from, and completed applications are to be sent to:

Department of Primary Industry and Energy
Australian Quarantine and Inspection Service
PO Box 858
Canberra ACT 2601

Live Animals	Ph: 02 6272 4578	Fax: 02 6273 2097
Other	Ph: 02 6272 5162	Fax: 02 6273 3709

5.1.4 Cocoon treatment

Cocoon collecting, stifling equipment and cocoon storage require specialised equipment and controlled environment rooms.

5.1.5 Reeling

Progression from manual to semi-automatic to automatic reeling equipment depends on the volume of cocoons to be processed. Appropriate equipment can be compared as cocoon supply increases. It should be noted that the type of equipment affects the quality of the yarn produced.

5.1.6 Classing

Raw silks need to be tested and classified to international standards. Technical equipment and expertise are required for this essential stage to enable silks to enter the appropriate levels in world trade.

5.1.7 Silk wastes and by products

Once a certain volume of silk is produced it is worthwhile processing silk wastes such as spun silk and silk noil yarns. This option should be incorporated into the initial plans.

Other by-products such as pupa and mulberry wastes can be used for animal feeds. Pupae and larvae can produce cosmetic oils, creams and pharmaceuticals. In addition, silkworms are being increasingly used in biotechnology. However, these options should not be used to determine the viability of a silkworm industry.

5.2 Silk processing

Sophisticated looms can be operated by a few skilled technicians, whereas less sophisticated equipment requires an experienced labour force that Australia does not possess. It is therefore

suggested that a small scale modern pilot plant be purchased for trials and training of operators and located at a training institute.

6. Suggested Industry Structure in Australia

6.1 Infrastructure

It is suggested that the silk industry in Australia be based on both small and large scale producers and that the collaboration of the following bodies be sought to establish the Australian sericultural industry on a firm footing:

- State Departments of Agriculture/Primary Industries (Apiculture would be the closest allied industry).
- Formal organisations, especially those involving women (National Farmers Federation, Country Women's Association).
- Rural Industries Research and Development Corporation- New Animal Products Committee.
- Research and Developments Units in Universities and State Government Departments.
- The textile industry.
- Corporate investors.
- Overseas consultants and sponsors (eg. India, Japan).
- Commonwealth and State Government Departments of Export and Trade.

6.2 Research Centre

6.2.1 Structure

At least one sericulture research centre needs to be established to undertake the huge range of development work required. This centre needs to have premises, equipment, training for research and technicians, and communication and co-operation with other research institutes with common objectives both within Australia and overseas.

6.2.2 Activities

Demonstrations, training programs and technical assistance for commercial producers (at the Sericulture Research Centre).

Collaborative development programs with fabric and clothing manufacturers to integrate production with industrial requirements both in Australia and overseas.

Market Intelligence Unit for monitoring silk trends and for identifying potential markets for specialised production. Specialised production may be required to tap into identified market opportunities such as those listed in Table 5.

TABLE 5 - SPECIALISED PRODUCTS THAT NEED TO BE PRODUCED ON DEMAND TO TAKE ADVANTAGE OF AN IDENTIFIED NEED IN THE SILK MARKET PLACE.

	PRODUCT
1.	Silkworm eggs (seed) (of various genetic types)
2.	Hatched silkworms (parent and commercial strains)
3.	Silkworms at various stages of growth (length)
4.	Cocoons (for breeding or spinning)
5.	Raw silk thread (of various diameters – deniers)
6.	Grey fabric (undyed) of coarse silk
7.	Grey fabric of medium and fine silk
8.	Dyed silk fabrics
9.	Manufactured goods from silk fabrics. eg. Rugs, Cloths - scarves, ties, shirts, skirts.

7. Five Year Plan for the Silk Industry in Australia

YEAR	RESEARCH INSTITUTE		STATE GOVT DEPT	SMALL SCALE PRODUCERS	LARGE SCALE PRODUCERS
	RESEARCH	DEVELOPMENT			
1.	Collect silkworms and mulberrys	Organise workshop Start webpage	Became aware and involved.	Became aware . Obtain information from webpage.	Became aware.
2.	Test germplasm characters	Run workshops	Send staff for training overseas. Attend workshops.	Attend workshops. Plant mulberries.	Attend workshops or have workshop at organisation. Plant mulberries.
3.	Import germplasm and compare with local	Multiply seed for producers.	Set-up reeling and testing laboratory.	Obtain silkworm seed from Research Institute.	Obtain seed (from overseas ?).
4.	Investigate problems	Provide solutions to producers problems	Send samples to market.Assist producers to solve problems.	Produce cocoons. Send to reeler . Send for testing.	Produce cocoons. Reel silk. Send for testing.
5.	"	"	"	Improve standards. Obtained improved germplasm.	Improve standards. Obtained improved germplasm.

8. Business Plan to Establish the Silk Industry in Australia

Purpose of business plan

This plan describes what is required to establish a business unit to produce three tonnes of raw silk fibre per year to trade on the international silk market. The total amount of raw silk fibre to aim for and the business structure suggested may vary in the future with greater knowledge and refinement of the production parameters under Australian conditions.

Production Phases

It is proposed that production should be staged in three phases (Diagram 1).

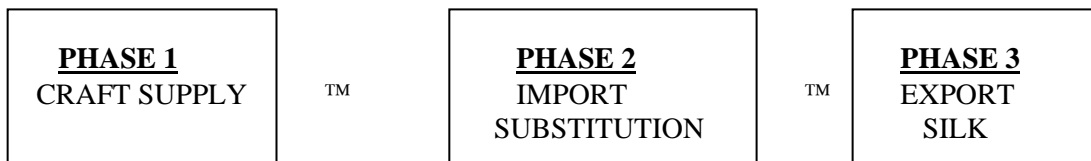


DIAGRAM 1: The three phases suggested for the development of a silk industry in Australia.

Phase 1 – Craft Supplies

Australia has seen the resurgence of many handcrafts in recent years. Some of the other new animal industries, such as Angora goats, Alpaca and coloured wool sheep, provide fibre for spinning and weaving by hand. Silk, being equally prestigious and soft to the touch, is likely to find favour amongst handcraft spinners and weavers.

It is suggested that initial promotion should be aimed mainly in the direction of encouraging women and children, especially country women and children, to grow mulberries and silkworms and to harvest the silk for themselves or others to use in manufacturing hand spun and woven fabrics and garments both for the local and the tourist trade.

This phase is low risk but would provide the necessary buffer time for learning the skills required to:

- i) produce silk
- ii) produce large quantities of silk
- iii) produce high quality silk.

If the silk industry developed no further than this in Australia, this phase will still be useful for testing a variety of silk production systems and for providing another source of income for women and children working from home.

It is planned, however, to link this phase with phases 2 and 3 when a number of these individual home production units would be linked into a single production unit.

Phase 2 – Import Substitution

Although not large on the global scale, Australia does import silk. The majority of this constitutes silk fabric. However, silk fibre is used as a special addition in woven cotton and wool fabric. It should be the aim of the Australian silk industry to attempt to match the quality of the imported fibre in partnership with Australian fabric manufacturers. This initiative would also give the Australian silk producers a benchmark on which to judge their own silk quality prior to entry into the international market in Phase 3.

The opportunity should also be taken during this phase to investigate the possibility of fabric manufacture in Australia in association with a textile institute. This would also provide the buffer time required to research and develop the techniques required by Australian textile factories to adjust their equipment to manufacture the range of silk fabrics required by domestic and international markets. It would be necessary for the factory management or a supply company to coordinate silk growing and purchasing to supply the factory with the increasing quantities required to gradually replace imports (see diagram 2).

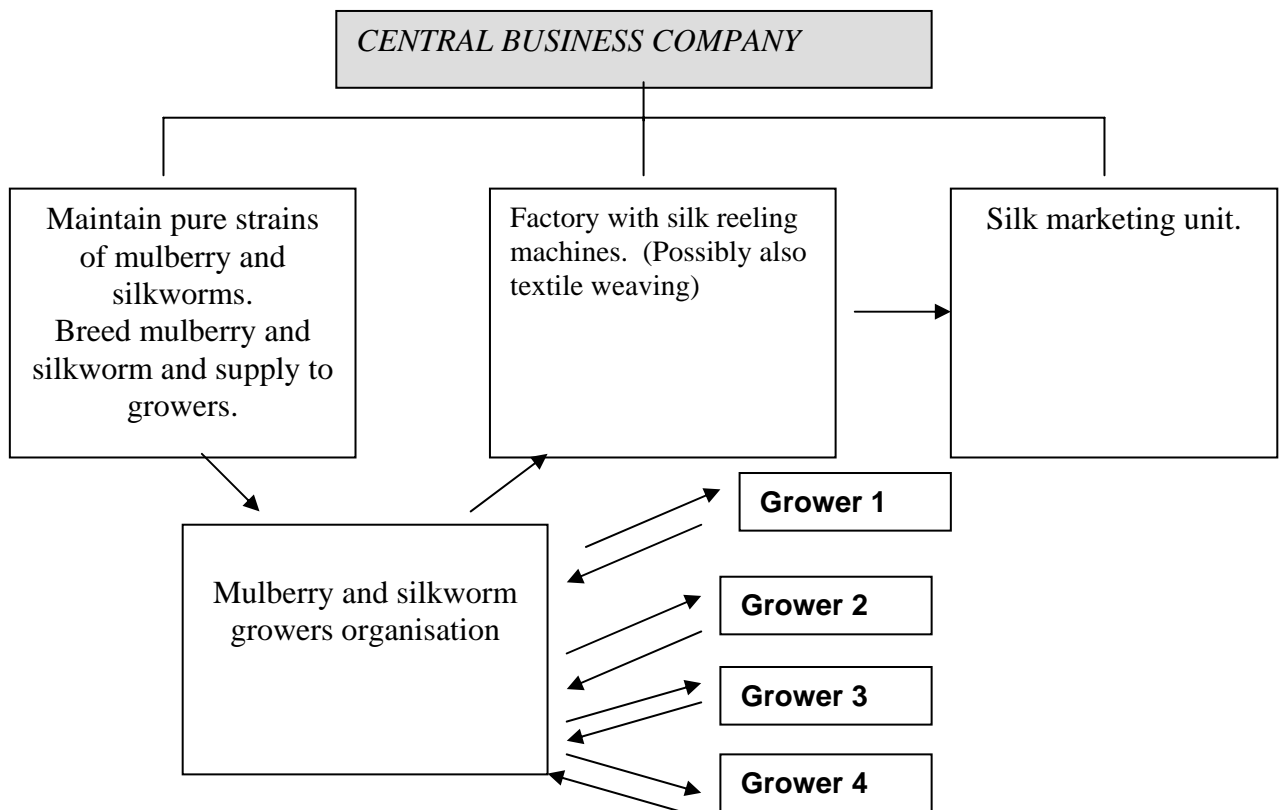


DIAGRAM 2: Suggested Company Structure

Phase 3 – Export of Silk

Silk could be exported as cocoons, reeled fibre or woven fabrics, each stage bringing substantially higher returns. It is expected that small quantities of silk would be available and tested on the international markets initially. The international interest and response to these initial marketing tests would be indicators of the future prospects of the Australian silk industry and of the amount of research and development still required to match international benchmarks.

The quantity placed on the international markets is not an inhibiting factor on the development of the silk industry in Australia, because both small and large quantities can be sold if they are the

required quality and price. The bottleneck in the system of gearing up to the international market is the volume required for an Australian manufacturer to break even on the costs of production. An attempt has been made to suggest what this volume is. However, the overheads and investment for a manufacturer depend ultimately so much on the decisions made by the manufacturer about the type and amount of equipment and staff purchased, that separate costings would have to be conducted for each manufacturer.

The structure suggested is a central business company that controls the production of silkworm eggs, the reeling of the silk from the cocoons and the marketing of the silk. The central business company would have at least these three divisions with dedicated facilities and an expert in each division to supervise each activity. The central business company may have a fourth division responsible for the production of mulberry leaves and feeding the silkworms and/or the company may arrange for this fourth activity to be undertaken by private growers.

