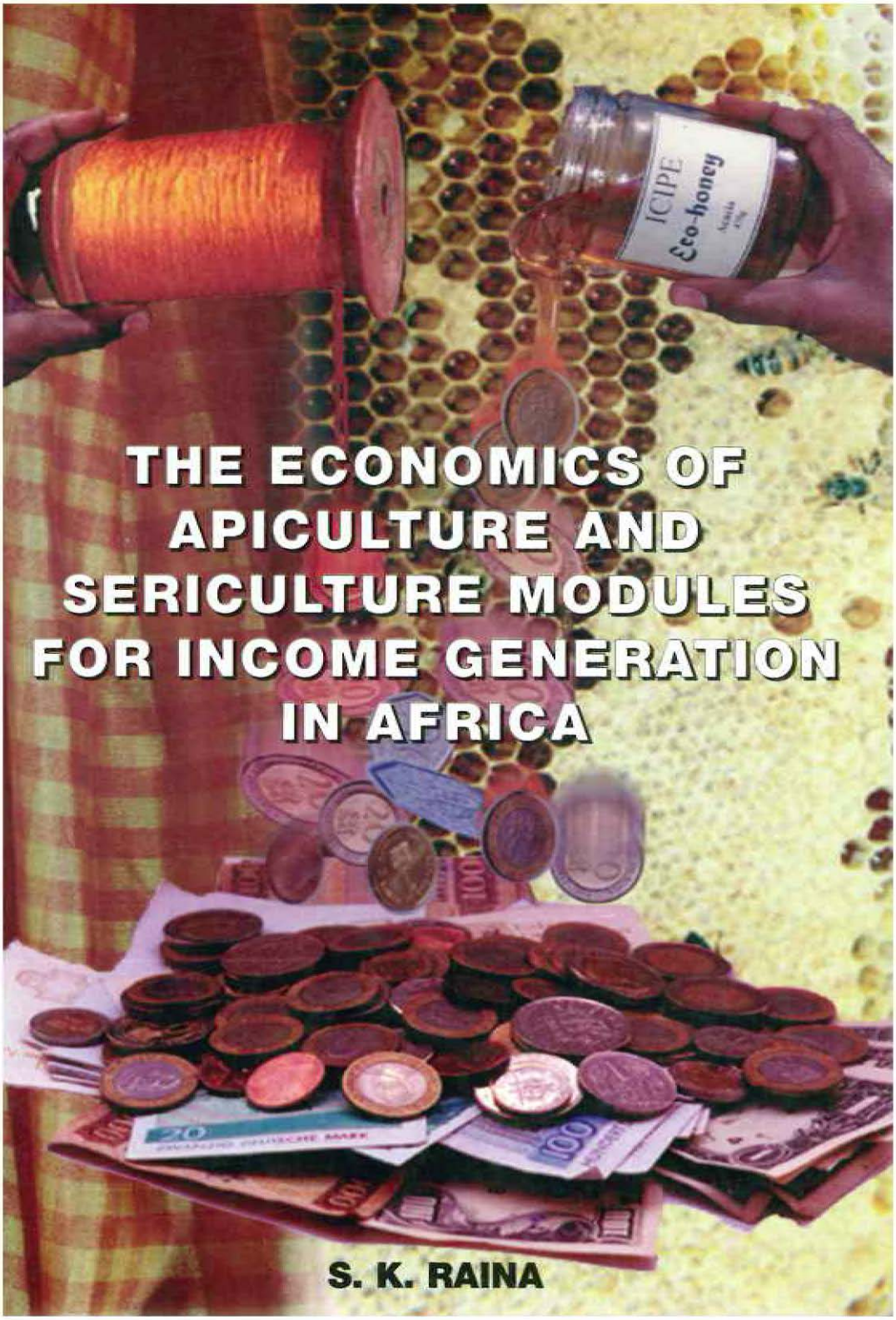

THE ECONOMICS OF APICULTURE AND SERICULTURE MODULES FOR INCOME GENERATION IN AFRICA

S. K. RAINA

THE ECONOMICS OF APICULTURE AND SERICULTURE MODULES FOR INCOME GENERATION IN AFRICA

by

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TABLE OF CONTENTS

		Page
Abbreviations		i
List of tables		ii
List of figures		iv
Acknowledgements		1
Contributing Authors and Specialists		3
Foreword		5
Prologue		7
Introduction		11
Chapter I	Basis of apicultural and sericultural economics	13
Chapter II	Economics of apiculture	19
Chapter III	Economics of mulberry silk farming	35
Chapter IV	Economics of African wild silk farming	57
Chapter V	Marketing of apicultural and sericultural products	63
References		77
Addresses of sericultural and apicultural equipment and material suppliers		79
Addresses of networking sericultural and apicultural institutes		81

ABBREVIATIONS AND DEFINITIONS

ICIPE	International Centre of Insect Physiology and Ecology
IFAD	International Fund for Agricultural Development
CAAS	Chinese Agricultural Academy of Sciences
Plant	Industrial production unit
Firm	Unit of ownership and control
Industry	All firms concerned with a particular line of production
FC	Fixed Cost
VC	Variable Cost
TC	Total Cost
AC	Average Cost
Q	Output
AFC	Average Fixed Cost
AVC	Average Variable Cost
ATC	Average Total Cost
MC	Marginal Cost
(TC	Change in Total Cost
(Q	Change in Output
AIC	Average Incremental Cost
P	Price
MPP	Marginal physical product
APP	Average physical product
MRP	Marginal revenue product
DFLs	Disease free egg layings
Nuc	Nucleus, a compact colony of bees
NGO	Non-Government Organization
NARS	National Agriculture Research System

LIST OF TABLES

Table 1. The marginal cost schedule

Table 2. The marginal physical product based on honey production and packaging module

Table 3. The marginal revenue product (MRP) of honey sale in perfect condition

Table 4. Cost to establish honey processing and packaging laboratory

Table 5. The cost schedule of honey processing and packaging per annum

Table 6. Optimal profit output

Table 7. The cost structure of an apiary

Table 8. The marginal physical product for first year and every season onwards for 4 established Langstroth hives

Table 9. Cost to produce honey per season (6 months) using 4 established hives capacity

Table 10. Optimal profit output of honey production from 4 established hives per season

Table 11: Water content, proline and acid in honey; comparison of Eastern and Rift Valley provinces (n = 62)

Table 12. Indicators of overheating; comparison between Eastern and Rift Valley Provinces

Table 13. Sugar content; comparison of Eastern and Rift valley Provinces

Table 14: Major costs and components of a honey quality control laboratory

Table 15: Cost of biochemical analysis

Table 16. Cost structure for queen-rearing and colony multiplication

Table 17. The best profit output of Queen rearing from two strong hives per honey flow season (approximately 3 months)

Table 18. The cost to equip an insemination laboratory for queen breeding in 1997

Table 19. Grading of cocoons

Table 20. Cost to establish a one acre (0.4 hectare) mulberry plantation

Table 21. Cost of rearing house and equipment

Table 22. Production of cocoons by bivoltine hybrids during first year

Table 23. Production of cocoons in the second and third year (Naro Moru and Laikipia)

Table 24. The marginal physical product (MPP) for a one acre plantation (year 1)

Table 25. MPP for second and subsequent years for a single farm family in Nyeri/ Nanyuki, Kenya

Table 26. Cost structure of the silk cocoon production per acre per annum for a single farm family

Table 27. The marginal revenue product (MRP) per acre of a single farm family

Table 28. Profit output of the cocoon production per acre per annum (single farm family)

Table 29. The expenditure for post-cocoon operations (Kenya)

Table 30. Economics of post cocoon operation units based on ICIPE apprenticeship stipend, single unit set-up (US $)

Table 31. Economics of post-cocoon operation units based on single industrial setup (US $)

Table 32. Economics of post-cocoon operation units (US $)

Table 33. The marginal physical product (MPP) for post cocoon operation based on the output from a power loom

Table 34. Cost structure of silk fabric production per month on a power loom

Table 35. The best profit output for a single family in a silk cloth weaving per month using one power loom (US $)

Table 36. Marginal physical product (MPP) for post-cocoon operation (based on handloom-weaving) per month

Table 37. Cost structure of silk fabric production per month

Table 38. The best profit output from handloom silk fabric per month is calculated (US $)

Table 39. Initial expenditure on design and screen printing unit

Table 40. Best profit output of screen-printed cloth per month

Table 41. Weight and size of cocoons of Gonometa sp. and Argema mimosae (Means SD)

Table 42. Comparison of cocoon weight, and cocoon shell weight and shell ratio % in Gonometa sp.

Table 43. Calendar of activities for farming of Gonometa sp. in Mwingi district of Kenya

Table 44. Calculated income in US dollars based on the data of one seasons per year (labour cost included)

Table 45. Calculated income in US dollars based on the data of one season per year (labour cost not included as a family enterprise)

Table 46. The marginal physical product for cocoon production

Table 47. Marginal Revenue Product for cocoon production (US $)

Table 48. Cost structure of the wild silk farm

Table 49. Optimal profit from the wild silk farm (US $)

Table 50. ICIPE standard Price for purchase of honey from beekeepers

Table 51. Beekeepers Production in the field in 1997 – 2000

Table 52. Cost of silk cocoons based on grades

Table 53. Production of silk cocoon, fibre and finished products and development of marketing outlet for sericulture farmers in East Africa.

Table 54 Farmers stock in hand (silk cocoon, fibre and fabric)

LIST OF FIGURES

Fig.1. Average Total Cost Curve

Fig.2a. Total cost in silk cloth output

Fig.2b. Marginal cost in silk cloth output

Fig.3. The marginal revenue product curve.

Fig.4. Types of beehives:

a. traditional log wood hive

b. top bar

c. Langstroth hive

Fig 5. Floral type in Mwingi, Kenya. (Inset) honeybee, *Apis mellifera scuttelata* (banded) and *A.m monticola* (black)

Fig. 6. Rectangular frame with honey-comb from Langstroth hive

Fig. 7 HPLC chomatogram of a honey sample

Fig. 8. Honey analysis at a quality control laboratory

Fig. 9. Queen cell frame after reception of grafted larvae in apiary

Fig. 10. Comparison of queen cell reception by worker bees in various seasons in a year in:

a. queen-right colonies

b. queenless colonies

Fig. 11. Insemination of a honeybee queen with specific drone semen

Fig. 12. Sericulture:

a. mulberry plantation, *morus alba*

b. egg card, B*ombyx mori*

c. fifth instar larvae of silkworm, *Bombyx mori*

d. silk cocoons (bivoltine)

Fig. 13. Mounted cocoons sorted for reeling

Fig. 14. Silk reeling and re-reeling machine

Fig. 15. Winding machine to transfer raw silk fibre to bobbins

Fig. 16. Single and double twisting machine

Fig. 17. Doubling single twisted yarn

Fig. 18. Degummed, bleached and dyed silk yarn and bobbins for the preparation of warp

Fig. 19. Creel of bobbins for warp preparation

Fig. 20. Weaving silk cloth on a hand loom

Fig. 21. Unfolding cloth from power loom beam

Fig. 22. Screen printing of silk cloth

Fig. 23. *Argema mimosae* on the lower leaf surface of *Sclerocarya birrea*

Fig. 24. *Gonometa sp.* female moth laying an egg on the shell

Fig. 25. Fifth instar larvae of *Argema mimosae*

Fig. 26. Fifth instar larvae of *Gonometa sp.*

Fig. 27. *Gonometa sp.* cocoon showing damage by parasitoids

a. Hymenoptera

b. Diptera

Fig. 28. Silk fibre from *Gonometa sp.*

Fig. 29. Local packaging and marketing of honey in Baringo

Fig. 30. Collection of honeycomb from beekeepers in Mwingi district

Fig. 31. Training of farmers from Mwingi district on honey harvesting, processing, Wax candle making and packaging at ICIPE

Fig. 32. Honey processing and packaging laboratory

Fig. 33. Marketing strategy for beekeeping; ICIPE model

Fig. 34 Marketing strategy for mulberry silk farming; ICIPE model.

Fig. 35. Marketing strategy for wild silkmoth farming; ICIPE model

Fig. 36 Sericulture farmers watch a silk reeling demonstration

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THE ECONOMICS OF APICULTURE AND SERICULTURE MODULES FOR INCOME GENERATION IN AFRICA

FOREWORD

The root cause of under-development is poverty. In Africa, during the last three decades, there has been a decrease in production of traditional export crops, as well as the unsustainable exploitation of indigenous forests and agricultural land. Insects are notorious pests and vectors of disease. Their potential benefit to the environment is often overlooked. Among the many activities that might assist the poor to escape their vicious cycle of poverty, are the raising of bees and silkworms in the practice of apiculture and sericulture.

The initial wealth of Asian countries originated with the silk trade. Beekeeping was also an important component of the early Asian economy. Currently, Africa is a known producer of honey, but the yield and quality of the honey produced is low. Increasing the profitability of beekeeping would require adapting apicultural techniques for the African culture and environment. With silk production however, the continent has little experience in sericulture, and the technology needs to be introduced at a basic level.

The profitability of any enterprise is the key to its success. To this end, the evaluation of marketing strategies, product quality enhancement, and the sustainability of production, should be addressed. At the moment, sericulture and apiculture are two new industries being developed in Africa. The technologies will enable small landholders to increase their economic well being through self-reliance, and not fleeting financial aid.

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PROLOGUE

The international environment which provides financial assistance has rapidly changed and donors are now emphasising goals which produce tangible results. In the North there is a continuing decline in government aid, and in the South it is a time of budget constraints and a shrinking of government services all of which affects rural areas. There is a world-wide shift towards privatisation, market-driven economies, and price liberalisation within which official development aid must operate. Finally, there is an undeniable link between poverty and environmental degradation where limited resources are being consumed with no prospect for renewal.

Development agencies have refocused their rural development policies in view of the dual need to combat rural poverty while maintaining natural resources. To this end, there has been increased co-operation between international agencies and the private sector. Through its apiculture and sericulture programmes ICIPE has worked with the rural small-holder to improve beekeeping and silk cocoon producing techniques, resulting in product marketability, and income generation for the resource-poor farmer. Since these agricultural practices conserve natural resources, these activities serve to conserve and protect the environment.

The role international organisations, local governments, and the private sector, play in providing an efficient and responsive infrastructure needs to be redefined in view of past shortcomings and dawning opportunities. The challenge is to determine where responsibility for service provision lies, i.e. within the government, public sector, international organisations, or private sector (profit or non profit making organisations).

In Africa a recent survey indicated that common problems in implementing sericulture and apiculture technologies include: unclear goals; lack of training, lack of managerial autonomy and accountability, and financial constraints (Raina 1998). Five approaches were suggested as a means to resolve these problems. To identify practical difficulties, a Sericulture and Apiculture Network (ICIPESANET) has been established which would serve as an interface between farmers, international experts, and country partners (NGOs and NARS). These concerned partners would study the production system, socio-economic profiles, resource endowments, biotic and abiotic constraints, the indigenous knowledge base and technological needs of the rural farmer.

Using this information appropriate sericultural and apicultural technology packages would be specifically designed for rural communities. The farmer would be responsible for all operations pertaining to their micro-enterprise. As a business financial incentives may help improve efficiency and accountability, and the goal would be financial autonomy and maximal profitability.

Application of Commercial Principles of Apiculture and Sericulture

In the absence of effective competition applying commercial principles is difficult and regulations must be applied to establish accountability. However, a restructuring of a business or industry to maximise competition will ease the regulatory burden. To reform the current business environment additional financial investment is required which would be used to financially support a growing industry. The infrastructure would be based on

commercial principles and regulated by competition in the private sector. The growth of the industry would be monitored and influenced by stakeholders and users. To this end, ICIPE in the early stages, would provide support through research development, financing, and assisting with operations and maintenance.

The private sector's capacity and willingness to assemble the resources needed to supply services in the construction, financing and operation of sericulture and apiculture in the rural sector differs in different regions of the world. In low-income East African countries, such as Kenya and Uganda, technical capability, the enabling environment, and private sector interest is typically low. Larger developing countries, such as India, have a greater technical capacity and a higher private sector interest (due to population size). In former socialist economies that are currently in transition, such as Russia, the technical capability is high, but an enabling environment for market activity is just emerging. In mid-income countries such as China, Mexico and Brazil, which are reforming their economies, the technical and managerial capabilities are high, and the enabling environment is reasonably well established.

The success of introducing sericulture and apiculture in these countries will be influenced by the economic climate in these countries. In most African, Latin American or South east Asian countries, where the economies are uncertain or evolving, it may be easier to regulate and financially assist private businesses through contractual agreements and regulatory governmental agencies or NGOs. This arrangement puts less private capital at risk and would be more stable in the long run as ownership would not change. These practices may attract private investors for sericultural and apicultural expansion in the developing and under developed countries.

Implementing reforms in sericulture and apiculture is facilitated if donors assist countries in strengthening their institutional capacity. Augmenting institutional capacity involves formulating appropriate policies and putting in place mechanisms for policy implementation, creating regulatory frameworks and strengthening human resources. This will create a positive enabling environment for the efficient and responsive delivery of sericulture and apiculture products in the market on a sustainable basis.

Countries can acquire the necessary knowledge, skills and financial resources for implementing sericulture and apiculture technologies from "outside", but commitment to reform must occur at "home". The effect of these improvements would increase the standard of living of subsistence farmers in developing countries.

Africa faces many challenges during the next 25 years. In this part of world foreigners have had the most influence on development policy and there exists a great deal of uncertainty and confusion about which strategies will work. The future prosperity of Africa depends on political stability, sustainable growth in agricultural production, reduction of population growth, and the protection of natural resources. Success in these endeavours requires policy-makers to foster the right institutional, infrastructural and financial environment for private sector growth.

Prosperous sericulture and apiculture micro-enterprises require improved profit oriented interventions. Through the transfer of knowledge and training. ICIPE is providing base support for these practices in East Africa. To evaluate the impact of these endeavours, surveys need to be conducted to determine how beekeeping and silkmoth rearing have

affected the standard of living of the resource-poor farmer. The surveys will identify problem areas and assist scientists in adapting economic and agricultural practices that will benefit the rural farmer and increase income generation in a sustainable manner. This is the tangible goal of ICIPE's apiculture and sericulture programs.

This book emerged in response to questions from African farmers about the benefits of raising bees and silkmoths for profit. For the last four years we have been training rural farmers throughout East Africa in the practice of apiculture and sericulture. The economic returns of these endeavours are now being realised. We have studied the financial aspects of these practices and designed an economic approach that will maximise the production and marketing of honey and silk in East Africa.

The book is divided into five main chapters.

The first chapter explains the basis of apiculture and sericulture economics.

The second chapter highlights apiculture methodology and the establishment of an apiary for the production of high quality honey and the rearing of queen bees in East Africa. A cost-assessment of the technology is shown.

The third chapter deals with sericulture and the technology involved to produce raw silk from domesticated silkmoth cocoons. A cost analysis of mulberry and silkworm rearing for the small landholder and the cost of producing silk cloth is provided.

In the fourth chapter, methods of wild silkmoth farming are discussed, as well as the means to achieve the highest profits from the practice.

In the fifth chapter, the strategy for effectively marketing honey, beehive products, and silk, are evaluated using both laboratory and field data. Controllable and non-controllable variables are considered in developing an economic strategy suitable for rural Africa.

We hope this book will demonstrate the benefits of employing sericulture and apiculture technologies to generate income and enhance the welfare of African households.

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October 2000

THE ECONOMICS OF APICULTURE AND SERICULTURE MODULES FOR INCOME GENERATION IN AFRICA

INTRODUCTION

Africa's wealth of insects yield many useful products. Currently Africans face enormous challenges in both conserving their biological heritage and improving their standard of living. With increased globalisation of the economy and limited environmental resources, it is imperative for African nations to collaborate with each other and to discover methods of adapting natural resources to human needs. Africans can no longer rely on the traditions that once clearly defined their role and position in their culture.

To improve and increase their economic status Africans need to adopt appropriate technologies that the West and The East have developed. The International Centre of Insect Physiology and Ecology (ICIPE), based in Kenya, East Africa, has introduced modern technologies that utilise honey bees (apiculture) and silkmoths (sericulture) as commercial insects. The improved management of these species and their products will generate income and ensure long term sustainability of natural resources in Africa.

In addition to their normal farming activities apiculture and sericulture technologies can be employed by resource-poor farmers. These practices provide attractive options for rural employment and income generation in harsh agro-ecosystems where food production is marginal and risk of crop failure is high. Farming systems using these technologies lend themselves to the conservation of natural resources, as resource management is an intrinsic part of the production technology.

Apiculture is a traditional occupation in most African communities. However, out-dated methods of harvesting honey greatly impair the economic return. ICIPE has developed improved beekeeping methods that have resulted in decreased African honeybee aggressiveness, improved queen-rearing, enhanced honey yield and quality, and the optimal production of other valuable hive products.

Most honey producing regions are in the tropics, and subtropics where nectar and pollen are available and largely under utilised. Beekeeping in Africa has the advantage of being a relatively inexpensive practice in comparison to other agriculture activities. Bees produce highly marketable products such as honey, wax, royal jelly, pollen, bee venom, and propolis. In addition, bees increase the yield of many tropical crops through increased bee pollination. In regions where food production is unpredictable, apiculture should improve the nutritional status of the rural poor and generate much needed income.

Sericulture, or the rearing of silkworms, is a new occupation for most Africans. Silk fibres can be harvested from both domesticated and wild silkmoths. In the indigenous forests in East Africa the biodiversity of wild silkmoths is deteriorating along with their habitat. Sericulture techniques appropriate for Africa will assist in conserving the wild silkmoth and its environment.

The rearing of the domesticated silkworm, which feeds on mulberry, is more profitable than growing most cash crops. Economic returns to farmers are more frequent than other crop production systems, since four to five silkworm cocoon crops can be harvested annually. Moreover, soil preparation is minimal as established mulberry plants live and produce luxuriant leaves for at least ten years.

The introduction of participatory agro-based sericulture and apiculture technologies offers the resource-poor farming community a means to better utilise locally available resources and improve food and fibre production. The successful rearing of bees and silkmoths in the rural community was achieved by shifting laboratory based technology to the field. On-site training and problem solving further led to the successful and profitable practice of sericulture and apiculture.

An interdisciplinary approach was used to study the production and marketing of apicultural and sericultural products. In Africa, the economic system is mixed, in that both the public (government) and private sector coexist and function together. The overriding economic consideration is to find a production and marketing strategy that elicits maximum profit at minimum cost. The successful marketing of a commodity depends upon supply and demand (product planning), product pricing, place of distribution, and promotion.

In this book, apiculture and sericulture practices throughout Kenya were used as economic case studies to determine the factors influencing production and marketing, which in turn, influence economic profitability. The results in this book focus on the actual cost of processing products, such as honey and silk, based on ICIPE's set up in Kenya. The data for marketing research was collected from selected farmers' fields in Kenya and the labour costs used the Government of Kenya and ICIPE wage rates, wherever applicable. Based on the actual production data, the marketing strategy for the sale of honey and silk was designed for the farmers as well as for the national and export market. Strategic models were designed to promote the economic sustainability of silk farmers and beekeepers.

CHAPTER I

THE BASIS OF APICULTURAL AND SERICULUTURAL ECONOMICS

S.K. Raina and D.M. Kimbu

To turn a profit from a commodity in the long term, money must be spent in the short term. In the initial economic outlay, there are both fixed and variable costs. Fixed costs (FC), which include the cost of building and machinery, do not change with output in the short run. These costs remain constant whether the business is producing a profit or not. Variable costs (VC) vary with output. As a firm produces more, it requires more labour, raw material, power, etc. The total cost (TC) of a product is the sum of the fixed and variable costs, i.e.:

$$TC = FC + VC$$

The total cost always rises with output. The variable cost always rises more rapidly at higher levels of output. It is in the interest of the firm to stay in production in the long run, in order to recover variable costs (Beardshaw 1996).

For apiculture and sericulture the output of product can be measured in module units. In apiculture, a module unit is the amount of honey produced by a single beehive in a season, or the number of bottles of honey produced in given period of time. In sericulture, a module unit is the amount of silk cocoons or silk cloth produced in given period of time. To find the initial cost required to produce a unit product, an average cost (AC) is determined:

$$AC = \frac{\text{Total Cost}}{\text{Output}} = \frac{TC}{Q}$$

Average cost can be divided into fixed costs and variable costs as follows:

$$\text{Average fixed cost (AFC)} = \frac{\text{Fixed Cost}}{\text{Output}} - \frac{FC}{}$$

$$\text{Average variable costs (AVC)} = \frac{\text{Variable Costs}}{\text{Output}} = \frac{VC}{Q}$$

The average fixed cost declines continuously in the short term as output increases. For example, the cost of machinery is recovered from the output. Whether the average variable cost increases or decreases, depends upon the rate at which the total cost increases. The average total cost is determined by the sum of the average fixed and variable costs, or by dividing total cost by output:

$$ATC = AFC + AVC = \frac{TC}{Q}$$

$$\text{Average Total Cost} = \text{Average Fixed Cost} + \text{Average Variable Cost} = \frac{\text{Total Cost}}{\text{Output}}$$

As long as the price of the product is higher than the average variable cost, the firm will make a profit. The average cost curve is U-shaped in the short run because of the law of diminishing returns. The average total cost always starts at infinity and then falls rapidly as

the fixed costs are spread over more and more units. It continues to fall until the point of optimum efficiency is reached. Average costs then begin to rise. For example, when producing honey, a firm incurs fixed costs in establishing the honey harvesting equipment such as a processor and extractor. In addition to this there are the variable costs of labour

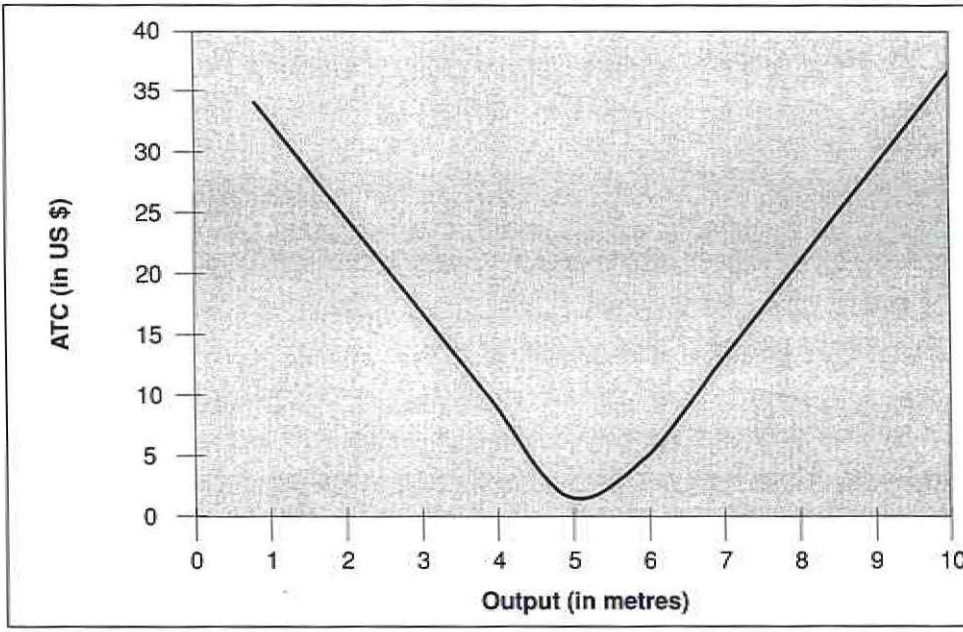

Fig. 1 – Average Total Cost Curve

and power consumption. When the equipment is operating at a maximum capacity, no additional amount of labour or electricity will increase output. Under these circumstances, honey production is affected by the law of diminishing returns. In the long run however, diminishing returns are balanced by the fixed cost of production.