Both the central business company and private growers may have to raise funds to purchase the required premises, equipment, facilities and staff.

The following is a summary of initial estimates of the cost of establishing and operating each unit.

1. COST OF ESTABLISHING COCOON PRODUCTION UNIT (excluding cost of land) (see Table 1)

i)	Cost of establishment of 1ha mulberry cultivation	\$119,352
ii)	Cost of establishment of sericulture unit	\$ 50,000
	Total establishment cost	\$169,352

2. PRODUCTION COSTS AND RETURNS FOR COCOON PRODUCTION UNIT

- i) Weight of mulberry leaf produced per year = 10 – 65 (av. = 30)t
- ii) Number of silkworms spinning cocoons per year = 0.3 – 3.6 (av. = 1.33) million
- iii) Weight of cocoons per year = 324 – 7200 (av. = 2014 *)kg
- iv) Sale price cocoons (AUD/kg) = \$4 - 7 (av. = 6.0)
- v) Total return per year on cocoons = \$1,000 - \$50,000 (av. = \$12,000)

** 12 hectares of this average production required to supply on automatic reeling unit*

3. COST OF ESTABLISHING AUTOMATIC REELING UNIT

i)	Cost of building	\$100,000
ii)	Cost of machinery and equipment	\$200,000
	Total establishment cost	\$300,000

4. PRODUCTION COSTS AND RETURNS FOR RAW SILK PRODUCTION (Producing 3t/year) (See Table 3)

i)	Amount of cocoons required per year = 24 t	
ii)	Cost of cocoons required per year	\$96,000 - \$144,000
iii)	Labour and overheads per year	\$22,000
	Total costs per year	\$118,000 - \$166,000
iv)	Production value of raw silk	= \$40 - \$56**/kg
v)	Total return from sale of raw silk	= \$120,000 - \$168,000
	Cross margin on raw silk per year	= \$2,000

** See footnote to Table 3.

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TABLE 1 - COST OF ESTABLISHMENT OF A SERICULTURE ENTERPRISE BASED ON ONE HECTARE MULBERRY CULTIVATION

i) ESTABLISHMENT OF MULBERRY CULTIVATION

		AUD
1.	Land preparation	1,000
2.	Cuttings, saplings (30,000 @ \$3.00) (spacing 60 x 30 cm)	<u>90,000</u> <u>91,000</u>
3.	Irrigation & Dip PVC pipe (63mm 4kg x 90m) @ \$5/m PVC pipe (50mm 6kg x 165m) @ \$5/m PVC tube (12mm x 8375m) @ 1/m Dipper 0 turbo key (41ph x 13612) @ \$1ea Ball valve (50mm x 5) @ \$40 Flush valve (50mm x 5) @ \$10 Fittings and accessories Transportation and Installation	450 825 8375 13612 200 50 500 <u>2500</u> <u>26,552</u>
4.	Water Equipment 170,000 l (38,000 gallons) per irrigation x 6-9 irrigations per crop (black clay – sandy loam) x 5 crops/year = 5.1 ml – 7.7ml/year. Pump & fittings x 1 Screen filter 1.5 PG x 1 Venturi manifold 1.5 x 1 Venturi assembly	1500 150 40 50 60 \$ 1,800
Total Cost		\$119,352

ii) ESTABLISHMENT OF THE SERICULTURE UNIT

TABLE 2: POTENTIAL PRODUCTION OF MULBERRY AND SILK PER HECTARE PER YEAR

No.	ITEM	AVERAGE	MINIMUM	MAXIMUM PRODUCTION
1	Number of plants (per ha)	30,000	25,000	45,000
2	Leaf yield (tonnes/ha/year)	30	10	65
3	Leaf/df (disease free laying) (kg)	9	10	8
4	Number dfl/ batch	666	500	1350
6	Number eggs/df	400	300	500
7	Number batches/year	5	½	6
8	Number dfl/year	3330	1000	8,000
9	Number eggs/year (million)	1.33	0.3	3.6
10	Effective rate of rearing (err%)	80	60	90
11	Number of cocoons (million)	1.06	0.18	3.6
12	Weight/cocoon (grams)	1.9	1.8	2.0
13	Total Weight cocoons (kg)	2014	324	7200
14	Weight cocoon/kg/100 dfl	60	30	90
15	Sale price cocoons (AUD/kg)	\$6.00	\$4.00	\$7.00
16	Gross return on cocoons (AUD/yr)	\$12,000	\$1,000	\$50,000

TABLE 3: AUTOMATIC REELING UNIT PRODUCTION COSTS (PER YEAR)

	Automatic Reeling Unit
Basins	4
Ends	80
Output of unit (average production)	10kg/day
Renditta (cocoon wt/silk wt)	8
Cost cocoons/kg	\$4 - \$6
Cost cocoons/year	\$96,000 - \$144,000
Other costs: Labour/year	\$19,000
Overheads	\$ 3,000
Total costs/year	\$118,000 - \$166,000
Returns	
Annual production (300 day)	3000kg
Return on raw silk	\$40 - \$46/kg*
Gross return/year	\$120,000 - \$168,000
Gross margin per year	\$2,000*

*** See Table 4: when raw silk price rises to \$60/kg, gross margin is \$10,000; when it rises to \$70/kg, gross margin is \$40,000; when it rises to \$100/kg, gross margin is \$130,000**

TABLE 4: AVERAGE RETURNS ON INTERNATIONAL MARKET SALES OF RAW SILK (1980-1992)

YEAR	PRICE IN CURRENT TERMS	
	USD/kg	AUD*/kg
1980	16.23	27.05
1981	15.17	25.28
1982	14.72	24.53
1983	13.57	22.62
1984	23.61	39.35
1985	27.28	45.47
1986	27.54	45.90
1987	27.19	45.32
1988	36.83	61.38
1989	73.52	122.53
1990	45.39	75.65
1991	27.55	45.92
1992	23.77	39.62
Average	28.64	47.74

Source: After Henle (1996)

*Calculated as AUD = 0.6USD

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9. Conclusions and Recommendations

Based on a review of the increasing demand for, and decreasing supply of, high quality silks in the world, and Australia's favourable position in relation to climate and technological capabilities, it is recommended that Australia commence research and promotion of silk production by both small and large producers supported by government and research agencies.

Australia should establish a Sericulture Research Centre and a silk market intelligence unit to facilitate the introduction and development of sericulture, moriculture and silk processing.

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11. Appendices

Appendix 1. Silk Production in Southern India

Report of a Visit to India to Investigate Sericulture Methods

Interviews conducted from 17 November – 13 December 1999

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17.11.99 PROFESSOR G DEVEGOWDA, Professor of Poultry Science at the University of Agricultural Sciences, Bangalore, introduced me to PROFESSOR GOVINDAN, Head of Department of Sericulture, University of Agricultural Sciences, Bangalore. Professor Govindan arranged for my visits to the Silkworm and Mulberry Germplasm Station, Hosur, the Central Silk Technology Research and Development Institute Bangalore, and the Karnataka State Sericulture Research and Development Institute, Bangalore. The Sericulture Department library has over 60 postgraduate thesis. (These are listed in the booklet “Literature on Sericulture” by Dandin *et al.*, (1994).

18.11.99 CENTRAL SILK TECHNOLOGY RESEARCH AND DEVELOPMENT
INSTITUTE, BANGALORE

MR JOYOOMMEN, Member Secretary, Central Silk Board, introduced me to Dr M V Samson, Director of the Central Silk Technology Research and Development Institute, CSB, BTM Road (Layout), Madiwala, Bangalore. Dr Samson explained post-cocoon processes and showed me the equipment and machinery used for training students and testing silk in reeling, bookmaking, spinning, weaving and silk quality testing. Dr Samson suggested that Australia should undertake a pilot study for two years looking at our own mulberry and silkworm germplasm. He suggested that sericulture should be taken up as a sideline, not as a fulltime occupation as it gets repetitive. If improved hybrid silkworms were imported into Australia it would be possible to get the original pure lines segregating again after several generations. He also said it was important to think about organic farming of silk as there was a good market for organics. Dr Samson outlined the procedure of submitting projects for research grants in India, and of the regular review panels who also help institutions to patent products. He mentioned the Japanese assistance to India via the JICA program (see details later). He said that the Research and Training Institutes work very closely with farmers. Farmers used to feed silkworms 20 times a day, but they now feed only once or twice a day, which is a great saving in labour. DR R N SINGH escorted me around the processing halls. He informed me that DR ANAN RAMAN, Lecturer in Botany at the Orange Agricultural College in New South Wales, Australia, was experienced in Mulberry tree production.

Cocoon marketing was also discussed. There are some 20 cocoon markets that operate 360 days per year in Karnataka State, the largest silk state in India. Cocoons cost approximately 120 rupees (RS) (approximately \$5 Australian*)

per kg weight of cocoon. If the price falls below 110 RS the state government buys the cocoons (this value acts as a floor price) and uses the cocoons in its own state reeling and fabric factories. (Note: This statement is at variance with the statements made by the state reeling factory, KSIC – see later). Private reelers only buy 4-5 days stock (say 400-500 kg cocoons) because of the outlay, and try to process and sell all purchases in 8-10 days to recoup their expenses.

* 25 rupees = 1AUD approximately

18.11.99 SILKWORM AND MULBERRY GERMPLASM STATION, HOSUR

DR MUKHERJEE of the Silkworm and Mulberry Germplasm Station, Hosur, Tamil Nadu, outlined the history of the development of the germplasm station. When the National Sericulture Project commenced with funding by the World Bank and the Swiss Development Co-operation in 1988/89, there was some concern about the implications of free trade through the GATT agreements and Intellectual Property Rights over developments, especially over genetic stocks in developing countries. A separate institution was set up to gather together stocks of germplasm that were being maintained by various moriculture and sericulture research institutes. The Australian Centre for International Agricultural Research arranged the transfer of mulberry germplasm from Australia. The present site was purchased in 1991 and buildings were occupied in 1993. They now have 824 mulberry accessions and 328 silkworm accessions which represent 90% of all known germplasm. The mulberry germplasms cover 15 species from 26 countries. Mulberry being a perennial tree needs time to grow for evaluation.

The first catalogues of measurement of germplasm characters have been published and the second edition of the mulberry catalogue is due out in 2000. The descriptions are very detailed. There are 105 characters for each mulberry accessions. These follow the guidelines of the International Plant Genetic Resources Group (IPGR). After comparing the characters of both mulberry and silkworm, the Central Silk Board authorises the release of certain varieties and these are legislated by government. The second step is to identify the best location in India for growing each germplasm. A network of regional testing stations are undertaking this evaluation at present. There are three designated climatic zones: tropical, sub tropical and temperate. The station also keeps non-mulberry silkworm germplasm which are classified as “semi-domesticated” (Tusa, Eri and Muga). These have different host plants and are reared outdoors.

Dr Mukherjee recommended that we survey the germplasm available in Australia (especially the mulberry trees). He would be interested in an exchange program with Australia for germplasm research. This has already been done with China and Brazil. ACIAR recognizes the station as the national germplasm site for mulberry in India. He demonstrated the computer information system for storage and retrieval of data and presented me with a copy of each of the germplasm catalogues.

13.12.99 KARNATAKA STATE SERICULTURE RESEARCH AND DEVELOPMENT INSTITUTE, BANGALORE

DR R RAGHURAMAN of the Karnataka State Sericulture Research and Development Institute, Bangalore, explained that the Institute began in 1981. The National Central Silk Board institute began in 1948. Infrastructure developed slowly in the 1950's and 1960's but the growth of sericulture and sericulture institutes has been very rapid from the 1970's to the 1990's. Because Karnataka produces 65-66% of India's silk, the state has its own government ministry and its own research and development institute.