In another instance, if the output of silk in one power loom is 120m in ten days (US $908.20) and the average variable cost is US $768.20 (table 30), and the average fixed cost is US $3,000. This will yield an average total cost of US $32.57 per metre per ten days. As the fixed cost is recovered, the average total cost will reduce accordingly (Fig. 1).

Determination of the cost of increased unit production

Marginal cost (MC) is the cost of producing one more (or one less) unit of a commodity, such as honey or silk. It is the ratio between the change in total cost (∇TC) and the change in output (∇Q). For example, in sericulture, if the production of silk increases from 1m to 2m (Table 1) then the marginal cost (MC) is:

$$MC = \frac{\nabla TC}{\nabla Q}$$

$$= \frac{7.568}{1} = \text{US } \$7.568$$

Thus, the marginal cost is obtained by dividing the increase in total cost (∇TC) by the increase in output (∇Q).

Table 1. The marginal cost schedule

Output, Q (Metres)	Fixed Cost, FC (US $)*	Variable Cost, VC (US $)	Total Cost, TC (US $)	Marginal Cost, MC (US $)
0	3000	0	3000	
1	3000	7.57	3007.57	7.568
2	3000	15.14	3015.14	7.568
3	3000	22.71	3022.71	7.568
4	3000	30.27	3030.27	7.568
5	3000	37.84	3037.84	7.568
6	3000	45.41	3045.41	7.568
7	3000	52.98	3052.98	7.568
8	3000	60.55	3060.55	7.568
9	3000	68.12	3068.12	7.568
10	3000	75.68	3075.68	7.568

*See table 34 (page 46)

From this example, the marginal cost of increasing silk cloth production from 1m to 2m on a power loom was US $7.568. This is the average incremental cost (AIC). While in this example, the marginal cost is constant at each level of silk output, in most cases, the marginal cost is different for each level of output (Beardshaw 1996).

The marginal cost is a rate that equates changing cost to product output. The change in marginal cost is related to the total cost and product output associated with an infinitesimally small movement along the TC curve. A change in fixed cost will affect the average cost, but not marginal cost, whereas a change in variable cost will affect both average and marginal costs (Figs. 2a and 2b).

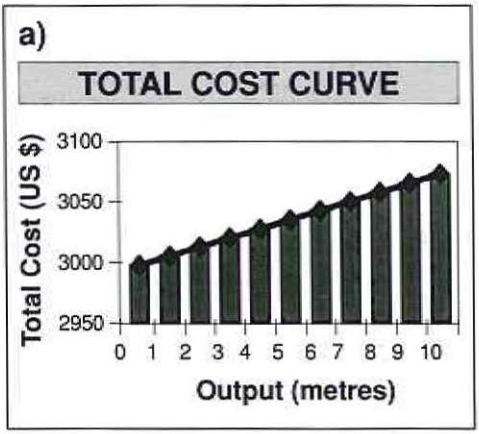

Fig. 2a – Total cost in silk cloth output

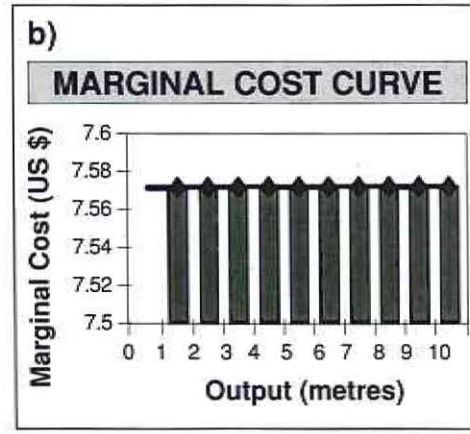

Fig. 2b – Marginal cost in silk cloth output

Optimal profit output

Under conditions of perfect competition, a firm does not control commodity market price. A business can only either sell or not sell at a given price. Therefore, when trying to maximise profit, the firm has to choose the output volume it expects would be most advantageous for profitability. For example, in a freely competitive market, beekeepers could choose how many bee colonies from which to harvest honey, but they could not control the price at which the honey is sold at harvest.

The best profit position for a business is to equate the price of the product with its marginal cost. If the marginal cost is less than the price of product, even when the marginal cost is rising, the firm will increase production because it is making a profit. If the output is small, and the cost of producing one unit is less than the revenue received from selling it, a profit will be made.

A business can increase profit by expanding output. As long as the selling price is above the average variable cost, the business will maximise its profits, or minimise its losses. The desired equilibrium for an industry occurs when product output is stable, and overall, the industry is making a profit.

The basis of production and productivity

Production is the total amount of a commodity produced, such as honey or silk. Productivity is the amount of a commodity produced per unit of resources used. When a firm is improving its efficiency, productivity will rise. If, through better management, more efficient equipment, or better use of labour, the firm manages to produce more, with lower resources, then it has increased its productivity. Alternatively, if the firm increases output, by increasing expenditure of resources, then despite the increase in output, productivity has decreased.

A common method to measure productivity, is to divide the total output by the number of workers. Another method used in agriculture is to express productivity as output per area. In sericulture, productivity can be expressed as the number of cocoons produced on a one hectare plantation. Alternatively, productivity may be described as the amount of silk cloth produced by one loom in ten days. In apiculture, productivity can be measured as the amount of honey produced by one hive in one year, or the amount of honey processed and packaged by a beekeeper in one month. Productivity rises when the average number of product made increases (i.e. bottles of honey), and productivity falls when the average number of product made decreases.

The marginal physical product (MPP)

The marginal physical product (MPP) is the change in the total output of product that results from employing one more variable factor. Average physical product (APP) is calculated by dividing output with the number of factors employed. For instance, one person may produce 11,520 bottles of honey per year. The marginal physical product in number of bottles per year is thus 11,520. With two people employed however, the 24,040 bottles of honey per year were produced and the marginal physical product was reduced to 12,520 (Table 2, page 21).

The marginal revenue product (MRP)

While the marginal physical product is measured in physical units such as volume of honey produced, or length of silk made, the measure may be expressed in monetary terms, by

determining the value of the product. Marginal revenue product (MRP) is the product of the marginal physical product and the price of that commodity:

MRP = MPP x P

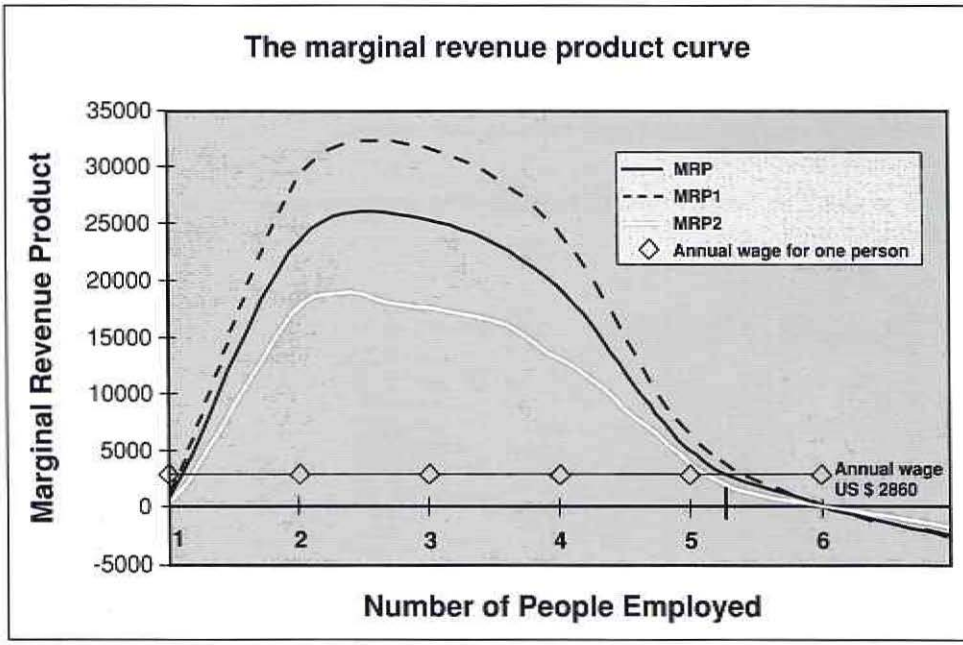

Fig. 3 – The marginal revenue product curve

The marginal revenue product is calculated to determine the quantity of a factor of production (i.e. number of people employed) a firm needs in order to produce a desired yield. Business will demand a factor of production when the marginal revenue product of that factor is greater than the cost of employing it. The firm's marginal revenue product curve for a factor is its demand curve for factor provided the price of the commodity produced remains fixed.

However, if the price of a factor decreases, the firm usually must purchase more of the variable factor. If all the firms in the industry do the same, this creates a rise in output, and therefore a fall in the price of the product.

The firm's demand for a factor

The marginal revenue product is the original price of factor (e.g. honey) and the quantity of the factor employed (Fig. 3). The shift from marginal revenue product (MRP) to marginal revenue product –1 (MRP1) shows the rise in the price of honey and the shift from marginal revenue product (MRP) to marginal revenue product –2 (MRP2) shows the fall in the price of honey. In general, the shift from marginal revenue product (MRP) to marginal revenue product –1 (MRP1) might result from improved technology or an increase in the price of the product. Alternatively, the shift from the marginal revenue product (MRP) to marginal revenue product –2 (MRP2) might result from a deterioration in technology or decrease the

price of the product. The best number of workers for a firm to employ in a production unit is achieved when the marginal revenue product equals the wage rate. If, for example, the wage falls, the firm would need to employ more people, but if the wage rises, the firm would have to reduce the number of staff.

There is a normal downward sloping marginal revenue product demand curve for factors of production (i.e. honey or silk), indicating the demand for more of a factor at a lower price. It has been assumed that the supply curve is horizontal, and that the firm could employ more of a factor without affecting its price. However, if an industry decides to employ more of a factor, it would probably need to pay more for this increase. This would result in a normal upward sloping supply curve.

Based on these economic methods, the resources and costs of apiculture and sericulture module units were calculated.

CHAPTER II

ECONOMICS OF APICULTURE

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Background to beekeeping

Beekeeping is a relatively inexpensive activity that can generate income for the rural smallholder. Most of the honey producing regions in the tropics and sub tropics have not yet been exploited. Apiculture provides a nutritious commodity and income from the production of honey. In addition to honey, bees produce other highly marketable products such as: wax, royal jelly, pollen, bee-venom and propolis. An indirect benefit of raising bees is increased pollination of tropical crops (Jones, 1999).

The choice of hives

Three types of hives are used for beekeeping in Africa. Ninety-five percent are traditional log hives (Fig 4a, page 49), top-bar hives (Fig 4b, page 49) and the more modern Dadant or Langstroth hives (Fig 4c, page49) are also used. The cost of the hives varies, as does the average amount of honey produced by each:

Type	Cost (US $)	Honey Harvest (kg)
Log	8	5 – 8
Top bar	16-22	10 – 12
Langstroth/Dadant	25-33	20 – 25

There are a number of disadvantages in using the traditional and top bar hives. The harvesting of honey is tedious and the process destroys the combs, which inhibits the growth of the colony (Liana and Borje, 1997). When top bar hives are opened, the bees are disturbed and sting in defence. There is no room for queen-rearing and beekeepers face the problem of colony multiplication. There is often swarming due to overcrowding, which is accompanied by a substantial loss of bees.

The Langstroth or Dadant hives are the most efficient to use for beekeeping. When using these framed hives, queen-rearing is simplified and colony multiplication is facilitated Morse and Hooper, 1985). This augments the volume of honey and bee products produced, which increases economic return. With these hives honey and additional bee products such as royal jelly, propolis, pollen, and bee venom, can be harvested without difficulty.

It is best if the newcomer to apiculture first talks to a local traditional beekeeper about the practice of keeping bees. The main obstacle in beekeeping is a fear of the sting. Beginners must learn to protect themselves from the bees. This includes proper use of smoke, the importance of dress, and knowing how weather conditions affect bee behaviour. In addition, there are different races of honeybees that are specific for specific environments and a suitable race should be selected for a particular habitat (Ruttner, 1988). In general, honeybees are easy to raise, and hives may be kept anywhere, as long as appropriate flora and water are available (Fig. 5, page 49).

The harvesting time depends solely upon the local floral cycle. In various ecological zones, flowering (and thus the harvesting of honey) occurs once or twice a year. During extreme weather circumstances, such as unexpected heavy rains or dry spells, the floral cycle may be adversely affected and the honey harvest may fail completely.

To keep bees, an apiculturist needs a veil, gloves, overalls, hive tool, and smoker. For a beginner, it is best to start with a minimum of four colonies (hives). Bees are either bought from an established apiary as nuclear colonies (nucs), or captured when swarming. The placement of hives depends upon floral availability. If there is no natural food source, the bees will abscond from the hives. Initially, for the first seven days, the bees should be fed sugar syrup twice a day to help new bees settle in a hive. The hive is established when foraging bees bring pollen into the hive (usually within two days). After the initial set up, a hive should not be disturbed for at least four weeks.

A colony requires six to eight months to become established. To prepare for the first honey crop, a honey chamber (super) is placed on top of a brood chamber after it has been established about six months. The frames in the honey chamber contain plain wax foundations. After eight to twelve weeks, during a favourable flow period, the honey chamber becomes full of honey. When the main flow ends, the honey is collected and no more honey can be harvested until the following season.