Some basic concepts about silkworms are that when one female moth lays a batch of eggs, the batch has to be certified disease free = 1 dfl (disease free laying). 100 dfl is a unit for which a block of mulberry plants is grown. A 1 hectare block of mulberry each 26-28 days produces 1000 kg (1 tonne) of leaves. There are two types of mulberry blocks: rainfed and irrigated. Rainfed blocks receive rain from the SW monsoons in June – August, and from the NE monsoons in September – November. Therefore these areas receive rain for 6 months of the year and are dry for the other 6 months. Irrigated blocks can produce 35 to 65 tonnes of leaves per hectare per year. With 5 crops a year this is 7-13 t/crop. Cocoon production has increased from 395 kg for 700 dfl to 481 kg in 1999/98. This has been due to better mulberry tree types and better mulberry leaf quality. The yield

of raw silk per cocoon has also increased ie the renditta (kg cocoon/kg raw silk) has decreased. In 1971/72, renditta was 17-18:1, in 1998/99 renditta is 7:1 (the state average is 9.1:1). Silkworm races are now more productive also. In 1970 the cocoon shell weighed 22 cgm, in 1990 shell weight was 34-38cgm and in some cases 50 cgm. Most silkworm farm units are small. There are only 5 farms as large as 10 hectares. In the Punjab area a co-operative farming unit covers 100 ha.

The silkworm moults four times for 1 day each, and feeds for 21 days. It weighs less than 0.5mg when hatched, but weighs 5-6g when it spins the cocoon. It therefore has to increase its weight 10,000 times in 25 days. Silkworms are of two types; purebreeds which are kept for seed (egg) production and hybrids which are kept for silk production. The Karnataka Silk Marketing Board (KSMB) buys cocoons when there is a plentiful supply of good quality cocoons. The Karnataka Silk Industries Co-orporation (KSIC) buys cocoons and processes them. The Karnataka State Silk Research and Development Institute (KSSRDI) is the third arm of the state ministry. It undertakes research in three areas: mulberry, silkworms and silk.

There are two types of silkworm races. The tropical multivoltine type has low silk quality, low egg numbers per laying (400), shorter filament length(<1000m), comparatively low shell % (13), low cocoon weight (1gm) but better disease tolerance and does better on poor quality (rainfed) mulberry leaves. The temperate bivoltine type has higher egg numbers per laying (500), longer filament length (>1000m), higher shell % (19-22%), heavier cocoons (1.7 – 2.0g), and stronger silk suited to automatic machines.

Chinese raw silk is cheaper (750-900 RS/kg) and better quality than Indian raw silk (1300 RS/kg). In trying to compete with China, India needs to look at soil, farmer and seasonal/regional differences. There are 10 types of soil/agroclimatic zones in India. The soil varies from red loam to sandy. Sandy soil can be upgraded and drip irrigation can be used to decrease water loss. The active root zone of mulbary is in the top 2 ft. It is deep rooted and can obtain moisture at depth. The young leaves contain 70-75% moisture. The first two silkworm instars have very specific requirements of temperature, humidity and nutrition. Mulberry varieties are Mysore (the local unimproved variety), S30, S26 and V1. Mulberries are planted as cuttings and left to grow for six months. They may be transplanted as saplings. They are allowed to develop 3-5 branches and when cut each branch develops 2-3 more branches. Mulberries are allowed to develop into trees in northern India but are cut low in southern India. Mechanical harvesting occurs in Japan and has been tialled in Mysore but there is sufficient labour in India for hand cutting mulberries.

With regard to silkworms the following are important:

- i) Breeds
- ii) Diseases
- iii) Nutrition
- iv) Seed Technology
- v) Rearing Technology
- vi) Entomology

There are four silkworm races:

- i) Japanese
- ii) Chinese
- iii) European
- iv) Tropical

There is a negative correlation between good silk production and survival capacity of the silkworm. Tropical races have good survival (95%) but cocoon weight is 1.8g. Seed technology: Eggs need to be well looked after during the ten days they take to hatch or the larval will be inactive. The farmer gets his eggs from a Seed Production Centre and transports them in a special Seed Transport Box that provides good humidity, aeration and cooling. The first two to three stages of the silkworm larvae need to be in an isolation chamber. They are kept on stands with ten shelves if fed with leaves or 3-4 shelves if fed with branches. The branch method is now favoured as it provides three dimensions for the silkworm to move, aeration is better, the life of the leaf is longer and worm handling is less.

KSSRDI promotes the use of a multipurpose pump which can be used for increased humidity, for disinfection and for pumping water. They advocate the use of three powders:

- i) for bacteria and virus;
- ii) for fungal control; and
- iii) for uzi fly control.

KSSRDI promote the development of by-products from the pupae: an extract for use against hypertension, a soap and a crème.

Research: KSSRDI apply to the state government for research funds. Projects are in three areas: silkworms, disease and technology. The government has a Research Advisory Committee (RAC) with three subcommittees: Mulberry, Silkworm and Technology. The subcommittees have ten members with representative from industry, university sericulture departments, farmers, silk processors and the Central Silk Board. The sub committees review the research programs each year and recommend modifications, improvements or cessation of projects. Staff have to present their findings to the subcommittee which meets twice a year. The RAC meets once a year. The RAC consists of the three subcommittee chairman, the chairman, the vice chairman and one other member. The RAC recommendations are sent to the government for funding. Funds may come directly from the government council, from the Science and Technology Department, from the Commerce and Industry Department or from International project funds. Both the Swiss and the Netherlands give funds for rural development in India. Seventy percent of the work of sericulture in India is performed by women.

22.11.99 AGRONOMY SECTION, CENTRAL SERICULTURAL RESEARCH AND TRAINING INSTITUTE (CSRTI), MYSORE

MR Y R MADHAVA RAO, Joint Director, Agronomy, indicated that mulberry was the silkworms sole source of food. Artificial diets are being trialed but they are ten times as expensive and are only used for young age worms, not for the great bulk of food. For good mulberry production one needs to have land and a knowledge of physical, chemical and financial aspects. Many rice paddy lands are being converted to mulberry growing as mulberry plants last 20 years. They are usually only part of the mixed farming enterprise but they give a regular income. Some farmers grow mulberry for silkworm farmers but they only get 1000RS (\$40) per acre for mulberry compared with 3000 RS (\$120) per acre for cocoons.

Packages for growing mulberry have been developed for farmers in different regions depending on soil and climate, especially rainfed and irrigated conditions. There are 300,000 acres of mulberry in India, 160,000 of which are in Karnataka. K2, S36, and V1 are improved varieties of mulberry. For irrigated soils, the recommended fertilizer input has been 300kg N, 120kg P and 120kg K per ha per year. It has been found that inorganic N requirement can be reduced by using azobacteria, and inorganic P can be reduced 40-50% by using mycorrhiza. These organisms are being prepared and sold in packages. Organic manure and sericulture waste recycled through earthworms are also being trialed and the methods can be patented. Micro-irrigation can reduce water requirements by 40%.

Intercropping can produce extra profit. Forty percent of Karnataka is rainfed and only produces 2-3 mulberry crops/year. There are three types of mulberry cropping:

- i) stripping leaves throughout;
- ii) strip leaves for the first three larval stages and then use branches for the last two stages;
- iii) cut shoots for all stages.

The silkworm grows 10,000 times in 20 days and requires leaves with a lot of crude protein (22-24%), carbohydrate (12-18%) and moisture content (70%). The success of bivoltine rearing is 70% attributable to leaf quality and 30% attributable to hygiene and disease control.

DR P K DAS, Senior Research Officer, has developed a microbiological package containing both *Azotobacter chrisococcum* and mycorrhiza and is trialling it on different mulberry varieties.

22.11.99 MULBERRY PATHOLOGY, CSRTL, MYSORE

DR D S CHANDRASHEKAR, Senior Research Officer, Mulberry Pathology, showed illustrations of mulberry infectious diseases. Mulberry diseases can be classified as caused by fungi, bacteria, viruses and nematodes.

Fungal diseases

Fungi take the highest toll on mulberries. They may be classified into:

- i) root diseases (“root-rot” caused by *Fusarium solani* and *Fusarium oxysporum* responsible for 30% plant mortality; “white root” caused by *Rosellinia necatrix*; “violet root-rot” caused by *Helicobasidium mompa*);
- ii) shoot diseases (“stem or trunk rot or heat-rot” caused by *Polyporus hispus* and *Ganoderma applanatum*); “cutting-rot” caused by *Fusarium solani*; “collar-rot” caused by *Phoma sorghina* and *Phoma mororum*); “mulberry stem canker” and “dieback” caused by *Botryodiplodia theobroame*);
- iii) foliar diseases (“powdery mildew” caused by *Phyllactinia corylea*; “leaf spot” caused by *Cercospora moricola*; “leaf rust” caused by *Aecidium mori* (*Cerotelium fici*)).

Bacterial diseases

Bacterial diseases are “leaf blight” caused by *Pseudomonas mori*, “stem rot” caused by *Bacterium moricolum* and “stem and leaf rot” caused by *Bacterium mori*. *Mycoplasma* causes “dwarf disease”.

Virus disease

The only virus disease is “Mulberry leaf mosaic disease”.

Nematodes

Nematodes are responsible for “root knot disease” caused by *Meloidogyne incognita*.

Diseases of nursery mulberries

Diseases of nursery mulberries such as stem-canker, collar rot, cutting rot and die-back cause about 30-35% mortality of cuttings and saplings in nurseries and fields. The mortality is over 50% for high-yielding, poor-rooting mulberry varieties. “Nursery-guard”, a biofungicide formulation of *Trichoderma pseudokoningii* has been developed for broadcast over the nursery bed prior to planting to protect against these diseases. It is 30-70% effective. Another biofungicide marketed under the name “Raksha”, a formulation of *Trichoderma harzianum*, has been developed for root rot disease. It is 40-90% effective. The application of *Trichoderma harzianum* and *Trichoderma pseudokoningii* has been found to reduce the severity of leaf spot and leaf rust by 60%. These latter

biological control agents are not quite as effective as the present chemical control agents of “Bavistan” (carbendazine and “Kavach” (chlorothalonil) which are 62-70% effective.

It has been found that mulberry genotypes S36 and V1 are moderately resistant (<20% incidence) to both leaf spot and leaf rust, and genotypes V1, S13 and S34 show less incidence of root knot nematodes.

13.12.99 MULBERRY BREEDING AND GENETICS, CSRTI, MYSORE

DR A SARKAR Joint Director, Mulberry Breeding and Genetics, introduced me to DR R BALAKRISHNA, Senior Research Officer, who showed me over the section and the plots of different mulberry varieties. The section has 427 accessions from 17 countries, including *Morus nigra* from Australia. The most desirable characters are scattered amongst the 427 accessions. The sexes are separate and therefore hybridisation is possible. They have been comparing varieties for 15 years and can now begin to recommend varieties suitable for different regions of India. Varieties have been developed that are more suited to rainfed or irrigated areas, alkaline soils or intercropping with coconuts. Varieties suitable for Southern India are:

Characteristics	Rainfed			Irrigated	
	Kanva (Mysore 5)	S-36	V-1	S-13	S-34
Leaf Yield (t/ha/year)	35	40	70	15	15
Rooting Ability From Stem Cuttings (%)	80	50*	94	[Better to alkaline	adapted soils]

* Therefor raise in nursery.

Three budded cuttings are made from six month old shoots. *M.nigra* is a diploid (28 chromosomes = 2n) but triploids (42 = 3n) are preferred. Field surveys for new germplasm are conducted, trees marked and cuttings taken. If the berries taste sweet the variety is good for silkworms. Buds sprout from cuttings in 20-28 days. A callus and root begin at 68 days. Can graft also but very tedious as a 1 ha area planted at 90 cm intervals holds 12,000 plants. Temperate origin mulberries bloom in Spring and Autumn. Tropical origin mulberries bloom when there is any disturbance. The male flower produces pollen and then falls off. The female flower persists to develop fruit. The species are difficult to tell apart. *M.serrata* and *M.laevigata* can be identified but *M.alba* and *M.indica* are confusing. Triploids do not breed and only propagate by cuttings. To plant cuttings, two buds (nodes) are buried and one is left above the surface. Those planted in a nursery are transplanted after four months with 90-99% success rate. Most irrigation is by flood irrigation every 8-10 days in sandy loam and every 15 days in clay loam. Triploids mature fast but become coarse. They are therefore usually used on slopes when maturity is delayed. The local variety of *M.indica* was introduced by Tipu Sultan 210 years ago. It has a low yield, a dissected leaf but good rooting and good disease tolerance. It was imported from Kashmir and West Bengal. A spiralling ornamental type, *M.serpentina*, has been imported from Italy. Spreading type branches are not used because bullocks cannot plough between the rows, and transpiration rate and hence water requirements are higher. *M.multicaulis* from Japan and Indonesia is being trialed as the female parent for crossing with existing varieties. It is less dormant and non-dormancy is dominant. Several *M.multicaulis* crosses have superior production traits. Research trials have found that varieties AR10 and AR11 are superior to S13 in water stress conditions and AR12 and AR14 are superior to S34 in alkaline soils.

If cuttings were imported into Australia the most important problem would be drying of the cutting because they will not shoot if planted ten days or more after cutting. Thailand imported varieties from Japan and they were found superior to their own varieties and were immediately released without further crossing. Sandy soil is best for establishing and rooting.

13.12.99 SOIL SCIENCE, CSRTI, MYSORE

DR E B SRINIVASAN, Deputy Director, Soil Science and Chemistry, recommended a soil having 14-20 cm of sandy loam for establishment and feeding of mulberries, then 60-100 cm clay loam for moisture retention for the deeper roots. Tank silt from septic tanks can be added to sandy loams. The pH of any added component should be opposite to that of the soil, to bring it closer to neutrality. Organic manures are added to increase water holding capacity. If it is a black soil, red earth is added and mixed together. A pH of 6.7 – 7.3 is best for mulberry plants. Outside pH 6.3 – 7.5 soils become problematic. The major problem in Karnataka is alkalinity. Gypsum, when added at 8tonnes/ha, caused a pH fall of 1 unit (eg. Black garden soil will fall from pH 8.5 to 7.5) and increased yield by 8t leaf. Gypsum is too expensive for many farmers and only elite farmers can take advantage of this. However naturally available products have been found that can substitute. Sugar cane press mud is good. It is composted for 2-3 months and 40t/ha will decrease pH by 0.75-1 unit. It has a very good water-holding capacity and high micronutrients concentration. Acid soils are more of a problem in Kashmir. Here burnt lime at 8t/ha increases pH by 1 unit. Salt is a problem in some soils and this is leached out by flooding.

Nutrient management: The major nutrients used by mulberry are NPK. 300kg N, 120kg P and 120kg K per ha are required per year. Mulberry requirement in the soil is 25% moisture, 25% air, 45% mineral and 5% organic matter. Mulberry leaf contains 1% N, so 30-40t/year leaf requires 300-400 kg N. If NPK in the soil is average, more fertilizer is given. If the analysis of NPK is above average, 25% less fertilizer is given. 75% of P is fixed in the soil, so when 120kg P is applied, only 30kg is available to the plant. At an average of 4-5 crops per year, this means 24-30kg P to add per crop. The P is added in two doses of 60 kg +60kg to the first and third crop only. If P was added to each crop, its availability would increase. Micronutrients are less available in alkaline soils. Foliar sprays are used for micronutrients of Fe, Zn, Cu and Mn. Packages of mixed fertilizer have been formulated to provide the required nutrients for every type of soil. Soil water and manure are analysed for farmers in the Soil Science and Chemistry Laboratory.

The section has found that vermicompost made from the castings of earthworms fed on mulberry and silkworm trash is a valuable fertilizer which is improved by the addition of rock phosphate, single superphosphate, Azotobacter and phosphate solubilizing bacteria.

26.11.99 MULBERRY PHYSIOLOGY, CSRTI, MYSORE

DR J KODANDA RAMARIAH, Joint Director and DR N R SINGHVI, Senior Research Assistant, Mulberry Physiology, said that there was not a great knowledge by farmers about the hunger signs of mulberry. The following signs of nutrient deficiency of mulberries have been shown in Wagnor pots using quartz sand.

1. Nitrogen (N): Growth stunted, quick yellowing of lower part of leaf starting on leaf margins.
2. Phosphorus (P): Cessation of growth, loss of green pigment, brown 'scorching' of leaf margins, quick yellowing of older leaves.
3. Potassium (K): Cessation of growth. Lower leaves become yellow. Necrosis at leaf margin spreading to whole leaf.
4. Calcium (Ca): Growth ceases and plant becomes weak and lodges. Leaf shape distorted. Brown oily spots on leaf. Lower leaves yellow and fall prematurely.
5. Magnesium (Mg): Growth ceases. Loss of green pigment (Chlorosis) between leaf veins; more prominent in younger leaves.

As many of these signs are similar, leaf analysis has been undertaken and 0.25% Ca, 0.15% Mg and 0.32% S has been found minimum concentration required for optimum leaf yield.

Work has been undertaken on plant growth hormones (PGH). Additional nutrients are required for the plant to be able to take advantage of growth hormones. Gibberellic acid has increased the leaf yield 15-65% in the genotypes studied so far. The leaves are being tested in silkworms. Cheaper forms of PGH's are being tested and salicylic acid, CoCl_2 and CoNO_3 have given positive responses.

MULBERRY TISSUE CULTURE, CSRTI, MYSORE

DR A K TEWARY, Senior Research Officer, Tissue Culture Laboratory, said that they look for factors responsible for maximising mulberry yield. For example, in Japan they have not enough land available to grow the mulberry leaves required for silk so they now grow mulberries for fruit. Australian stocks of Morus australis should be investigated because it multiplies rapidly in tissue culture. Tissue culture greatly assists breeding because multiplication is the main problem. With cuttings there is a wait of 6-8 months, and there are many failures, and transportation kills 50%. Tissue culture is an alternative but is costly compared with cuttings. However to plant 10 acres with 120,000 plants is expensive in time. Tissue cultures can be hardened and transplanted directly into the field. When mulberries are pruned at 30 days, they bud. The bud is used in the medium of agar or cheap agar substitutes (China grass, sago, maida).

Different hormones are used for each variety. Once established their buds can be used, so multiplication is rapid. The buds can be grown in soil or potting mixture in polythene bags. Cuttings are difficult to grow in temperate regions so shoots are used. Species tolerant to saline and drought can be easily screened by including saline in the potting medium.

26.11.99 SILKWORM MOLECULAR BIOLOGY, CSRTI, MYSORE

DR S SREEKUMAR, Senior Research Assistant, Molecular Biology, described the following projects.

- (a) RFLP Technique (Restriction Fragment Length Polymorphism) is used to obtain better cocoon quality. To identify DNA markers close to genes responsible for cocoon shell quality, two silkworm strains, B20A and Cnichi with high and low silk ratio respectively, but with low and high disease resistance respectively, were selected and bred for 10 generations of full sib mating to prove homozygosity. They were then mated and the F_1 and F_2 generations raised. From the F_2 generation, high shell ratio females were back crossed with Cnichi males to produce a BC1 generation. Repeating this for 10 generations produced Cnichi containing the B20A character of high shell ratio.
- (b) Bulked Segregant Analysis:
DNA is collected from individual larvae from high shell and low shell ratio lines and placed in two pools. A number of restriction enzymes were tried. EcoRV enzyme yielded a distinctively different polymorphic pattern from these two pools. Sixteen low copy probes were able to show distinctive DNA patterns for the hybrid between these two lines.
- (c) Improving Disease Resistance:

Fifth stage larvae were orally inoculated with a nuclear polyhedrosis virus which contained a luciferase reporter gene. After 15 hours post infection (hpi) luciferase was seen in the midgut of susceptible and tolerant breeds, but after 48 and 72 hours more luciferase was found in the fat cells and tracheal tissues respectively of the susceptible breed than in the tolerant breed. This method can be used to rapidly identify nuclear polyhedrosis virus tolerant strains of silkworms.

27.11.99

SILKWORM BREEDING LABORATORY, CSRTI, MYSORE

DR N SURESHKUMAR, Joint Director, Silkworm Breeding (JICA Project), explained that the Japan International Co-operation Agency program was designed to increase the production of bivoltine silk because it was of better quality and the only silk in demand on the international market. The JICA project knew that India consumed all of its own silk at present, but they would be able to export in future if production efficiency increased. When JICA started 6 years ago, Dr Manu brought commercial hybrids from Japan to India. He found that he could get the same production and quality in India. Bivoltine silkworms need more care and technical control than multivoltines so to ensure the best chance of success of implementation, only farmers with a separate rearing house and a good record of production were chosen for the implementation stage of the program (Most Indian farmers have very low technical knowledge and capability, and rear silkworms in a room in their own homes).

The program starts and ends with disinfection of the rearing house; 2-3% formalin and 2% bleaching powder are sprayed on the walls, floors and equipment after clean out. The farmers only receive the third stage larval. Incubation and young age worm rearing is done on a government station because of the need for greater care.

Crosses of bivoltine males with polyvoltine females are used to take advantage of the greater field robustness of the local polyvoltine and to avoid having to break the diapause of a bivoltine female in the field. Both breaking of the diapause of the pure bivoltine strains and cold storage of the multivoltine strains are required to maintain the stocks in the laboratory. Improved strains are selected after breeding and production testing. Most of the economic characters of silkworms are polygenetic so it is not possible yet to use molecular genetics for this purpose. Different strains were selected as suitable for different climatic conditions (States) in India. In particular, strains have had to be selected that are resistant to high temperatures and high humidities. A special high temperature chamber run at 36⁰C is used to select strains with 80% survival rate (1HT and 2HT).

The (Mysore) strain silkworm first introduced into Karnataka by Tipu Sultan is still the most robust and hence the most widely used polyvoltine (MY1). The pure strains of bivoltines that have been found best for breeding hybrids in India are designated as: KA, NB4D2, NB7, NB18, CC1, P2D1, N, P5, SH6, CA2, PM, YS3, SF19, PAM101 and PAM111.

13.12.99

SILKWORM PHYSIOLOGY, CSRTI, MYSORE

DR P K CHINYA, Deputy Director, and DR K TRIVEDI, Senior Research Officer, explained the following projects undertaken by the laboratory:

1. Plant hormone ecdysteroid:

An anti-juvenile growth hormone analog has been found to improve silkworm growth and silk quality in Czechoslovakia, Russia and Japan. In the Silkworm Physiology laboratory, an ecdysteroid has been extracted from the plant *Sesuvium portulacastrum* and found to hasten the maturation events and synchronize the spinning activities of silkworms. It was administered orally to race CSR2 x CSR4 at the onset of spinning and the results compared with the results using the moulting hormone from China. Both treated groups completed maturation (cocoon spinning and pupation) in 36 hours, compared with 48 hours for the non-treated silkworms.

2. Artificial diets:

350 diet formulations have been tested using locally available low cost ingredients such as soy flour, groundnut (peanut) cake, china grass and mulberry leaves. Only the first two larval stages have been used. One of the formulae (no. 630) gave results equal to mulberry leaves. A sterol has been isolated from mulberry leaves which attracts silkworm larvae. Synthesis of the sterol is being attempted so that a completely non-mulberry diet can be developed. This will help to decrease the area of mulberry required to be grown for silkworms.

3. Selection for feed efficiency:

Strains of silkworms are being compared for feed conversion efficiency when fed high quality mulberry leaves. This trait has the potential to decrease the cost of feeding silkworms and will be used in breeding programs provided the silk quality is not affected.

4. Utilisation of sericulture waste:

Wastes from sericulture, silkworm litter and moths have been extracted to produce pectin and chitin respectively. Pupa have been cultured to produce proteases and lysine. Pupa powder can be used to replace the costly ingredient presently used in fermentation media used to produce protease. The E42 mutant of *Corynebacterium glutamicum* produced the most lysine in a broth containing pupa powder. Other UV mutants are being tested for greater lysine production from pupa powder.