During the dry period African bees usually abscond from hives to seek a site with a new food supply. A few apicultural management strategies can inhibit absconding and retain up to 80% of the bees in a hive during the dry season. Only two-thirds honey should be harvested from the colony and the remaining one-third left for the bees to eat d ing the three to four month dearth period. Empty combs in the honey chamber shoulu be removed to avoid wax moth infestation. Water in plastic bowls should be provided daily. During the rainy season, beekeepers should grow wild plants (preferably Oscimum sp.) and indigenous flowers around apiaries to sustain the colonies during the dearth period. The roof of the hive should be painted white and covered during the dry season with a thick layer of grass to help inhibit hive desiccation. The grass should be cleared during the rainy season. The apiary should be placed in a shady area at least three feet above ground level. Grease or used motor oil should be applied at the bottom of the hive stands to discourage ants.

To maximise honey yield the hive must be properly maintained. To increase the stability of the honeycombs, the frame foundation (a sheet of wax or plastic that fits inside the frame) should be fortified with wire. The frames are placed 1½ inches apart and the bees inhabit the intervening area (bee space). Initially, the hive contains four to five frames, on which the bees build combs and the queen lays eggs. This takes approximately 6-8 weeks. When the bees fill all the cells in the frames, extra frames are added until the brood chamber is full (requires 4 months). In a normal colony, three-quarters of the combs fill with bees, which hang in a cluster beneath the comb. This is the time to place the super (honey chamber) over the brood chamber. During a good honey flow period, the frames in the super will be filled with honey in eight to twelve weeks (Fig. 6, page 49). During the initial set up, an extra four months are required for the bees to build the comb. When three-quarters of the comb is capped with wax, the frame in the super is removed and the honey is harvested. This is done with an extractor in a ventilated room maintained free of bees. An electrical extractor or manual extractor may be used.

Economics of beekeeping

The marginal physical product (MPP) based on honey production

In honey production, the marginal physical product (MPP) is the change in total output resulting from the employment of one more person of a variable factor. In the production and packaging of honey, one processor, one centrifuge and one packaging machine

comprise a single module unit. The average physical product (APP) is calculated by dividing the output with the number of units employed (Table 2).

The marginal revenue product (MRP)

While the marginal physical product is measured in physical units such as volume of honey produced, the measure may be expressed in monetary terms (Table 3).

Table 2. The marginal physical product based on honey production and packaging module.

Number of workers	Extraction and processing of the honey in kg/year	Output of honey bottles, Q of 0.5kg/year	Marginal Physical product (MPP) in number of bottles/year	Average physical product (APP) in number of bottles/year
0	0	0	0	0
1	5,760	11,520	11,520	11,520
2	12,020	24,040	12,520	12,020
3	14,400	28800	9,600	9,600
4	15,600	31,200	2,400	7,800
5	15,600	31,200	0	6,240
6	14,800	30,000	-1,200	5,000

Note: Data based on bottles of honey produced per month at ICIPE's Commercial Insects Programme processing, packaging and training laboratory

Table 3. The marginal revenue product (MRP) of honey sale in perfect condition

Number of people Employed	Marginal Physical Product (MPP) in kg/year	Price (P) of one bottle of honey (US $)	Marginal revenue product (MRP) (US $)
0	0		
1	11,520	2	23,040
2	12,520	2	25,040
3	9,600	2	19,200
4	2,400	2	4,800
5	0	2	0
6	-1,200	2	-2,400

In the above example, if a third person is employed in honey processing, and adds an additional 9600 bottles of honey, and if each bottle is sold for US $2.00, then the marginal revenue product is US $19,200 (MRP = MPP x P). If the honey is sold at a reduced price, then the marginal revenue product would be calculated as MRP = MPP x MR, where marginal revenue (MR) is the change in a firms revenue as a result of the fluctuation in the pricing of the honey.

Model cost structure of a honey firm (in US $)

The actual minimum cost required to establish a honey processing and packaging unit in Nairobi, Kenya, in 1997, is given in Table 4. These expenses represent fixed costs.

Table 4. Cost to establish honey processing and packaging laboratory

Item	Cost per item (US $)	Total (US $)
1 Honey Processor (100 litres)	900	900
1 Honey extractor (6 frames)	900	900
2 Balances	500	1000
1 Honey bottling plant	2700	2700
Bottles (20,000)	0.4	8000
Labels (20,000)	0.05	1000
Utilities		500
TOTAL		**15000**

In addition to fixed costs, variable costs such as: bee purchase, labour (one person), and electricity costs (US $13,292) are incurred yearly. From this, a cost schedule may be projected (Table 5).

Table 5. The cost schedule of honey processing and packaging per annum

Number employed	Total output (Q) of honey bottles/year	MPP bottles/year	APP bottles/year	Fixed costs of production (FC) (US $)	Variable costs of production (VC) (US $)
0	0		0	15,000	0
1	11,520	11,520	11,520	15,000	13,292
2	24,040	12,520	12,020	15,000	22,820
3	28,800	9,600	9,600	15,000	33,980
4	31,200	2,400	7,800	15,000	39020
5	31,200	0	6,240	15,000	42,020
6	30,000	1,200	5,000	15,000	43,660

Variable costs can be calculated for a period of one year. Variable costs include the price paid for honey purchased from beekeepers (US $1.7/kg), labour (US $3,000/person/year), and utilities (US $500/tonne of honey processed/year)

Based on these cost structures of honey processing and packaging, the optimal profit obtained from honey production in one year was calculated (Table 6).

Table 6. Optimal profit output

Number of people employed	Output of honey, Q bottles	Unit Price per bottle, P (US $)	Marginal revenue product, MRP (US $)	Total revenue, TR, (P x Q)	Total cost, TC, (FC + VC)	Total profit, TP (TR - TC)	Marginal cost, MC ($\nabla TC/\nabla Q$)
0	0	2	0	0	15,000	-15,000	1.15
1	11520	2	23040	23040	28,292	-5,252	0.76
2	24,040	2	25,040	38400	37,820	580	2.34
3	28800	2	19200	57600	48,980	8,620	2.1
4	31200	2	4800	62400	54,020	8,380	∞
5	31200	2	0	62400	57,020	5,380	–
6	30000	2	-2400	60000	68,660	-8,660	

Marginal cost (MC) is obtained by dividing the increase in total cost (∇TC) by the increase in output (∇Q), MC = ∇TC/∇Q

Cost structure of an apiary

To set up a small apiary of four hives in East Africa, the following costs are involved when the materials are locally made (Table 7).

The average honey production per apiary in the first harvest is 20 kg x 4 = 80 kg

The average local selling price of honey is US $2 x 80 kg = US $160

In the first harvest a beekeeper will recover 80% of the establishment cost. In the subsequent years, a beekeeper can earn an average of 1.5 times more than the initial profit.

The various factors of honey production are combined to project expected optimal profit over a period of time (Tables 8, 9, 10).

Table 7. The cost structure of an apiary

Item	No. required	Cost per item (in US $)	Total (in US $)
Ten frame hive with one honey chamber	4	25	100
Queen excluder	1	5	5
Hive stand (wooden)	1	5	5
Nucleus colony (purchase can be avoided if swarm is made available)	4	7	28
Veil	1	5	5
Overall	1	15	15
Gloves	1 pair	4	4
Gum boots	1 pair	10	10
Hive tool (steel metal)	1	3	3
Smoker	1	8	8
Beeswax	1kg	5	5
Feeder (plastic or wooden)	4	0.5	2
Grease/oil, rubber band		2	2
Sugar	8kg	1	8
TOTAL			**200**

Table 8. The marginal physical product for first year and every season onwards for 4 established Langstroth hives

Number of workers	Production of honey in kg per season	Output of honey production in kg, Q	Marginal physical product, MPP (kg/ season)	Average physical product, APP in kg/ season.
0	0	0	0	0
1	80	80	80	80
2	80	80	0	40

Table 9. Cost to produce honey per season (6 months) using 4 established hives capacity

Number of workers	Total output of honey production per season (kg)	Marginal physical product (MPP) per season (kg)	Average physical product (APP) per season (kg)	Fixed cost (FC) (US $)	Variable cost (VC) (US $)
0	0	0	0	0	0
1	80	80	80	164.00	66*
2	80	0	40	164.00	96**

* labour cost of the beekeeper himself

** Part time additional labour of US $30

Table 10. Optimal profit output of honey production from 4 established hives per season

Number of workers	Output of honey production (Q) (kg)	Price of one kg of honey (P) (US $)	Marginal revenue product (MRP) (US $)	Total revenue (TR)=PxQ (US $)	Total cost (TC)=FC+VC (US $)	Total profit (TP)=TR-TC (US $)
Season I (9 months)						
1	80	2.00	160.00	160.00	230.00	-70.00
2	80	2.00	0	160.00	260.00	-100.00
Season II (6 months)						
1	80	2.00	160.00	160.00	85.00	+75.00
Season III*						
1	80	2.00	160.00	160.00	45.00	+115.00

* The regularity in honey flow depends on a good floral cycle and rainfall

Thus, if the establishment of the bee colony takes 6 months, and if the flora and weather conditions are suitable, then in the following 3 months the production of honey starts at approximately 20 kg per hive. Once the colonies are set, four hives should produce approximately 80 kg of honey every six months. Initially, during the first season, no total profit will be made as a result of start-up costs. However, a profit should be expected during the second season and each season thereafter.

Honey Quality Control

The variable flavour of honey arises primarily as a result of the different plants on which bees derive nectar and honeydew, which in turn, are influenced by variable climatic conditions. The honey flavour is governed by a combination of chemical compounds found in the nectar and/or pollen of plants foraged on by bees. Despite this the main constituents of honey are similar. For commercial sale, ëtable honey' undergoes a rigorous quality control testing to ensure its high grade. The level of moisture, pH, amino acids, sugars and enzymes, in honey, give an indication of its quality and the measurement of these indicators, as described by Bogdanov *et al*, (1977), is outlined on the next page.

Moisture

The amount of water in honey affects its stability and ability to resist spoilage by yeast fermentation. Generally, the higher the moisture content, the higher the probability the honey will ferment upon storage. The maximum percentage of water permissible in honey is 21%. Water content, given as percent moisture, is determined by the refractive index of strained and homogenized honey, and is obtained using a hand-held refractometer.

Proline

Proline is the major free amino acid in honey. The quantity of proline in honey is related to the ripeness of honey. Honey quality decreases with decreasing proline content, and the minimum level of proline (mg) per kilogram of honey is set at 180. To measure proline, honey is mixed with ninhydrin and formic acid, and the resulting coloured sample is examined using a spectrophotometer. The absorption of light is correlated with the level of free amino acid.

Free acidity and pH

Ash and free acids are contaminants of honey and can be measured by electrical conductivity. The higher the level of ash and acid, the higher the conductivity. The limit of allowable free acids in honey is set at 40 meq/kg honey. To determine the level of acid, honey is dissolved in water, free of carbon dioxide. The pH is measured and the solution titrated with sodium hydroxide solution to pH 8.30.

Hydroxymethylfurfural (HMF)

The freshness of honey is measured by the level of the biochemical hydroxymethylfurfural (HMF), which is a metabolite of the sugar fructose. HMF is affected by heat and increases as the temperature of honey increases. The maximum level of HMF allowed in table honey is 40 mg/kg honey. To determine the level of HMF, honey is dissolved in water and treated with chemicals. The UV absorption of the solution is found and equated to the quantity of HMF.

Enzymes

Honey contains trace amounts of enzymes, which are affected by high temperature and storage. The levels of diastase and invertase enzymes indicate the extent of heat and storage damage of honey. The levels of diastase and invertase enzymes in honey must be above 8 S units and 50 U/kg respectively. The activity of these enzymes in a honey sample are determined spectrophotometrically.

Sugars

Honey has a high sugar content, which gives it sweetness, energy value and viscosity. Honey is composed primarily of the monosaccharides, glucose and fructose. The minimum limit for these sugars is 60%. The relative quanitity of these sugars may determine honey's tendency to crystallize. Honey with a glucose:water ratio less than 1.7 tends to remain liquid for a long time, as does honey with a high percentage of fructose. Sugar quantity in honey can be determined using High Pressure Liquid Chromatography (Fig 7, page 26).

Major importers and packers will only buy high quality honey. In Kenya, honey was collected from two provinces, Eastern Province and the Rift Valley Province, and analysed for quality. The results are shown on page 27.