30.11.99 SILKWORM PEST MANAGEMENT

DR K S PRASAD, Senior Research Assistant, Pest Management, explained that the pests of silkworms are uzi fly, the dermestid beetle, ants, lizards, rats, squirrels and birds.

1. Uzi fly (*Tricholyga bomliscis*) is a serious pest of silkworm larvae and pupae in all silkworm states. It was severe in West Bengal and Assam and has now spread to Karnataka. The Uzi is a large fly about 1cm long with prominent black and grey longitudinal stripes on the back of the thorax. The first and second silkworm instars are rarely attacked as they are too small, but the larger worms are used as a laying platform. Three hundred eggs are laid usually one per worm so loss from one fly is severe. The eggs hatch in 48 hours and the maggots burrow their way into the body of the silkworm. A black spot appears at the point of entry after penetration. The maggot lives on the silkworm tissues and when fully formed it exits killing its host. An infection of a fifth instar may not prevent cocoon spinning but the cocoons cannot be used for seed or silk as the maggot exits from the pupa and through the cocoon. Dead pupa strain the cocoons. Control of the fly is mechanical by the use of nets and fly screens at all entry points. The flies like the light so painting rearing room black and keeping the light dim will not attract the fly. Uzi traps, consisting of trays of kerosene or insecticide in water can also be used to catch the flies on the outside of the fly screens. Chemical control involves spraying the silkworms window every second day with an uzicide. A natural predator, *Neselas thymis*, that parasitises the uzi pupa in soil, can be used.
2. *Dermestes ater* and *Dermestes cadaverinus* (dermestid beetles) are also about 1 cm long with brown elongated oval bodies and club shaped antennae. They used to only eat stifled pupae in silk cocoons, but they are now attacking the silk moths also. The beetle is polyphagous and attacks other valuable materials such as leather, furs, dried fish, carpets and woollen goods. Control is by thorough cleaning to prevent attractive egg laying areas within the cocoon holding areas, and by not holding cocoons for too long. Fumigation of cocoon stores with methyl bromide for one day or chloropicrin for 3 days is effective for silk cocoons. Synthetic pyrethroids and neem products are good residual insecticides.

3. Ants commonly attack and kill silkworms in the rearing trays. Water holding antwells are placed under the feet of the rearing racks. At the time of spinning, rotary mountages are hung from the ceiling and the legs of standing chandrikes are smeared with kerosene or ash to prevent the passage of ants.
4. Lizards, rats and squirrels will invade rearing houses and eat silkworms. Having a 3ft gap between the steps and the rearing house prevents their entry.
5. Birds (especially sparrows) will take silkworms from chandrikes kept outdoors. Chandrikes should therefore be left indoors until the cocoons are spun.

13.12.99 SILKWORM GENETICS, CSRTI, MYSORE

DR S K ASHWATH, Senior Research Officer, and DR M NOBLE MORRISON, Senior Research Assistant, Silkworm Genetics, outlined their present projects. Japanese silkworm breeds do not have amylase isozyme. Native silkworms do and this trait may be linked to the greater disease resistance of local silkworms. Near Isogenic Lines (NILs) of popular biovoltine breeds introgressed with amylase isozymes from multivoltine donors (Pure Mysore and Nistare) are being field tested for disease resistance. The hybrid GEN3 x GEN3 scored highest for survival and cocoon traits. A large number of gene markers are known for silkworms and a collection of these genetic stocks is kept in Japan. All the silkworm strains with gene markers have been obtained from Japan (5 multimarker stocks carrying marker genes with 22 linkages to cocoon traits) and they have been distributed to stations where their production and disease tolerance are being tested. Most productive traits are polygenetic. Eleven chromosomes are known to carry cocoon traits. The section is particularly interested in DNA markers on the 9th chromosome. They will be analysing DNA markers in near isogenic lines next year in collaboration with the Molecular Biology group using the polymerase chain reaction (PCR) technique. Silkworms are used for general chromosome studies, however, unlike the *Drosophila* fly, the chromosomes are quite small so cytological work is more difficult.

1.12.99 SILKWORM BREEDING, CSRTI, MYSORE

MR B K KARIAPPA, Deputy Director, Silkworm Breeding, gave the history of development of the present day multivoltine strains and crosses. The Pure Mysore (PM) multivoltine strain has been used by farmers for centuries and they have great confidence in this strain. It is the hardest strain but is not very productive. Its renditta is 9-10. It is more productive when crossed with another polyvoltine strain that has also been present for many years, Cnichi. The PM x Cnichi cross does better than other strains in the common conditions in Karnataka – no irrigation and small mulberry leaves of low nutrient value. In these conditions the extension staff provide technical backup demonstrating hygiene and disinfection methods. Once a farmer shows he can handle the technical side he is offered improved strains of silkworms eg. PMXNB4D2, and then BL24 x NB4D2 which produces a longer filament (900m). The multi-voltines have yellow silk. The NB lines are new bivoltines with white silk. The farmers are chosen after a survey has assessed four aspects:

1. The status of their mulberry garden
2. The status of the rearing house
3. Inputs to the mulberry garden (manure, irrigation)
4. Conclusion that the farmer has the knowledge and interest to look after the improved strains.

The next step is a technical package of three components:

1. The young age worms are reared for the farmer until the third stage larva (when they are more robust)
2. The farmers are given the worms with a guaranteed buy back of cocoons at 10% more than they are getting for their present cocoons.
3. All technical assistance and demonstrations are given free of charge or subsidised. (“Post-authorisation discipline”). This encouragement has to be given because farmers are not confident in changing from an established strain of silkworm. The reelers are biased towards the traditional multivoltine silk also. Reelers have to be shown that the shell percentage is higher and that they will get more silk to sell from the bivoltine strain cocoons.

Several new strain crosses have been released for assessment in the field with the aim of finding the best cross for each region. BL23 x NB4D2 is being trialled in rainfed areas and B24 x NB4D2 in irrigated areas. These hybrids produced an average yield of 47.3kg/100dfis compared with 35-42kg/100 dfis for PM x NB4D2. A new multi x multi hybrid has also been released. Its field results are improved filament length and raw silk % and a renditta of 11.5 for BL24 x Cnichi as against 13.0 for the established PM x Cnichi. A new multi x bi hybrid, BL43 x NB4D2 suitable for irrigated areas, is also being tested for authorisation. Laboratory trials have found that five new lines (BL62 x CSR2, BL65 x CSR5, BL67 x CSR5, BL68 x CSR5 and BL69 x CSR5) are significantly superior to PM x BL24 incocoon weight (>1.3g), shell weight (>21cg) and cocoon shell ratio (>17%) and significantly superior to PM x NB4D2 and BL24 x NB4D2 in shell weight, SR%, filament length and renditta. All these lines have also shown a shorter larval duration (22-23 days) compared to the PM strain (28-29 days).

The breeding program is divided into five aims:

1. Improved productivity and stress resistance in bivoltine silkworms;
2. Improved productivity and silk quality of multivoltine breeds and hybrids;
3. On-farm field evaluation of bi x bi and multi x bi hybrids;
4. Selection of single hybrids for high silk recovery; and
5. Selection of double hybrids for higher pupation rate, cocoon shell ratio, robustness and silk quality.

MR MALLIKAJUNA, Assistant Director, National Silkworm Seed Production Centre, CSB, Mysore, explained the “Grainage”, or silkworm egg production, system in India. Five Indian states grow silkworms. Three states in the south, (Karnataka, Tamil Nadu and Andhra Pradesh) grow silkworms all year, while in the north two states, (West Bengal and Jammu/Kashmir), grow silkworms seasonally and not in the winter. Different types of silkworms have to be produced for the two regions but it requires forward planning to co-ordinate the supply of silkworms at the same time as the farmer has young growth of mulberry. Maintaining the required strains and producing the required number of eggs is the responsibility of the grainage units. Three hundred million eggs per year are required by Karnataka state alone. Thirteen central government units 80 state government units and 800 private individuals are licenced to produce and sell silkworm seed. The farmers have an average of 0.2-0.85 ha landholding for mulberries. With this they require 200-250 disease free layings (dfls)/crop and rear 5-6 crops/year. The yield of cocoons is 45-50 kg/100dfls, but can go to 65-70 kg (70-80kg for bi x bi cross). The return in the market is 125-140 rupees (RS) (\$5-6)/ kg cocoon. So one acre of land produces 100-120kg cocoons returning 15-18,000 RS/crop x 5-6 = 75-90,000 RS up to 1 lakh (=100,000) RS per year (approximately AUD \$4000), a good income for India.

The breeding cocoons are bought at a premium (250 RS/kg bivoltine cocoons and 180 RS/kg multivoltine cocoons) from P₁ (Parent) breeders. There is a hierarchy of selected private breeders in the system set up by the government. The P₃ (great grand-parent) breeders and the germplasm and P₄ stations maintain pure bred stocks. Twenty of their cocoons are sent to P₂ (grand parent) breeders and 30% of their cocoons are sent to the P₁ (parent) breeders. Twenty percent of these cocoons are sent to the grainages where cross breeding and sales of the F₁ generation takes place. P₃ – P₁ and grainage units have to be isolated and have excellent hygiene and husbandry conditions and the system is organised this way mainly to prevent the transmission of pebrine disease.

Farmers requirements for seed increase when rainfall increases because they have extra mulberry leaf growth. The centre needs a lead time of 15-20 days to increase or decrease the through put and farmers will usually give 15 days notice of their requirements. The Unit knows that demand will be low in December and high in January and has monthly targets of seed production. However, if the target is too high multivoltine seed can be kept for 20 days in a refrigerator at 5° (or for a longer period for bivoltines), and then the seed takes 8 days to hatch, so the Unit has a 28 day buffer period to adjust production. This Unit had the following seed production figures (in lakhs, = x 100,000) for 1999.

MONTH	PRODUCTION	CUMULATIVE
April	0.94	0.94
May	1.62	2.56
June	1.06	3.62
July	0.93	4.55
August	1.28	5.83
Sept	1.64	7.47
Oct	1.34	8.81

To arrange cross breeding, the cocoons of each strain are kept in one layer on round woven bamboo trays in different rooms but under the same light regime. To stimulate emergence, special fluorescent lights are switched on at 2am. Within half an hour the males start to emerge. These are removed from the trays. The polyvoltine males are discarded, and the bivoltine males placed in a refrigerator and an equal number are spread amongst the set of emerged polyvoltine females. Not all

moths emerge on the one day. All males emerge on the first day but it takes 4-5 days for all the females to emerge, with approximate proportions of 10%, 25%, 35%, 20%, 10% for the five days.

The staff work on shifts and the early morning shift starts at 2am. The emergence commences about 2.30am and goes to about 6.30am each day. Lights go off at 7am until the next day at 2am. There are approximately 5000 cocoons in a tray and pupation of 11-12 days is allowed. Therefore today's set of cocoons (2.12.99) were spun on 21/22.11.99. The male moths are used twice over a 4-5 day period and refrigerated at 5°C in between. Therefore only half the number of bivoltine cocoons from P₁ units is required to the number of multivoltine cocoons for a multi x bi (the commonest) cross. (Notes: Crosses of silkworms in India are designated as female x male, not male x female). Mating takes 3-4 hours and at the end of that time the joined pairs are placed in a well on a seed card, because the female starts laying eggs immediately she decouples. When they decouple, the male is removed and again placed in cold storage until the next mating. 24-48 hours are allowed for the female to complete egg laying.

When the layings are complete the egg sheets are dipped in 2% formalin for two minutes and then inspected and if any cell has less than 300 eggs it is not counted as a dfl. All females are inspected for pebrine after laying and the laying from an infected moth is destroyed. Each sheet has 20 laying cells, so a farmer would buy five sheets of 20 dfls if he wanted 100 dfls.

There is a schedule of gradually decreasing temperatures (25°, 15°, 5°, 2.5°) for 24 hours each to place eggs in storage, and these are reversed to bring eggs out of storage for sale. Eggs have to be treated very gently to preserve their viability.

13.12.99 KARNATAKA SILK INDUSTRIES CORPORATION, WEAVING FACTORY, MYSORE

MR JAYAPAL described, and escorted us around, the silk weaving factory. Raw silk skeins are received from the DSIC filature works and soaked in coconut oil, soap and hot water to make the silk smoother in running through the machines. One end of each skein is dyed a different colour to identify its eventual use as either warp or weft silk. When the silk is wound from the skein or hank onto weft bobbins it is "doubled" (two to four threads) and may be twisted to make the stronger longitudinal thread or warp. When it is wound onto cones it is for rewinding onto the pirn shuttles for use as the cross thread weft, in fabric weaving. Yarns like crepe and georgettes require a high rate of twisting. High twist rate causes shrinkage so these fabrics shrink after weaving. Minute snarls occur creating wave effects on the fabric. There is a natural tendency for the twist to unwind so to set the twist it is subjected to damp heat (steam). The sericin softens in the process and helps to cement the twisted threads together as it cools. About ten minutes steaming is sufficient for organzine threads but more time is required to set highly twisted crepe and grenadine threads. Twisting reduces the sheen of silk. Some threads, usually used on the edge of the cloth, are made of fine silver wire which may be overplated in gold. These fabrics are highly prized.

After weaving, the cloth is degrummed in a soap and soda solution. It is then bleached and dyed and/or printed and usually cut into sari lengths of 5 ½ metres.

The types of cloth or fabric produced are:

- i) Taffetas: These are fine soft fabrics made with plain weave and no twisted thread. They are closely woven, smooth and have a fine cross rib as the ends (warps) greatly outnumber the picks (wefts).
- ii) Crepes: These have a crinkled, puckered or pebbly surface due to the use of highly twisted yarns in the weft and sometimes in the warp also.

- iii) Crepe-de-Chine: A light weight fabric made with S and Z highly twisted yarns alternating in the weft.
- iv) Georgette: A fine light weight open texture fabric generally in plain weave, made from crepe yarns, usually two Z twisted and two S twisted yarns in both the warp and weft.
- v) Chiffon: A very light, sheer, open-mesh fabric made from highly twisted yarns.

Samples of these fabrics were purchased.

13.12.99 KARNATAKA SILK INDUSTRIES CORPORATION, FILATURE,
T.NARASIPUR, MYSORE

MR RETE HELLI, General Manager introduced us to MR P GOPALA, the assistant master maintenance, at the Silk Filature (Reeling) Unit at the Karnataka Silk Industries Corporation Ltd. Mr Gopala said that the Unit had a capacity of 1500kg cocoons/8 hour shift, but because it is winter and because they prefer bivoltine cocoons, the present throughput is 300-400kg/day. The reason why they prefer bivoltine is that it is the best quality, which they have a policy to buy, and also because it can be processed on automatic reeling machines at twice the rate of the weaker multivoltine silk that has to be processed more slowly on semi-automatic machines. The cocoons come in "green" (fresh) and are put through a 4 hour hot air drying stage when they are held at 120°C, then 90°C then 60°C for 45 minutes each. The cocoons can then be stored from 48 hours (minimum) to 6 months (maximum). Present purchase price of cocoons is 130 RS/kg polyvoltine cocoons, and 200-230 RS/kg for bivoltine cocoons. The renditta (kg cocoon/kg silk) is 5.5-6:1 but for polyvoltine at present (Winter) it is 11:1 (in Spring it is 8.5:1). The drier was made by Yamoto Company in Japan. It operates by blowing air across steam heated pipes controlled by thermostats. The air ducts are insulated by fibreglass. About 60% of weight of the cocoon is lost during the drying. The bivoltine length of thread is 800-900m (cf 2-3 times longer in Japan). There is not enough bivoltine being grown and marketed in India to keep the filature unit going at fully capacity.

Double cocoons (dupions) (ie. when two silkworms spin their cocoons together) cannot be processed with the other cocoons. They are larger than normal cocoons and are easily separated by hand and processed on a special reeling unit that reels 25-30 cocoons together to produce a thick 50 denier thread used in heavy fabrics like upholstery.

Before reeling normal cocoons, the dried cocoons are put through a cooking machine where the temperature of the water is raised and lowered several times to enable full water penetration of the cocoon shell and softening the sericin. After cooking, the multivoltine cocoons are reeled on a semi-automatic reeling machine where the threads are fed onto the reels by hand. Each fibre is about two denier (a poor fibre is 1.5 to 2, and a good fibre is 2.2) so from 10-15 cocoons are fed together to make a fibre of 26-28 denier. Each employee is responsible for 6 reels (normally 12 reels when in full operation) and each reel is tested for denier and the workers have their pay reduced if the denier is not within the accepted limits. The semi-automatic reeling machine runs at 175rpm. The automatic reeler runs at 180rpm. The latter has a 20 reel basin (per person) and an automatic threading mechanism. Output of the automatic reeler is 3kg/worker/day compared with 1.4kg/worker/day for the semi-automatic reelers.

After the first reeling, the reels are placed in a sealed vessel containing water, coconut oil and a softening agent and the reels are subjected to three cycles of vacuum and release, to rehydrate the dry silk and allow it to be rereeled onto layer square reels from which the silk is removed and twisted into a yank or skein which is then tied with other yanks in a book of 2 kg, worth 1500 RS/kg. (Dupion is worth 700 RS/kg).

Denier is checked on an Indian made denier measuring machine. The first 450m of a reel is rereeled in the laboratory and placed on the denier scale which is graduated in denier units.

MR MUTHU KRISHNAN, the Deputy Manager (Production), was interested in supplying Australian cotton and wool spinners with silk because silk mixture fabrics are in demand for clothing such as light weight suits.

The remnants of the cocoon after reeling are used. The pupa is separated and powdered and used for poultry and fish food (It is no longer used for oil extraction).

The cocoon market is kept buoyant by the participation of the government reelers in the open auction system. KSIC purchases both bivoltine pure and bivoltine cross cocoons, but would prefer all bivoltine pure cocoons (ie. the top of the market) if they were available. Other reelers know that the government will bid up to a fair price level so they cannot collude with each other to keep the prices low. The KSIC filature unit does not have to sell its raw silk on the open market. It supplies the silk used at the KSIC textile plant and is credited with a fair nominal price from which it makes a profit.

04.12.99 GRAINAGE SECTION, CSRTI, MYSORE

MR S B NAGAREATA, Grainage Section, indicated that the pure bivoltine and multivoltine breeding laboratories at CSRTI send their cocoons here for preservation, emergence, mating, egg laying and egg storage.

The cocoons are spread in a single layer on wooden trays for 9-10 days at 25⁰C and 80 % RH until emergence. A sample of 5-6 weak looking cocoons is tested for disease. The cocoons of the test sample are cut open and the pupa crushed and tested for pebrine. If any pebrine is detected, the tray will be discarded. (The rule is that wooden trays should be used, but bamboo trays are still being used at some grainages because they are cheaper (25-30RS) than wood trays (>100RS)). The pupae may all be cut out of the cocoons and separated according to sex. The male is smaller. Males only emerge on the first day. Females emerge over 2-3 days (10%, 80%, 5%). Emergence is about 90% and the ratio of males to females is usually 60:40. The males are separated and mated twice. Mating is called coupling and the abdomen are joined together with two hooks for more than three hours during which time there are two to three ejaculations.

The pairs are forcibly decoupled at 3 hours and the males kept a 5⁰C until the next day. After two matings the males are discarded. Oviposition of the females takes place in cells on a card or without restraint on starch coated craft paper. There are 20 cells on each card and the moth is confined to the cell using a plastic ring. She is kept here for 24 (maximum 48) hours, during which time she lays 300-500 eggs (bivoltine = 400 – 500). The eggs laid on coated craft paper are washed off in water and stored in a net bag in standard units of 54g of loose eggs. The eggs are then dipped in 2% formalin for 5-10 minutes and dried in the shade.

Because the bivoltine eggs enter diapause after 24 hours, if diapause is to be broken for immediate hatching, acid dipping has to be done on the first day. Hot acid treatment is at 46.1⁰C using HCl at SG of 1.075 for 5 minutes. Cold acid treatment is either 20⁰ or 25⁰C for 60 or 90 minutes respectively using HCl at a SG of 1.1.

All female moths are examined for pebrine after egg laying. They can be crushed in a small mortar using a pestle or several may be blended together with KOH solution, placed in a test tube, filtered, centrifuged and the precipitate examined on a slide under the microscope to identify spores. Eggs which are to be preserved are taken through a series of cooling steps to enter storage for different lengths of time from 4 to 10 months. From cold storage it takes 3 days at 15⁰, 20⁰, 25⁰ to bring back

who picks the mulberry leaves does not enter the room containing the larvae. The rearing house should be ant-capped and not have connecting steps. Usually there is a gap of 3ft between the top of the step and the entrance to the house. This is to prevent the entrance of small predators such as lizards. Workers in the rearing house should remove their outside shoes and put on inside shoes or thongs before entering the larval room. Once the larvae move to the late age rearing room, the young age rearing room can be used to store mulberry shoots where they can be kept in the dark with high relative humidity to retain leaf moisture.

The design of rearing appliances depends on the number and type of rearing. The appliances required are: stands, trays, leaf chopping board, heater, humidifier, shoot rearing racks. An infra-red moisture meter is very important as the leaves should have >75% moisture content. Often the farmer has a separate small "chawki" mulberry plot which is frequently irrigated and well fertilized to produce the most nutritious leaf. This plot may grow S36 variety which has a higher MC%, while the rest of the mulberry garden may grow V1 or K2 for the late age larvae.

There are five or more types of mountages in which the cocoons are spun: the spiral "chandrike", the "bottle brush" or "hedgehog", (both hand made from bamboo), the concertina like cardboard cells which are held in a rotary frame, and two types of plastic mesh which can be folded to make comfortable resting places in which the fifth stage larvae spin their cocoons. The farmers like the chandrakes as they are cheap to make (180RS) and they can be hired from a supplier just for the 4-5 day mounting period. Their disadvantage is that they may not let enough air through the back to dry the silk evenly and reeling may therefore be more difficult from these cocoons. The rotary mountage gives excellent exposure of the cocoons to even drying. The worm urinates just before spinning the cocoon and the mountage and mounting room need good ventilation to get rid of the high moisture content.

Experiments conducted by the section show that:

- i) any reduction in feeding of the fifth stage larva results in increased disease incidence, and decreased yield and quality of cocoons;
- ii) mounting fifth stage larvae within six hours after disinfection of the mountages reduced percentage of good cocoons, shell ratio and reeling parameters compared with batches mounted 12 to 16 hours after disinfection;
- iii) a low cost leaf preservation chamber can be made from bamboo in three parts, a rectangular base, a surrounding mat and a central funnel which allows the heat of the leaves to escape;
- iv) previously tested inventions of egg carrying bags, low cost incubation device, blue polythene sheets for chawki rearing, shoot rearing and bottle brush mountages can be successfully adopted by farmers;
- v) bamboo rearing trays coated with water soluble 'Lac' (lacquer) were superior to uncoated trays or trays coated with the traditional cow dung in producing greater larval weight and lower disease incidence.

06.12.99 REELING SECTION, CSRTI, MYSORE

MR G N RAMASWAMY, Senior Research Officer, Reeling Section, described the background to the reeling process used at the section. Cocoons come from different laboratories at CSRTI and they are both mulberry and non-mulberry cocoons. About 90% of the mulberry cocoons are multivoltine and 10% are bivoltine. The silk standard is not of international grade so the World Bank and Japan have assisted in raising the quality. About 15,000 tonnes of raw silk are produced in India, but there is a demand for 25,000 tonnes, so 10,000 tonnes of raw silk are imported from China. Local consumption is 90% for saris. Hand looms are mainly used in India and these use a heavier silk, 28/30 denier (coarse) and 18/20 denier (medium) produced by multi x bivoltine silkworms. The 13/15 denier (fine) bi x bi cross silks are woven on power looms and used for making crepes and jacquard fabrics.