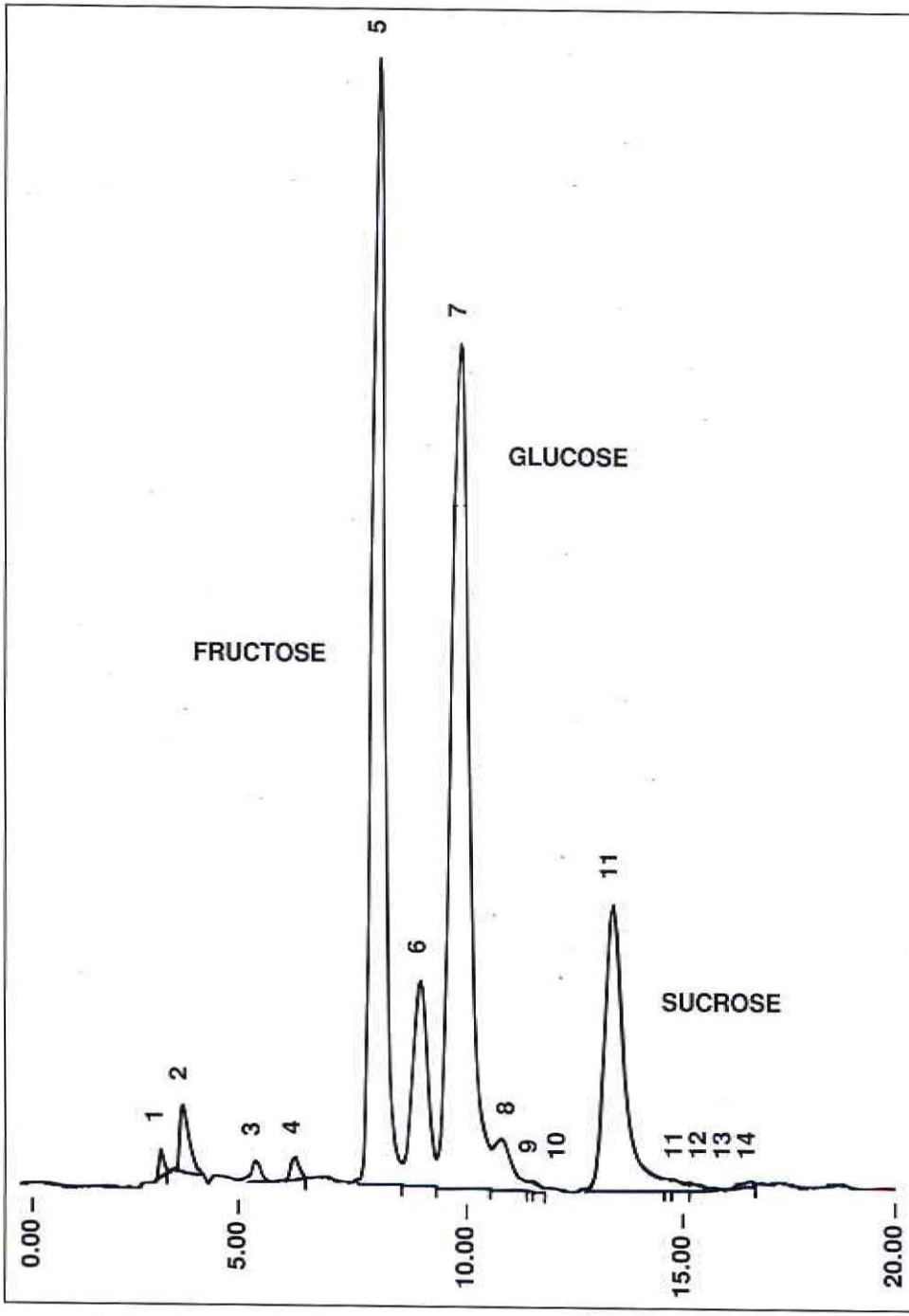


Fig. 7 – The quantity of sugar in honey as shown using high pressure liquid chromatography.

Table 11: Water content, proline and acid in honey; comparison of Eastern and Rift Valley provinces. (n = 62)

	Eastern		Rift Valley		
	Range	Mean ± SE	Range	Mean ± SE	Limit
Moisture	16.75-19.6	18.05 ± 0.14	16.3-21.0	18.36 ± 0.18	≤ 21%
Proline	267.56-389.24	940.9 ± 23.08	272.63-1155.19	586.7 ± 3.54	≥ 180 mg/Kg
pH.	3.78-4.67	4.19 ± 0.05	3.61-4.44	3.99 ± 0.04	
Free acidity	12.25-116.42	50.3 ± 5.77	18.06-56.82	32.8 ± 1.56	≤ 40 meq/Kg

Sixty-two samples of honey were tested from the two provinces, and all but two honey samples contained less than 21% water. All honey samples contained a higher amount of proline than the minimum limit required. In respect to free acid, six honey samples from the Rift Valley Province, and 11 samples from Eastern province contained a level of free acid outside the accepted limit.

Table 12. Indicators of overheating; comparison between Eastern and Rift Valley Provinces

	Eastern		Rift Valley		
	Range	Mean ± SE	Range	Mean ± SE	Limit
HMF*	Trace-51.65	16.43 ± 2.49	4.9-22.23	6.8 ± 0.97	≤ 40mg/Kg
Diastase	5.17-68.52	18.52 ± 3.38	7.37-22.61	12.29 ± 0.47	≥ 8 S units
Invertase	43.39-289.08	138.5 ± 13.04	57.5-235.23	123.91 ± 7.14	≥ 50U/Kg

* Hydroxymethylfurfural

Of sixty-two samples of honey tested from the two provinces, only one sample of honey from the Eastern province had an unacceptable level of HMF. All honey samples had more invertase enzyme activity than the minimum 50 U/kg. Three samples of honey from the Eastern Province and one from the Rift Valley had less diastase enzyme than acceptable.

Table 13. Sugar content; comparison of Eastern and Rift valley Provinces

	Eastern		Rift Valley	
	Range	Mean ± SE	Range	Mean ± SE
Fructose (%)	27.82-45.62	39.87 ± 0.78	25.63-51.03	40.48 ± 0.79
Glucose (%)	21.14-42.10	29.71 ± 1.08	22.60-42.26	29.89 ± 0.91
Sucrose (%)	Trace-1.89	0.19 ± 0.08	Trace-4.76	0.54 ± 0.20
Fru[1] + Glu[2]	60.12-84.91	69.57 ± 1.28	60.55-85.02	70.37 ± 1.17
Fru / Glu	0.69-1.87	1.39 ± 0.05	0.73-2.03	1.40 ± 0.05
Glu / moisture	1.20-2.28	1.65 ± 0.06	1.11-2.20	1.63 ± 0.05

[1]Fructose [2]Glucose

All sixty-two honey samples tested from the Eastern and Rift Valley Province contained more than the minimum limit of fructose and glucose required. In addition, the level of sucrose in these honey samples was less than the maximum limit of 5%.

In summary, more than 90% of the honey produced in two provinces in Kenya met the European Union quality standard for table honey. Only in respect to free acid level, did a

few samples of honey contain a higher free acid level than that allowable for export. Reasons for this need to be determined and the problem addressed. However, the remaining biochemical indices suggest that with proper bee management, Kenya is capable of producing a high quality of honey.

Establishing a honey quality control laboratory

To test honey quality, a control laboratory has to be established. This was done at ICIPE to monitor honey produced by farmers throughout Kenya (Fig. 8, page 50). The cost to establish the quality control facility is shown in Table 14.

Table 14: Major costs and components of a honey quality control laboratory

Item	Cost (US $)
Laboratory (15' x 10') space preparation	15,000
Air conditioner	1,000
HPLC setting	40,000
Service charge for HPLC setting (20% of total cost)	18,000
HPLC grade solvents	5,000
Spectrophotometer	10,000
Small equipment (pH meter, refractometer)	3,000
Reagents and glassware	10,000
Trained research assistant (per annum)	6,000
TOTAL	108,000

The cost to analyse the various biochemical constituents of honey are shown in Table 15. The prices reflect current market reagent costs, and are subject to change. The quality control tests must be completed before honey can be exported commercially.

Table 15: Cost of biochemical analysis.

ANALYSIS	PRICE (US $)
Moisture	1
Proline	5
Free acidity and pH	7
Sugars	10 (per sugar)
Hydroxymethylfurfural (HMF)	11
Invertase	6
Diastase	8
Service charge	9

Colony multiplication

Queen-rearing

The rearing of bee queens serves to improve and expand honeybee colonies, and can increase honey yield three-fold in Africa. When a colony is two to three years old the current queen must be replaced with a young queen. Queens can be mated naturally, or artificially inseminated with specific drones in attempt to select desirable traits in the offspring. Ideally the latter technology may resolve the behavioural defects of African honeybees (such as aggressiveness and absconding) and increase honey yield. Successful queen-rearing (Fig. 9, page 50) requires a strong established beehive colony, a Langstroth or similar type hive and a locality with suitable flora.

Queen-rearing must be synchronized with drone breeding. To breed the drones (male bees), the hive is prepared by isolating one third of an intact honeycomb, and placing it in the centre of a brood chamber. Within 7-8 days, the worker bees build a drone comb, where the old queen lays her eggs. In 24 days, the eggs hatch and the drones emerge. In 15 days they are sexually mature and ready to mate with a queen in flight, or their semen is available for artificial insemination.

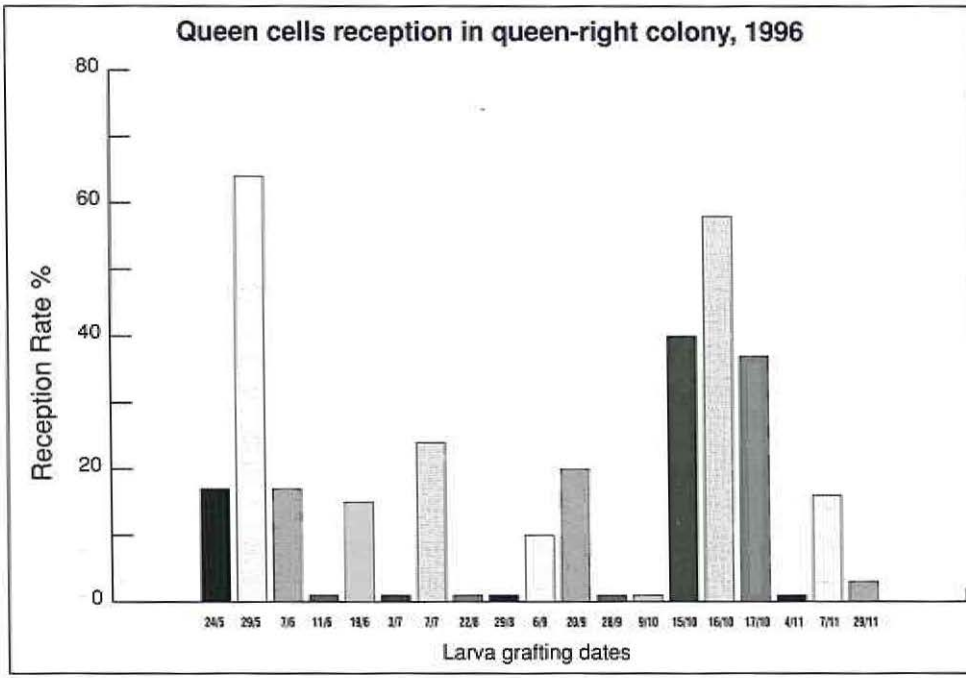
To initiate queen breeding, the old honeybee queen in the colony is identified. In the queen-right method, the queen is confined in the brood chamber. In the queenless method, the queen is removed and placed in a separate nucleus box (Nuc). The queenless or queen-right colony is left overnight. It is advisable to use queen-right colonies since the queenless method weakens the colony. The following day, queen cell cups are placed in the middle frame position of the colony for one half hour, during which time the bees clean and polish the cells. These cells are then removed (Fig. 10a, page 30 and Fig. 10b, page 31).

Next, honeycomb from a colony which contains young larvae (less than 24 hours old) is grafted into the polished cell cups and placed in the centre of the honey chamber. If the grafted larvae are accepted, the following day the larvae will float in royal jelly produced by the worker bees. In five days the queen cells will be sealed with wax. At an ambient temperature of 20-25°C, the queens will hatch in 12-13 days.

Before the queens hatch, they are isolated and placed in an individual queen cell holder, which is placed in a nuc box containing honey, pollen, and bees (approximately 1000). The holder is placed between any two frames in the nuc box. On 12th or 13th day, the queen emerges and is fed by the young bees. On the 16th day the queen is ready to mate. The drones should be fully mature at this time.

The queen either mates naturally in-flight, or is artificially inseminated (Fig. 11, page 50). After mating or insemination, the queen returns, or is returned to the hive. If the queen lays more than 1500-2000 eggs per day, she is considered a good and fertile queen.

In the final step, the colony is divided. Two brood frames are selected that have bees on all four sides. The sealed frames are placed in the middle of the hive and sandwiched between two frames of honey and pollen. The bees are left overnight to experience queenlessness. The following day, a mated queen is placed in a queen cage. Sugar candy is put at the cage entrance. The bees chew the candy and release the queen. A new colony has been made, or the queens are ready to sell.