The physical character of multi-voltine silk is not as good as bivoltine. The multi-voltine cocoons have soft shells, a filament length of 800-1000m and 10-12 kg cocoons are required for 1 kg raw silk, compared with bivoltine with harder shells, a higher shell ratio, filament length of 1400-1600m and a renditta of 6-7. The quality of thread is assessed in terms of tenacity, elongation, neatness, cleanliness and evenness (see later).

In India, the commonly used processing of cocoons starts with stifling the pupa either using the sun or steam. Sun stifling takes many days, during which time pests and rain may damage the cocoons and the UV rays degrade and dull the silk. Steam stifling is used in Southern India. It takes half an hour, but this is not enough time to remove the 60% of moisture in the pupa. Electric oven drying for 5 hours is also required. The Japanese system keeps the cocoons stationary or moves them on a conveyor belt through a series of heated chambers from 100°C-50°C (not over 120°C). After stifling the cocoons can be stored on racks away from water as the sericin will absorb water. There are five types of reeling machines.

1. Chaka
2. Cottage basin
3. Multi-end
4. Semi-automatic
5. Automatic

The small reels are 7.5cm, from which the silk is reeled onto standard reels. The silk hank then is removed and can be sold at a silk exchange. A reeler who produces 10 kg silk/day would return 100,000 RS (\$4,000 AUD)/year.

The warp thread is the strongest. It is “doubled” and twisted. There are 200-800 twists per m. Steam will help hold the twist by softening the surrounding sericin. The higher quality silks have more twists, but there is a limit before it will break. Also twisting dulls the sheen of silk. The number of picks (weft threads)/cm and warp threads/cm differ.

There may be 6000-8000 warp threads in a width of 1 metre and each thread may be 150-1000m long. The warp threads are usually separated into groups before being wound onto the beam (roll). The beam is set up on the weaving machine with the warp threads each threaded through the loom gating. There are two sets of warp threads that move through each other to hold the weft thread in the weaving process. The weft thread is shot from side to side by the shuttle or pirn. These movements are done by hand in hand weaving but are mechanically driven in automatic machines. Following weaving, the fabric is degummed, bleached, weighed, dyed and printed and finished. Finishing may be for one or more of the following purposes: scrooping, crease resistance, flame retardance, oil/water repellence, ant-static, light stability, anti-microbial, anti-fungal or antimildew properties.

Tests applied to silk are:

- 13 denier measurement (weight in gms of 9 km of silk);
- 14 number of breaks per hour in winding the thread;
- 15 maximum deviation in 15 pieces;
- 16 a serigraph is used to measure tenacity and elongation:
 - tenacity is measured in g/denier
 - the filaments from 7-8 cocoons are placed on the machine the denier measured, and the weight needed to break that denier size is recorded as is the % elongation of the thread before it breaks;
- 17 cohesion is measured on a thread containing 7-8 filaments to find how many strokes it takes to break the sericin binding and separate the filaments;

- 18 neatness: absence of hairs on the surface of the thread;
- 19 cleanness: absence of dirt or leaf residue in the thread;
- 20 yield;
- 21 evenness: absence of variation in fibre diameter of the thread.

07.12.99 P4 BASIC SEED FARM, CSB, HASSAN

MR VEDAVYASA, Senior Research Assistant at the P4 Basic Seed Farm, Hassan, indicated that the farm exclusively breeds eight races of bivoltine silkworms. The new races bred are CSR2, 4, 5 for winter (August-February) production, which have 23-25% shell ratio; and CSR18,19 for summer (March-July) production, which have 21% shell ratio. The traditional bivoltine races, NB4D2 and NB18 are also maintained. 90% of silk production in Karnataka is by cross breeds utilising the male bivoltine crossed with a female multivoltine. Other seed farms keep the multivoltine stocks. This farm has four crops per year (May, August, November, February) and preserves layings in three different schedules: long term chilling (LTC) for 2-3 months, 4-5 months (120-150 days) and six months (175-210 days), to enable seed to be supplied to farmers throughout the year. Each batch is divided into three and preserved by one of the three schedules. The following methods are used to hatch the seed.

LTC: After warming these layings are treated with 1.1 SG HCl at 48°C for 5-6 minutes and they then hatch 11-12 days later.

4 – 6 mth: Warm at 15°C for 1 day, then increase to 25°C. No acid treatment is required.

No Storage: If seed is for immediate use without storage, the eggs are treated with 1.075SG HCl before 18-20 hours after laying. They hatch on the 11th day.

The pupa are cut out of the cocoons and males and females are selected. Twenty to forty beds of each race are reared and the best 3-5 beds are selected for breeding each generation. Quality is judged on pupation rate, single cocoon weight, single shell weight, and shell percentage. If beds 9, 11, and 13 are the best then the following matings occur F9 x M11, F11 x M13, F13 x M9. Males are preserved at 7-10°C and paired with females at 8-9am each day, and depaired at 12-1 pm. Either acid treatment of the layings occurs at 3-4pm or the seed is stored. The aim is to maintain the characteristics of the races constant not to improve them. Abnormals are removed but otherwise all males and females in a selected bed are mated. Stock is sent to P3 seed centres every 15 days.

08.12.99 SILKWORM PATHOLOGY, CSRTI, MYSORE

DR NADARAJU, Deputy Director, Silkworm Pathology, described the agents in four pathogenic groups that cause silkworm diseases:

- a) Protozoal: Common name “Pebrine”, caused by a microsporidian *Nosema bombycis* and strains N1K-2r, N1K-3h, N1K-4m of *Nosema* Sp. [Note that *Nosema* is also the cause of “Foul Brood” in bees]. Silkworms are infected by transovarian and horizontal transmission: Affected worms become flaccid (a general sign for all silkworm diseases) and fail to grow. The protozoan invades the muscles and most organs. It is detected as oval spores (1.5-2u x 3-4u). All moths after laying and suspect infected larvae are ground in a blender with 2ml 2% Ka OH for 2 minutes, filtered and the filtrate centrifuged. The precipitate is placed on slides and examined under a microscope. Any diseased batch of worms is burnt and any eggs of an infected moth are also burnt. This method is capable of controlling an outbreak and maintaining a low level of infection. A more rapid dipstick method of diagnosis is now available.

b) Viral: There are four viral diseases of silkworms, two by “occluded” or capsulated viruses (Nuclear and Cytoplasmic Polyhedrosis) and two by “non occluded” or non-capsulated viruses (Infectious Flacherie and Densonucleosis).

i) Nuclear Polyhedrosis (“Grasserie” or “Haluthonde”).

The agent is a baculovirus. The disease causes a shiny (instead of a dull) skin prior to moult and failure to moult. The haemolymph becomes turbid white due to the presence of large numbers of hexagonal or pentagonal polyhedra capsules containing the virus. Infection is by horizontal transmission from contaminated equipment. The virus can persist for up to 15 years. Good disinfection of rearing houses between batches with 0.3% slaked lime in addition to formalin fumigation will inactivate the virus. The bed disinfectant “vijetha” is used just after each moult for all disease agents.

ii) Cytoplasmic Polyhedrosis is not present in India

iii) Infectious Flacherie.

“Flacherie” is a syndrome caused by Infectious Flacherre virus together with one or more of densonucleosis virus, cytoplasmic polyhedrosis virus, streptococcal and staphylococcal bacteria and/or *Thatta roga*. Young affected larvae become lethargic and lose appetite. Later they become flaccid and have retarded growth. The cephalothoracic region becomes translucent. The midgut becomes turbid white due to accumulation of polyhedra and faeces may be white/black. The larvae ferment and smell foul. Spraying with 0.3% slaked lime in addition to formalin fumigation is recommended between batches and “vijetha” after moulting. Good control of temperature, humidity and leaf moisture is required to control the disease.

c) Bacterial: Bacterial diseases of silkworms (“Flacherie”) are usually only secondary to virus diseases. Several bacteria cause septicaemia (*Bacillus*, *Streptococcus* and *Staphylococcus*). Four bacteria attack the digestive system (*Streptococcus*, *Staphylococcus*, *E.coli* and *Proteus* and one produces toxaemia, *Bacillus thuringiensis*). Bacteria increase in poor environmental conditions such as high temperature, high humidity, poor ventilation, diseased leaves, improper feeding etc. All these diseases cause softening and putrefaction of the dead worms.

iv) Septicaemia. Bacteria penetrate into the haemolymph and multiply there. A typical symptom is loss of clasping power of the prolegs. The worms may vomit or have diarrhoea. On death the body becomes black or sometimes other colours such as yellow or brown. The infection is caused by physical damage to the worm so careful handling will prevent the infection. The affected worms are burnt or buried.

v) Bacterial diseases of the digestive tract. Bacteria multiply in the intestines and associated organs and the larvae lose control. They become sluggish and slow growing. The worms may vomit or have diarrhoea.

vi) Toxaemia (“Sotto”). The *Bacillus* organism secretes a toxin which is absorbed from the gut. The worm ceases to eat. The nervous system is affected by the toxin and the worm may show spasms or paralysis. Prevention is by avoiding swallowing the toxin, so rapid removal of other diseased worms is essential before the *Bacillus* grows in the decomposing body. Thorough clean out between batches is required to remove the agent.

d) Fungal: (“Muscardine”) diseases can be caused by over eight fungi: *Beauveria bassiana*, *aspergillus flavus*, *A. oryzae*, *A. taneri*, *Paecilomyces farinosus*, *Sporospora uvella*, *Metarrhizium anisopliae*. The obvious characteristic of this type of infection is mummification of the dead larvae which become hard and powdery white like sticks of chalk. Infection occurs through the skin. Infections of pupae and moths also occur. These infections are more common in winter and in the rainy season. Transmission is by wind borne dispersion of the fruiting bodies (conidia) that cover the surface of the infected worm. General hygiene will reduce the incidence of these organisms. Because *Aspergillus spp* are fairly resistant, 3% formalin is required for effective fumigation. Dust the moulted worms with slaked lime to reduce surface moisture. Specifically, dust 1-2% Dithane M45 in slaked lime or captan in kaolin on the worms after each moult or use formalin chaff.

GENETIC TOLERANCE: Breeding for resistance or tolerance is another approach to decreasing the incidence of those diseases. Because Densonucleosis susceptibility/resistance is controlled by a single gene, it has been found possible to select a tolerant line of silkworms which are now being tested for tolerance to other infectious agents. Tolerance to all the other agents is polygenetic and therefore not as amenable to selection. Inactivated attenuated vaccines are also being developed by tissue culture but control of administration is a potential problem. Spraying the vaccine on leaves is thought to be the best method for oral inoculation.

QUARANTINE: These disease agents probably do not occur in Australia. They can be prevented from being released with imported germplasm in Australia by quarantine and testing. Legally imported stock (eggs) can be tested and guaranteed free of infection by CSRTI, but they can also be tested in Australia for at least one generation while in quarantine.

EXTENSION: All silkworm farmers in India are known to the Extension Service and either the farmer calls the Extension Staff if he has a problem or the Extension Officer visits the farm on a regular basis and checks for disease and demonstrates hygiene methods.

RESEARCH: In addition to the genetic tolerance and vaccine research, present research is aimed at:

- vii) Early diagnosis of disease, especially in young age (chawki) larvae.
- viii) Finding natural “eco-friendly” plant products that prevent or treat these diseases. Staff have identified eight plants with potential to provide natural chemicals effective against these diseases.
- ix) Finding disinfection methods (such as ClO₂) that can be substituted for formalin, because most rearing houses are not air tight and cannot be fumigated.