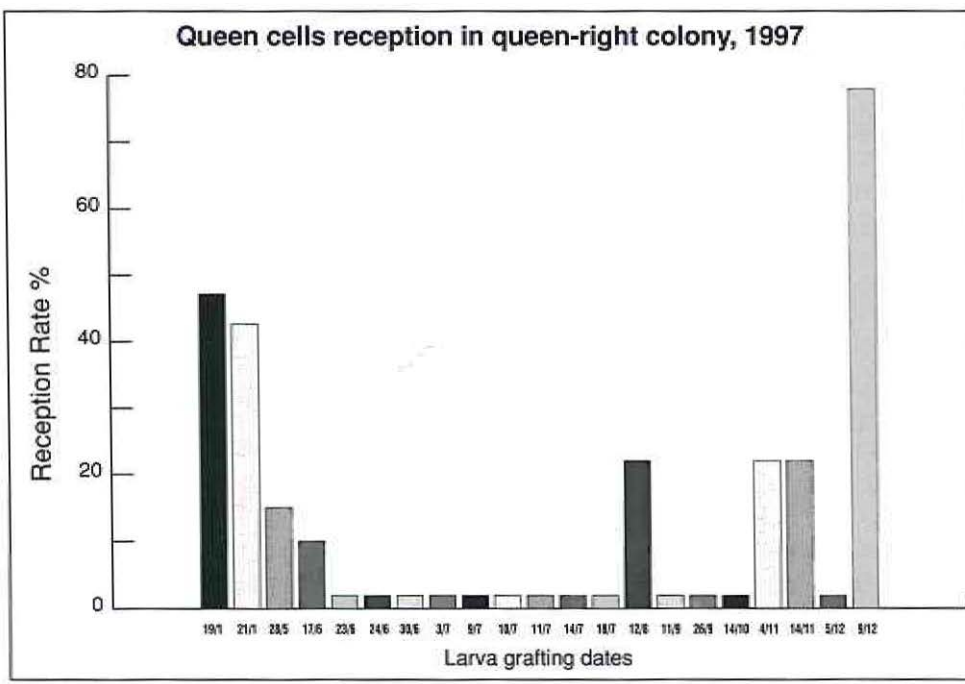
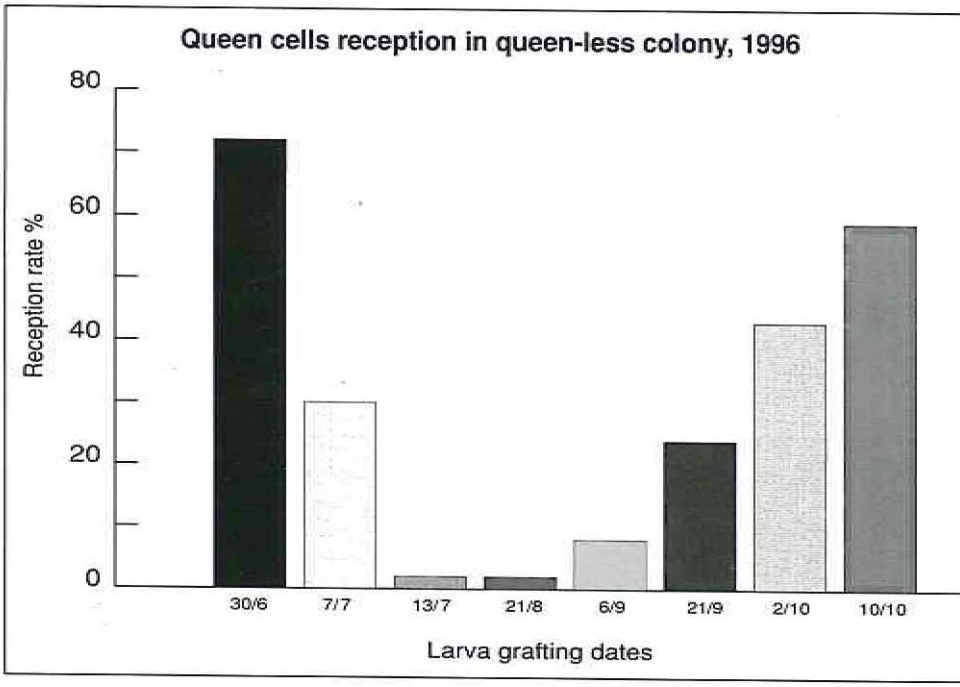


Fig. 10a – Queen cell reception by worker bees in queenright colonies in various seasons of the year.



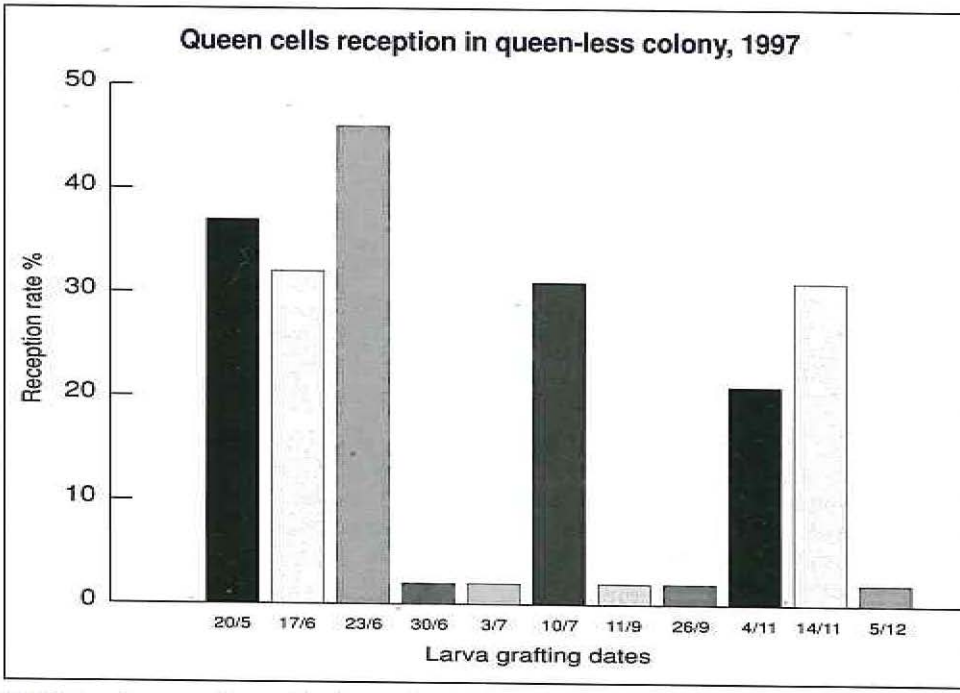


Fig.10b – Queen cell reception by worker bees in queenless colonies in various seasons of the year.

Economics of Queen-rearing

Cost to manage and multiply colonies by raising honeybee queens

Successful and lucrative beekeeping depends upon the honey producing capability of the honeybee strain. To this end, the high quality of individual queens is extremely important. Commercial queen breeders and institutions specialising in apiculture, maintain bee races that are genetically true to type through artificial insemination or controlled breeding in isolated mating yards. Queens are bred to produce bee colonies which yield high quantities of honey.

The cost to rear queens is shown in Table 16.

Table 16. Cost structure for queen-rearing and colony multiplication

Item	Number required	Cost per item (in US $)	Fixed Cost, FC (US $)	Variable Cost, VC (US $)
Strong colony for drone rearing	1	32	32	0
Strong colony for grafting	1	32	32	0
3-4 frame nucleus box	6	10		60
Queen cages	10	1		0
Frame for grafting queen cell cups	6	0.5		3
Grafting tools	6	1		6
Beeswax	½kg	5/kg		2.5
Queen markers	8	1		8
Sugar	10kg	1		10
Sugar candy	¼kg	2/kg		0.5
Training*	Once	35	35	
TOTAL			**99**	**100**

*The training was done at ICIPE, Nairobi, Kenya. Local materials for hive construction were used.

Thus, the total cost (TC=FC+VC) involved in establishing a queen-rearing facility with two hives is US $199. The average number of queens a beekeeper can produce with one rearing from two colonies is 20. In one honey flow season a beekeeper can rear queens twice, to produce 40 queens.

The average local price for a mated queen is US $7. Thus, a queen rearer can make US $280 in one season. After the initial outlay of expenses, subsequent rearings will incur a seasonal cost of US $10 – $15. In East Africa (at ICIPE), a trained queen-rearer is paid US $3000 per annum. As shown in Table 17, page 33, one trained queen-rearer provides a high profit margin to beekeepers.

Table 17. The best profit output of Queen rearing from two strong hives per honeyflow season (approximately 3 months)

No. of workers	Average Output of Queen production per Nuc box (Q)	Price of one Nuc box with mated queen (P), (US $)	Marginal Revenue Product (MRP), (US $)	Total Revenue TR=PxQ (US $)	Total Cost TC=FC+VC (US $)	Total Profit TP=TR-TC (US $)
1st Honey flow season						
1	40	13	520	520	199	321
2	40	13	0	520	199	420
3	40	13	0	520	199	420
2nd Honey flow season						
1	40	13	520	520	100	420
2	40	13	0	520	100	420
3	40	13	0	520	100	420

Cost to establish insemination laboratory

Insemination is used to generate strains of bees for producing high yields of honey, pollen, propolis and royal jelly. Artificial insemination can also be used to produce bees that are less aggressive and have a decreased tendency to abscond. Special training is required to artificially inseminate a queen bee. ICIPE established a breeding laboratory to inseminate queen bees with drone semen. The cost to establish this laboratory was US $30,000 (Table 18).

Table 18. The cost to equip an insemination laboratory for queen breeding in 1997

Item	Cost (US $)
Lab of 10 x 10ft with electricity and water connection	15,000
Swienty Insemination apparatus with binoculars	4,000
Biological hood for keeping the apparatus	6,000
Carbon dioxide cylinder and other accessories	3,000
Chemicals, Nuc boxes, queen markers etc.	2,000
TOTAL	**30,000**

Beekeeping can become a lucrative business for small-scale farming community in Africa if economics and proper management practices are observed critically.

CHAPTER III

ECONOMICS OF MULBERRY SILK FARMING

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Background

Sericulture is the practice of raising silkworms to produce raw silk. It is labour intensive and suited to Africa for income generation and self-employment in rural and semi-urban areas. The farmers can undertake sericulture as rural micro enterprise initiatives in addition to their normal farming activities (Figs. 12 a-d, page 51).

An acre of mulberry provides gainful employment all year round for 4 people in a family. In the silk producing sector, reeling, spinning, dyeing, warping, weaving, finishing and processing of silk fabrics provides employment to a large number of people.

A small mulberry plantation

A minimum one acre (0.4 hectare) piece of land is recommended for mulberry cultivation. Before the biyearly rains, the land is prepared by weeding, ploughing, digging, and levelling. Seven tonnes of farmyard manure per acre per annum should be mixed with the soil.

At the onset of the rain, the mulberry cuttings are planted. The type of mulberry variety used depends upon the climatic conditions where the mulberry will grow. There are high leaf yield varieties (Kanva-2 or Thailand) and a drought resistant variety (Embu). In fertile soil, the mulberry cuttings (5000 /acre) are planted in 3' x 3' rows. In less fertile soil, the mulberry cuttings (11,000 / acre) are planted in 2' x 2' rows. The mulberry should have 5-6 buds per cutting (Jolly, 1986, Ullal & Narsimhanna, 1987, Zheng, *et al*,1980)

If the rain fails, the land should be irrigated once every 15 days. Sixty days after planting, 5-8 gm of mixed fertilizer (NPK), should be added around the soil of each plant (approximately 25-40 kg per acre – cost US $40). In 7-8 months, the mulberry plants can support the rearing of silkworms. Pruning is recommended when the mulberry is one year old. After this time pruning twice a year gives the soft and cushiony leaf that the silkworms require. After the first year, NPK fertiliser (100:50:50 per acre/year) should be added to the soil.

A mud house or wooden structure with an area of 25' x 20' x 10', with good cross ventilation should be built to rear the silkworms. Bamboo or hard wood treated with an anti-termite solution provides the base support for the hut. The hut should be disinfected with a 2% solution of formalin. Lime powder should also be sprinkled around the hut. It is important to maintain a high level of antiseptic hygiene inside the hut.

Fifty thousand silkworms (2 cases or 100 disease free layings) can be reared in the hut. The rearing equipment required includes:

- Three tier rearing bed racks or bamboo racks for tray rearing
- Mountages
- Wooden or bamboo trays

- Knives
- Cleaning nets
- Leaf collection baskets, leaf chamber (4'x3'x2') and antwells.

In the first year, if the rains are favourable, one cycle of silkworm rearing is possible. As the sericulturist gains experience, 4 – 5 rearings per year are likely (Raina, *et al*, 1999).

Silkworm rearing and cocoon production

Silkworm eggs from high yielding bivoltine *Bombyx mori* hybrids should be purchased from a reputable silkworm egg production laboratory. The eggs must be suitable for the climatic condition of the area where they will grow. Eggs or young larvae should be transported during cool hours to avoid desiccation. To ensure uniform egg hatching, the egg surface should be disinfected with a 2% solution of formalin for 7 minutes.

After the eggs have been removed from the cold storage and brought to the room temperature they should be incubated at 20 – 22°C for 5 days and 23 – 25°C for 4 – 5 days. The relative humidity should be 80%. During egg incubation, a cycle of 16 hours light: 8 hours dark, should be provided. To provide uniform embryonic growth, twenty-four hours before hatching, the eggs should be placed in a black box, or covered with black paper. On the day of hatching, the eggs should be exposed to light for 30 minutes. Following this protocol, 98% of the silkworm eggs should hatch.

The newly hatched larvae feed on young mulberry leaves (chawki rearing). A tray containing chopped mulberry with a high moisture content are brushed with the young larvae. The brushing is done with feathers or nets. Each tray should receive at least 5 disease free layings (DFL)[1] (2500 larvae). The trays are covered with polythene paper and stacked one on top of the other. Larvae are fed four times a day except when moulting. These activities should be done in a central place by an expert trainer. Farmers are given third instars for further rearing.

The larval (silkworm) lifespan is 25-30 days. During this time, the silkworm moults four times and casts off its old skin. The gap between two moulting periods is an instar. The larvae are contained in a three-tier shoot rearing rack (15' x 5' x 8') which accommodates 30,000 larvae or in trays each with 300 hundred larvae. The rack can be made from local wood by a local carpenter. The racks should be placed to provide adequate spacing and aeration. Nets of various mesh size are used to clean the rearing area. Cleaning is necessary to decrease the incidence of viral, fungal or bacterial infestations. The hut should be dusted with lime for disease prevention once a day. Late stage silkworms require 70% relative humidity and a temperature of 24°C. Care should be taken not to allow the humidity to increase above 70% during the fifth instar rearing. A higher humidity than this may give several breaks in reeling and decreases the silk quality.

The larvae stop feeding and move to a corner of the rack when they begin to spin cocoons. The colour of the silkworm changes from white to translucent opaque, and the silkworm shrinks slightly. Mature silkworms are transferred to a mountage (5' x 3'), which can accommodate 800-900 larvae. For a good silk harvest, ventilation during spinning is crucial (Hisao, 1994, Krishnaswami, *et al*, 1973, Lim, *et al*, 1990).

[1] 1 DFL has approximately 500 eggs

The larvae spin silk cocoons in 24 hours and metamorphose into pupae. On the fifth day the cocoons are harvested. They are dried in the sun or in a hot air room approximately 10 x 10 x 10 metres. In a hot air room, hot air is blown through small out-lets to heat the room. The green cocoons are heated to 120°C for half an hour and then at 100°C for 2.5 hours. The racks are removed from the room and the cocoons placed in semi-dry conditions. They are kept at room temperature for 5 days and then placed in the heating room again and left at 100°C for 3.5 – 4 hours. Good cocoons are sorted and stored for transport to market or locally reeled (Fig. 13, page 52).

After the first year, the sericulturist can produce up to 370 kg of grade-B cocoons, worth US $807. With skill and experience, after two years, a farmer may produce grade-A quality cocoons (Table 19).

Table 19. Grading of cocoons

Grade	Number of cocoons per Kg	Filament length of a cocoon (metres)
A	500-599	Above 1000
B	600-699	900-999
C	700-799	800-899
D	800 and above	< 799 not suitable for multiend reeling

The production of raw silk

Currently, ICIPE has established a post-harvest cocoon facility, which produces silk cloth from silk cocoons. In the first stage of processing, the cocoon silk fibre is unwound. Initially, dry cocoons are placed in a vacuum for ten minutes to extract the air. They are boiled in water for 10 – 12 minutes. Older cocoons (if stored six months or above) are boiled for 18 minutes. The silk fibre consists of two main proteins, fibroin (80%), and sericin (20%). During boiling, 1-1.5% sericin gum is removed and 18-19% gummy proteins remain.

Next, the cocoons are brushed with a hand-brush or stick to obtain the free end of the fibre. Brushed cocoons with free ends are put in a reeling basin that is filled with warm water (40° – 60°C). The free fibre end from 10-12 cocoons is fed into a reeling machine and the thread is pulled through small reel guides, which adjusts the denier of the raw silk. The cocoons, floating in warm water, bob up and down as the filaments are drawn upwards and wound on small reels. When the cocoon is nearly completely unwound, new cocoons are added to the reeler (Fig. 14, page 52) (Corbman, 1985).

The reeled silk fibre is then placed for 2 – 3 minutes in the vacuum chamber. Re-reeling is done in a hot chamber at 44°C. This process eliminates protein gum spots and improves the silk fibre quality. The silk fibre is transferred onto the standard reels and re-reeled to produce silk threads. Skeins are made in a group of six with four folds. They are packed with a pressing machine and ready for export (a kilogram of raw silk thread sells for US $32-45).

For silk cloth: winding, twisting, doubling and twist reeling

To produce silk cloth, raw silk threads are placed on light winding reels and wound on to small bobbins (Fig. 15, page 52). The wound bobbins are then placed on a twisting machine and twisted according to the specification of the cloth (Fig. 16, page 52). The twisted silk is collected on drum bobbins and transferred to a doubling unit (Fig. 17, page 52). On this machine, the yarn is doubled or tripled. The bobbins are then fixed on the double twisting unit for a final twist. The drum bobbins containing the twisted yarn are steamed for 20 minutes. In a row of ten, the drum bobbins are fed into the reeling machine, and the twisted silk is reeled.

Degumming, Bleaching and Dyeing of Silk yarn

The twisted silk yarn contains 18-19% of sericin gum. To remove the protein gum, the twisted silk hanks are soaked in soapy water and then boiled in a 5% sodium bicarbonate solution for one hour. The degummed yarn is washed in clean water. The fibres are soaked in a 2% solution of boiling hydrogen peroxide solution for 5 minutes and then washed with clean water again. An optical whitening agent is added to give the yarn a snow-white shine. After bleaching, dye of the desired colour is applied and 10% aluminium sulphate is used to fix the colour. The dyed skein is dried and placed in the winding unit where it is threaded onto bobbins (Fig. 18, page 53) for the making of silk cloth (Gohl and Vilensky, 1983, Grosicki, 1988).

Warping and Weaving

120 or 240 bobbins of bleached or dyed silk yarn are placed in a spinning machine on a standard creel, which is formed from a series of vertical and horizontal bars (Fig. 19, page 53). The 120/240 threads are pulled through the comb and passed through a fine grid, then transferred onto a warp. Fifty-six such strips, 120-300m long are produced on the warp. These strips are fed onto the beam and then transferred to a hand or power loom. The mounting of the yarn is done by pulling each individual thread through four eyelids and one comb rid and fixed on the rolling bar in the front of a loom.

The power loom (72 picks per minute) is used to weave the yarn into fabric (Fig. 20, page 53). One person operates a power loom and can produce 10 to 12m of silk in 8 hours. Using a handloom, 3 to 5m of silk can be produced in 8 hours (Fig. 21, page 53) (Marsh, 1979, Grosicki, 1988).

Designing and screen-printing

Screen-printing is the transfer of a pattern to cloth. The design is placed over fine silk gauze and transferred to the gauze by a light sensitive emulsion. The design is now fixed to the gauze. The screen (gauze with design) is placed over stretched fabric. With a squeegee, printing paste is pulled across the screen. The printing paste is pushed through the design onto the fabric (Fig. 22, page 54).

ECONOMICS OF SERICULTURE ACTIVITIES

Economics of mulberry plantation and rearing activities

Using a one-acre mulberry plantation as a case study, the economics of raising silkworms for profit was determined. The cost of preparing the mulberry plantation is shown in Table 20 on page 39.

Table 20. Cost to establish a one acre mulberry plantation

Particulars	Man-days	No. of person required & daily rate in US $	Total cost (US $)
Preparation of land (digging, levelling, weeding etc.)	9	5 @ 2.50 per day	112.50
Fertilizing with farmyard manure	7 tons	1 @ 50.00	50.00
NPK fertilizer	40 kg	40.00	40.00
Application of manure	3.5	2 @ 2.50 per day	17.50
Layout (3'x3') planting material (free) 5000 cuttings	2	2 @ 2.50 per day	10.00
Irrigation, fertilizer and maintenance (first year)	25	1 @ 2.50 per day	62.50
Total			**292.50**

In 1998, the initial start-up cost to establish a one acre (0.4 hectare) mulberry plantation was US $292.50.

The cost to erect and equip a mud rearing hut is shown in Table 21.

Table 21. Cost of rearing house and equipment

Particulars	Unit cost (US $)	Total cost (US $)
Rearing house 25x20x10 capacity of 100 Dfls or two cases of silkworm (1997 price)	500	500
Rearing stands (2) for shoot rearing size 15x5x8 with mats	133	267
Wooden trays (25) for young age rearing (size 3x2x2.5) with plywood base	2	42
Local mountage 25 (5'x3')	2	42
Nets (different size) 50 (2-4mm, 10mm, 15mm, 20mm)		33
Wet and dry bulb thermometer	5	5
Chopping knives and chopping board	3	3
Antwells 12	0.4	5
Leaf chamber (4'x3'x2')	8	8
Disinfectant: Lime, benzoic acid, paraformaldyhyde, ethanol, dettol, etc.		17
Total		**917**

Thus, the amount of money required to prepare the plantation and the hut for silkworm rearing is US $1,209

The net income derived from producing silkworm cocoons during the first year is shown in Table 22 on page 40.

Table 22. Production of cocoons by bivoltine hybrids during first year

Date	Particulars	Sale of cocoons (US $)	Expenditure (US $)	Net income (US $)
2 Sept	Brush 100 Dfls* (50,000 silkworms)	–	14.00	-14
2 Oct	Harvesting of cocoons (50 kg)	208.30	50.00	158.30
15 Nov	Brush 100 Dfls	–	14.00	-14
16 Dec	Harvesting of cocoons (50 kg)	208.30	50.00	158.30
	Total	**416.60**	**128.00**	**288.60**

*Dfls: disease free layings

Thus, in the first year, US $128 is spent in rearing the silkworm cocoons, and a return of US $289 is achieved. The profit made from selling cocoons is related to cocoon quality (Table 19). Grade-A cocoons sell for US$4.20/kg, grade-B cocoons for US $3.30/kg, grade-C cocoons for US$2.50/kg, and grade-D cocoons for US $0.30/kg.

The net income derived from sericulture practices in two field sites in Kenya, Naro Moru and Laikipia, during the second and third year of mulberry plantation is shown in Table 23.

Table 23. Production of cocoons in the second and third year (Naro Moru and Laikipia)

Crop	Dfls	Period	Production	Gross income US $	Expenditure US $	Net income US $
1	150	April-May	80kg/A grade	336	78	258
2	150	July-Aug	80kg/A	336	78	258
3	150	Aug-Sept	80kg/A	336	78	258
4	150	Nov- Dec	75kg/A	315	62	253
5	75	Feb-March	40 kg/B	132	25	107
Total	***675***	***8-9 months***	***355 kg***	***1455***	***321***	
			Dfl cost		95	
			Maintenance, electricity, etc		50.00	
			Total	**1455**	**466**	**989**

Thus, in the second year, the net income from selling silk cocoons is US $989. As seen earlier, the total start-up cost to prepare the plantation and the mud hut was US $1,209. Since mulberry can produce luxuriant leaves for a period of 10 years, and the rearing house, if properly maintained, should last 10 years, these initial costs can be spread over this time period:

US $1,209 over 10 years = US $120.9 a year

In the second year, the cocoons produced sold for a total of US $989. The profit from this sale, after subtracting the initial start-up cost (spread over 10 years) is:

US $989 less US $121 = US $868 per year

The net profit made after taking into consideration the initial start-up cost of US $1,209 is:

US $1,209 less US $868 = US $341

However, during this time period, the farmer will receive cash income from cocoon sales to help repay start-up costs. From the third year on the sericulturist's net profit rises substantially.

Economic analysis for establishing sericulture

The marginal physical product (MPP) obtained after the first year from a one-acre mulberry plantation is shown in Table 24.

Table 24. The marginal physical product (MPP) for a one-acre plantation (year 1)

Number of workers	Production of cocoon in kg per annum	Output of cocoon production (Q)	Marginal Physical product (MPP) (kg/annum)	Average physical product (APP) in kg / annum
0	0	0	0	0
1	75	75	75	75
2	150	150	75	75
3	180	180	30	60
4	180	180	0	45

Note: Mulberry plants take 8-9 months to become established under normal weather conditions. Hence, only one or two crops of limited dfl's can be reared initially. In calculating the profit margin, the first year production should not be considered.

The MPP derived during the second and subsequent years from sericulture on a one-acre plantation run by a family of five, is shown in Table 25.

Table 25. MPP for second and subsequent years for a single farm family in Nyeri/Nanyuki, Kenya

Number of worker	Cocoon Production (kg/annum)	Output of cocoon production (Q) (kg/annum)	Marginal Physical Product (MPP) (kg/annum)	Average physical product APP (Kg/annum)
0	0	0	0	0
1	150	150	150	150
2	250	250	100	125
3	300	300	50	100
4	370	370	70	92.5
5	370	370	0	74

The cost structure for producing silk cocoons on a one-acre plantation during the second and third year is shown in Tables 26, 27, and 28 on page 42.

Table 26. Cost structure of the silk cocoon production per acre per annum for a single farm family

Number of workers	Total output of silk cocoon (kg/annum)	Marginal physical product (MPP) (kg/annum)	Average physical product (APP) (Kg/annum)	Fixed cost (FC) (US $)*	Variable costs (VC) (US $)**
0	0	0	0	916.70	0
1	150	150	150	916.70	366.00
2	250	100	125	916.70	465.70
3	300	50	100	916.70	559.70
4	370	70	92.5	916.70	642.70
5	370	0	74	916.70	692.70

* Includes cost of rearing house and rearing appliances.
** Includes the cost of mulberry management and dfl.

Table 27. The marginal revenue product (MRP) per acre of a single farm family

Number of workers	Marginal physical product (MPP) (kg/annum)	Price of 1 kg of cocoon, P (US $)	Marginal revenue product (MRP) = MPP XP (US $)
0	0	0	0
1	150	4.20	625.00
2	100	4.20	416.70
3	50	4.20	208.30
4	70	4.20	291.70
5	0	4.20	0

Table 28. Profit output of the cocoon production per acre per annum (single farm family)

Number of workers	Output (Q) of cocoon production	Price (P) of 1kg of cocoon Grade A (MPPxP)	Marginal revenue product (MRP)	Total revenue (TR) (PxQ)	Total cost (TC) (FC+VC)	*Total profit (TP) (TR-TC)	Marginal cost (MC) (∇TC/∇Q)
0	0	4.20	0	0	916.70	-916.70	2.44
1	150	4.20	625.00	625.00	1282.70	-657.70	1
2	250	4.20	416.70	1041.70	1382.30	-340.70	1.8
3	300	4.20	208.30	1250.00	1476.30	-226.30	1.2
4	370	4.20	291.70	1541.70	1559.30	-17.70	∞
5	370	4.20	0	1541.70	1609.30	-67.70	–
Year IV	370	4.20	291.70	1541.70	660.30	881.30	

*Total profit is calculated on the basis of grade A cocoon price.

Marginal cost is obtained by dividing the increase in total cost (∇TC) by the increase in output (∇Q), MC = ∇TC/∇Q

In summary, if four persons are employed in sericulture, the total annual profit estimated from the third year onward is US $881.30.

Economics of the post-cocoon operation

The initial investment required to establish a post-cocoon operation is shown in Table 29.

Table 29. The expenditure for post-cocoon operations (Kenya)

Item	Expenditure (US $)
Machines (reeling to weaving) (reeling, re-reeling, winding, twisting, doubling, twist reeling, warping, power loom with jacquard and handloom	80,000
Training and installation	35,000
Shipment	14,000
Building shade – 40" x 30" x 20"	30,000
Total	**159,000**

The cost is based on that incurred at ICIPE in 1998. The equipment was supplied by R.K. Industries, Ramnagaram, India.

The cost to produce silk cloth in terms of time (hours) and income earned is shown in Tables 30 – 36.