21.12.99 ENGINEERING SECTION, CSRTI, MYSORE

DR SATISH VERMA, Executive Engineer, is responsible for the maintenance of the farm equipment at CSRTI and also for developing improvements in buildings, equipment and farm machinery as required by local farmers.

Buildings: The building protects the silkworms from the elements. In Karnataka 80-90% of the time the temperature is over 25°C, so temperature must be reduced. The energy bill is the same to reduce temperature as to heat, however a heater is much cheaper to purchase (say \$20) compared to an air conditioner cooler (say \$1000).

Mulberry Planting: Mulberry being a dicotyledon is deep rooted. Mulberries can be propagated by seed or by cuttings. Seeds are used in the northern states (Jammu/Kashmir, Uttar Pradesh and Delhi) where they develop 8-10m rooting systems and are allowed to grow into trees in a forest or beside the road. There is no cultivation practiced and there is a lot of variability. There is no seed selection practiced for mulberry in India. In the southern states of India (Karnataka, Tamil Nadu

and Andhra Pradesh) the genetic code of mulberry is maintained by growing shoots. These can be directly planted in the field or they can be planted in a nursery and the ensuing saplings can be transplanted into the field. The saplings are usually prepared by hand cutting with a knife. A 1 acre plot requiring 10,000 plants at a spacing of 3ft x 3ft (1m x 1m) would need 6-7 man days of labour because one man can cut 1500-2000 cuttings per day. It is not very interesting work and young people do not do a good job so it is given to older people. The Engineering Section has constructed a circular saw and stand that will cut 1500-2000 cuttings per hour. Therefore the cuttings for one acre can be done in one day. Cuttings planted in nursery beds require only 15cm of fine soil. A rotavator has been constructed that produces a fine tilth and levels the field. To plant cuttings in "pits" (not advocated now) or at the side of the road as in Bangladesh and Russia a posthole digging machine has been made to give plenty of depth for the hole. To plant cuttings or saplings in the field and allow for the deep root growth, a subsoiler and chisel plough have been manufactured to cultivate 1-1.5m below the surface. Ploughing is done after the first rain to make it easier and the ground is then left for 2-3 months for the trench to fill with water and micro organisms to develop. The saplings/cuttings are planted in the trench at the end of the rainy season. Deep ploughing is repeated in 2-3 years. It is a good water harvesting system and provides good soil drainage and decreases water logging. The cuttings could be planted mechanically using a machine like a sugar cane planter or semi-automatically using a machine like a potato planter.

Cultivation of mulberry garden: Cultivation used to be done using bullocks but most farmer use small tractors now. Cultivation between the rows of mulberries is required to control weeds, break up the soil to improve aeration and water penetration and to destroy parasites that pupate in the soil. To avoid damaging new shoots, cultivation is done within three weeks of pruning the mulberry trees. The Engineering Section has taken an existing tractor power unit and changed the spacing of the plants to accommodate the 3ft (1m) width. Previously the plants were spaced 3' x 2' or 3'x3' which did not allow for the cultivator, so every second row has been moved 1ft so that the row spacings are now 4', 2', 4', 2' etc allowing the unit to cultivate one side of each row. A toolbar can carry tines to also cultivate between the 2ft space. Mulberry are very hardy plants and can take quite a lot of damage and still keep growing. After several cuttings of shoots the crown of the main stem becomes large and knotted and has to be removed. A circular saw attachment has been made to operate off the tractor power unit and cut the crown off the trunk at ground level. The variety of mulberry makes a difference to ease of access to the rows. Variety S36 is a good yielder but the shoots have a tendency to grow laterally and cover the tilling area, whereas variety V1 has very strong erect stems and leaves the tilling area free enabling better access for harvesting and inspection. The Japanese have mechanised harvesters which either cut and leave the shoots on one side of the row to be collected later, or with a loading machine incorporated to collect the shoots at the same time.

Mechanisation in the rearing house: Power spray units are promoted for disinfection of rearing houses. The units can spray 2% formalin, but formalin is corrosive and unpleasant to work with. Chlorine dioxide is non-corrosive, is not unpleasant and the room does not have to be sealed. A mechanical dusting machine, run from the mains or battery powered, has been made to decrease the unpleasant dust in the room that occurs with bag shaking. Rotary mountages for cocoon spinning have been introduced from Japan and their use is spreading. The Engineering Section has made a cocoon deflossing machine, simplified for easy maintenance, from a Japanese design.

13.12.99 SERICULTURE EXTENSION METHODS, CSRTI, MYSORE

MR M RAVEENDRA, Senior Research Assistant, Training Division, discussed the back ground to sericulture extension in India. CSRTI has an extension function, but the Central Food Technology Research Institute does not. They have a marketing function. The difference is that they offer commercial exploitation developments to a few companies. Because sericulture is undertaken by a large number of small farmer units, the government needs to be involved in assisting farmers to be

more efficient and more productive so that the farmer's life is easier and he has a better income. The country needs the development also to provide greater benefit to the community and to try to earn export income. Farmers do not necessarily see the reasons why they should change what they are doing, because on the whole they are satisfied if their work is sufficient to supply their family's needs. Farmers see themselves as undertaking a profession and following the tradition of their parents, so they are reluctant to change. There is validity in this because they accept that farmers' crops and income fluctuate, but they spread the risk of loss by multicropping and mixed farming. Monoculture has greater risks and they don't want to be vulnerable to a failure of income. They are not interested in greater profits so they rarely consider alternatives to the traditional way of doing things. There are several examples of this in India eg. the traditional breed of cow has a low milk yield, but the farmers do not like crossbred cows. They have a great affinity to their own breeds. It is the same with silkworms. They like yellow cocoons and they feel they must do things the way their parents taught them eg. chopping leaves. Often their mulberry plants have been producing leaves for 30 years so they do not feel right in uprooting them for a new variety. Extension people have to firstly understand the thinking of farmers, and then convert the message they want to give into a proper form acceptable by farmers. The most effective method of getting a message across to farmers is not to say how good the new method is, but to use an "unlearning process". In this process the extension worker challenges the farmer, by saying that his present methods are wrong. The extension worker then waits for the farmer to challenge him to say how he would do it better. Farmers can be divided according to attitude into five groups.

1. Innovators who take risks and may lose their investments. They are happy to introduce new ideas because they hope for a better income. They become very close to the extension workers and get a lot of benefit thereby.
2. Early adopters. By seeing new ideas in action they believe.
3. Early majority
4. Late majority.
5. "Laggards", the last adapters.

New farmers will adopt new practices more readily because they do not have any traditional methods to worry about. It is less necessary to follow up new farmers than traditional farmers to make sure they are sticking to a program. Everyone has a goal. Extension workers try to get the individual's goal to match the national goal. Unfortunately extension workers are usually not whole farm people but come from specialist areas such as sericulture or sugar cane, so the goals they have is to get the whole farm concentrating on their specialisation. The farmer may have several extension people from different areas advising him and he won't follow any of them because he is confused or the advice is conflicting.

There are different types of silk traditionally produced in different areas.

1. Mysore silk: It was hand loomed but is now both hand and power loomed. It was a finer silk previously but the method of making the fine silk has been lost.
2. Kanchipuram (near Madras): This is a heavy silk still handwoven. It takes 15 days to weave 6 metres and so is very expensive. It is woven in three strips. The two edge strips are woven separately and interlocked with the centre weaving.
3. Banares: May still be hand loomed.
4. Kashmir: Hand loomed
5. Damardium

Indian people recognize each type of silk fabric and are proud of their own type of silk, so the demand for traditional silk types is very strong. Therefore the national goal of improving silk

quality for the international market really only applies to the amount of silk that would be exported which is virtually nil at present.

Appendix 2: Failure of Previous Attempts at Establishing a Sericulture Industry in Australia

Mulberry trees were introduced into Australia in the early days of European settlement as feature, shade and fruit trees as well as for silkworm food. John Macarthur, the father of the sheep industry in Australia, planted some specimens in his garden at Parramatta in 1796 and some of these survived into the 20th century.

The Australian Agricultural Company, formed in England in 1824, introduced mulberry into New South Wales for the purpose of commencing a silk industry, but the project did not proceed beyond the original plantings.

Surgeon R.C. Jameson in 1842 strongly advocated the establishment of an Australian silk industry employing the labour of “young persons of either sex”. T. H. Braim (1846) reported that mulberry was suited to the soil in New South Wales and that, because silk production had been tried successfully on a small scale, it should be produced on a large scale.

In 1848, Mr Beuzeville attempted to establish a silk production farm at Eastwood near Sydney, but the venture failed because of lack of funds and poor mulberry.

In 1849 Mrs Bladen Neill established the Victorian Ladies’ Silk Association, a joint stock company, and was granted 1000 acres of land at Mount Alexander near Castlemaine by the Victorian Government. This project failed because of the unsuitability of the land. Mrs Neill also established a silkworm farm on her own land at Corowa, NSW, but the dust from the road killed her silkworms.

Little interest in silkworms was reported in the 1850’s due to pre-occupation with gold discoveries, but around 1862, Charles Brady of Manly, NSW, began experiments to breed a more resistant strain of silkworm more suited to Australian conditions. This was the time of devastation and death of the silk industries in Europe due to pebrine disease. Brady managed to import and maintain healthy strains of silkworms on his property at the Tweed River, NSW, but the project was not continued because he was not able to gain government support to expand the industry. Both Brady and Neill continued to promote the establishment of a silk industry in Australia throughout this period.

In 1870, William Coote commenced silk farming at Rocky Waterholes (Salisbury/Rocklea) in Brisbane and in recognition of his efforts was given a grant of land in 1875 valued at 680 pounds by the Queensland Government. He imported improved strains of silkworms from Italy in 1875, but they were diseased (with “the black disease” – probably pebrine) which eventually led to the loss of all of his silkworms by 1877 (Coote, 1877).

A similar large silkworm venture commenced by Affleck and Howard at Albury, NSW, in 1875 also failed after eight years due to the death of all stock from pebrine disease introduced from Europe.

In 1880, some Italians who were skilled in silk production formed the New Italy Settlement in NSW. In 1891, Sir Henry Parkes, the Colonial Secretary, agreed to the appointment of Reginald Champ as overseer of the first official attempt to establish commercial sericulture. There appeared to have been encouraging results early, but Champ lacked sufficient knowledge or ability and the scheme gradually failed.

In 1893, a publication titled “Sericulture; or silkworms and how to rear them” written by R. W. McCulloch, was published by the Department of Agriculture in Brisbane, because of “the numerous applications received for silkworm eggs and information on the subject”.

In 1894, an article giving full instructions for sericulture was published in the Agricultural Gazette of New South Wales, and instruction by Charles Brady was advertised to take place at Booral plantation.

Several people were producing silk yarn at this time, entering it into exhibitions and winning prizes eg. George Thorne of Rose Bay, Sydney and later at Castle Hill won several medals at overseas exhibitions.

In the 1890's, Louis Frederick Wurm pioneered silk production in South Australia. He was awarded 100 pounds by the South Australian government for producing the first 100 pounds of silk in the colony. He won a number of medals for his silk in Europe and America. He was forced to move to Adelaide because of ill health and the enterprise ceased because the area was not as suited to silkworms. Nevertheless he showed that silkworms could be reared in less time in Australia than in Europe.

In 1911, a Silk Culture Society was formed in NSW to encourage a revival of interest in sericulture. In 1921 the Society was given mulberry cuttings from the Sydney Botanic Gardens, and a reeling machine and silkworms eggs from India by the NSW Department of Agriculture. The Society was making its own reeling machines by 1927.

Interest in growing silkworms and harvesting silk has continued from that time to the present. For example, Olive Aslett published a comprehensive booklet titled "Silkworms" in 1945.

This review of early attempts to establish a silk industry in Australia shows that projects failed because of technical reasons such as lack of knowledge and disease. None of them failed because of poor quality product. In fact, it appears that the silk produced compared favourably with overseas silk. Now that so much more is known about the techniques of sericulture and moriculture, it may be an opportune time to again attempt to establish a commercial silk industry in Australia.

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