Table 30. Economics of post cocoon operation units based on ICIPE apprenticeship stipend, single unit set-up (US $)

Operational unit	Cost	Man-days and stipend	Production cost	**Selling price	Net income
Reeling and re-reeling	391.70	8.5 @ 10.00	476.70 for 12.5 kg yarn	500.00	23.30
Throwing: winding, twisting, doubling, twist-reeling	476.70	8 @ 5.80	523.40 for twisting 12.5 kg	600.00	76.60
Degumming, bleaching, dyeing	523.40 + 83.30 (606.70)	2 @ 10.00	626.70	762.60	135.90
Warping/mounting of the yarn	626.70	5, 4 persons @ 28.30	768.20	994.50	226.30
Weaving and finishing 120 m fabric	768.20	10, 2 persons @ 14.00	908.20	1,248.00	339.80
*Garment (53 shirt) Size: M, 10%; L, 70%; XL, 20%	908.20	3 @ 6.00 per shirt	1226.20	35.00 per shirt (1855.00)	628.80

Note. Purchase of 94 kg cocoons grade A @ 4.20/ kg, Renditta- 6.5 (number of cocoons making 1 kg of raw silk)

*Data based on the production target of 120 m fabric of 105 cm width utilising 12.5 kg of double twisted yarn of 38/40 denier.

**Selling price is based on 10% profit margin over production cost.

Machine maintenance and electricity cost @ 3% of production cost excluding handloom maintenance.

Table 31. Economics of post-cocoon operation units based on single industrial set-up (US $)

Particulars of operational unit	Cost	Man-days and wages	Production cost	Selling price	Net income
Reeling and re-reeling	391.70	8.5 days @ 2.50	413.00	500.00	87.00
Throwing (winding, twisting, doubling and twist reeling)	413.00	8 @ 2.50	433.00	600.00	167.00
Degumming, bleaching and dyeing	516.30 (433.00 + 83.30 for dyeing material)	2 @ 2.50	521.30	762.60	241.30
Warping and Mounting	521.30	5, four persons @ 10.00	571.60	994.50	422.90
Weaving and finishing (power loom)	571.60	10, one person @ 2.50	596.60	1248.00	651.40
Weaving and finishing (hand loom)	571.60	30, one person @ 2.50	646.60	1336.90	690.30
Power loom Garment (*53 shirts: Width of the cloth is 105 cm)	596.60	3 @ 6.00 per shirt	914.60	1855.00 35.00/shirt	940.40
Hand loom garment (*48 shirts: Width of the cloth is 95 cm)	646.60	3 @ 6.00 per shirt	964.60 132.40 [c]	1920.00 40.00/shirt	955.40

Note. *Data based on the production target of 120 meter fabric of 105 cm width utilising 12.5 kg of double twisted yarn of 38/40 denier.

**Selling price is based on 10% profit margin over production cost.

Purchase of cocoons 94 kg grade A @ 4.20/ kg, Renditta- 7 kg.

Machine maintenance and electricity cost @ 3% of production cost excluding handloom. Labour wage are calculated at the minimum wages rate stipulated by the Kenyan government.

To calculate monthly income of a unit, 26 working days per month were used.

Table 32. Economics of post-cocoon operation units (US $)

Serial No.	Particulars of operational units	Cost	Man-days and wages	Production cost	Selling price	Net income	Income per month
Unit 1	Reeling & Re-reeling	391.70	8.5 days, 1 person @ 2.50	413.00	500.00	87.00	266.10
Unit 2	Throwing (winding, twisting, doubling and twist reeling)	500.00	8, 1 person @ 2.50	520.00	600.00	80.00	260.00
Unit 3	Degumming, bleaching and dyeing	683.30 (600.00+ 83.30 for dyeing material)	2, 1 person @ 2.50	688.30	762.60	74.30	965.90
Unit 4	Warping and mounting	762.60	5, 4 persons @ 10.00	812.60	994.50	181.90	945.90
Unit 5	Weaving and finishing (power loom)	994.50	10, 1 person @ 2.50	1019.50	1248.00	228.50	594.10
Unit 6	Weaving and finishing (handloom)	994.50	30, 1 person @ 2.50	1069.50	1336.90	267.40	231.70
Unit 7	Power loom Garment (*53 shirts: Width of the cloth is 105 cm)	1248.00	6, 2 persons 6.00/shirt	1566.00	1855.00 35.00/ shirt	289.00	1252.30
	Handloom garment (*48 shirts: Width of the cloth is 95 cm)	1336.90	6 days 2 person 6.00/shirt	1654.90	1920.00 40.00/ shirt	266.00	1152.70

Note:

Purchase of cocoons 94 kg grade A @ 4.20/ kg, Renditta- 7 kg. Machine maintenance and electricity cost @ 3% of production cost excluding handloom.

Labour wages are calculated at the minimum wages stipulated by the Kenya government.

To calculate monthly income of a unit, 26 working days per month were used.

Data were based on the production target of 120m fabric utilising 12.5 kg of double twisted yarn of 38/40 denier.

Table 33. The marginal physical product (MPP) for post cocoon operation based on the output from a power loom

Number of people employed	Production of silk fabric (m/month)	Output of silk fabric (Q) (m/month)	Marginal Physical Product (MPP) (m/month)	Average physical product (APP) per month
0	0	0	0	0
1	120	120	120	120
2	280	280	160	140
3	280	280	0	93.33

Table 34. Cost structure of silk fabric production per month on a power loom

Number of people employed	Total output of silk fabric per month	Marginal physical product (MPP) per month	Average physical product (APP) (m/month)	Fixed cost (FC) (US $)*	Variable cost (VC) (US $)**
0	0	0	0	0	0
1	120	120	120	3,000.00	921.70
2	280	160	140	3,000.00	1,808.70
3	280	0	93.33	3,000.00	1,958.70

* Power loom cost without jacquard

** Processed and bleached silk yarn, electricity and stipend.

Table 35. The best profit output for a single family in a silk cloth weaving per month using one power loom (US $)

Number of people employed	Output of fabric production (Q) (m)	Price per meter (P)	Marginal revenue product (MRP) = MPP x P	Total revenue (TR) = P x Q	Total cost (TC) = FC + VC	Total profit (TP) = TR - TC
Month I						
1	120	9.20	1,104.00	1104.00	3,921.70	-2,817.70
2	280	9.20	1,472.00	2576.00	4,808.70	-2,232.70
3	280	9.20	0	2576.00	4,958.70	-2,382.70
Month II						
2	280	9.20	1,472.00	2576.00	2242.00	+334.70
Month III						
2	280	9.20	1,472.00	2576.00	1808.70	+767.30
Month IV and onwards						
2	280	9.20	1,472.00	2576.00	1808.70	+767.30

Note: If the power loom operates at minimum of 8 hrs per day for a month, then the best profit estimated from third month is US $767.30 and remains constant as the market price is increased.

Table 36. Marginal physical product (MPP) for post-cocoon operation (based on handloom-weaving) per month

Number of people employed	Production of silk fabric in m/month	Output of silk fabric (Q) in m/month	Marginal Physical Product (MPP) in m/month	Average Physical Product (APP) per month
0	0	0	0	0
1	60	60	60	60
2	150	150	90	75
3	150	150	0	50
4	150	150	0	25

Note: Calculations are based on handloom operation of 8 hrs per day. Warping and mounting operations are excluded.

Table 37. Cost structure of silk fabric production per month

Number of people employed	Total output of silk fabric per month	Marginal Physical Product (MPP) per month	Average Physical Product (APP) (meters/month)	Fixed Cost (FC) (US $)*	Variable Cost (VC) (US $)**
0	0	0	0	0	0
1	60	60	60	1,333.30	535.70
2	150	90	75	1,333.30	1040.00
3	150	0	50	1,333.30	1190.00

* Cost of machine. ** Cost of processed bleached yarn and stipend.

Table 38. The best profit output from handloom silk fabric per month is calculated (US $)

Number of people employed	Output of fabric production (Q) (m/month)	Price of silk fabric/m P	Marginal revenue Product MRP=MPPxP	Total revenue TR=PxQ	Total cost (TC)=FC+VC	Total profit (TP)=TR-TC
Month I						
1	60	9.20	550.00	550.00	1,869.00	-1,319.00
2	150	9.20	825.00	1,375.00	2,373.30	-998.30
3	150	9.20	0	1,375.00	2,523.30	-1,148.30
Month II						
2	150	9.20	825.00	1,375.00	1,081.70	293.30
Month III & onwards						
2	150	9.20	825.00	1,375.00	1,040.00	335.00

In handloom weaving, the best profit output begins after the second month and remains constant from the third month. Monthly fluctuations in yarn and fabric prices are related to the market. Institute-based handloom production yields a profit margin of US $335 per month.

Economics of designing and screen-printing

Two people are required to screen-print one fabric. In eight hours, the output of screen-printed cloth should be 15-20 meters. The quality of screen-printing depends on the paste, pigments, fabric, and the screen used in printing (Tables 39 and 40).

Table 39. Initial expenditure on design and screen-printing unit

Particulars	Unit Cost (US $)	Fixed Cost (US $)	Variable Cost (US $)
Preparation of screens (includes artworks and exposing 20 screens)	84.00	1,680.00	0
Pigments (7 colours)	17.00	0	119.00
Printing paste (40kg)	4.00	0	160.00
Silk material (400meters)	10	0	4,000.00
Labour* (2 people for 26 man days)	16.00	0	480.00
Expendables (Masking tape, pins, papers, etc.)	0	10.00	
Total		**1,680.00**	**4,769.00**

Total Cost (TC) = Fixed Cost (FC) + Variable Cost (VC) = US $6449.00

The variable cost includes printing paste, pigments, silk material, labour, and other expendables. If properly maintained the life span of screens is five years or more.

Table 40. Best profit output of screen-printed cloth per month

People employed	Output of printed fabric (meters per month) Q	Price per 1 meter printed fabric P (US $)	Marginal Revenue Product MRP (MPP x P) (US $)	Total Revenue TR (P x Q)	Total Cost TC (FC+VC)	Total Profit TP (TR-TC)
0	0	20	0	0	1680	-1680
1	208	20	4160	4160	4289	-129
2	520	20	6240	10,400	7649	+2751
3	650	20	2600	13,000	9189	+3811
4	650	20	0	13,000	9429	+3571
2nd month onwards	650	20	2600	13,000	7509	+5491

Note: If three persons are employed then the total out put estimated from second month and onwards will be US $5,491 per month.

Advantages

Small-holders and poor farming communities can undertake sericulture as an agro-based cottage industry in addition to their usual agricultural activities. Most African countries have an excellent climate for the growth of mulberry, and the rearing of the domesticated silkworm *Bombyx mori*. The technology for producing raw silk was optimised for East Africa and economic studies indicate sericulture can be a lucrative business in this region.

APICULTURE

Types of beehives:

Fig. 4a – traditional log wood hive *(above)*

Fig. 4b – top bar *(above right)*

Fig. 4c – Langstroth hive *(right)*

Fig. 5 – Floral type in Mwingi, Kenya.
(Inset) – Honeybee, *Apis mellifera scuttelata* (banded) and *A.m monticola* (black)

Fig. 6 – Rectangular frame with honey-comb from Langstroth hive

Fig. 8 – Honey analysis at a quality control laboratory

Fig. 9 – Queen cell frame after reception of grafted larvae in apiary

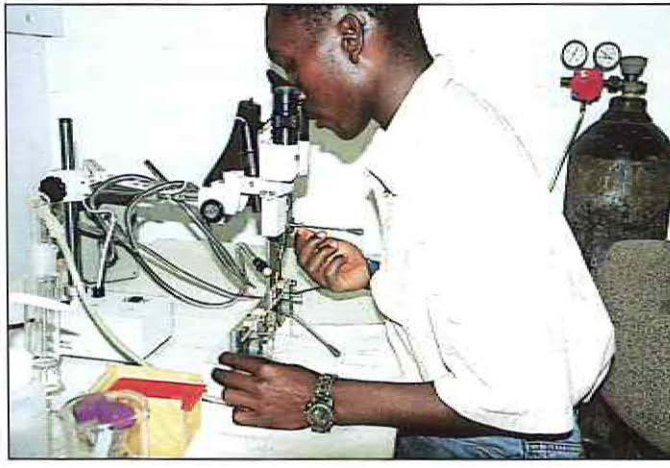


Fig. 11 – Insemination of a honeybee queen with specific drone semen

SERICULTURE

Fig. 12a – mulberry plantation, *morus alba*

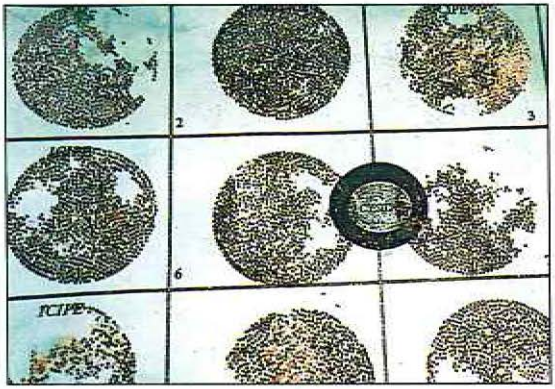


Fig. 12b – egg card, *Bombyx mori*

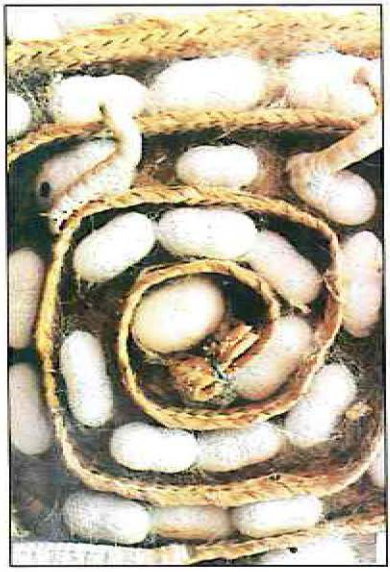


Fig. 12c – fifth instar larvae of silkworm, *Bombyx mori*

Fig. 12d – silk cocoons (bivoltine)

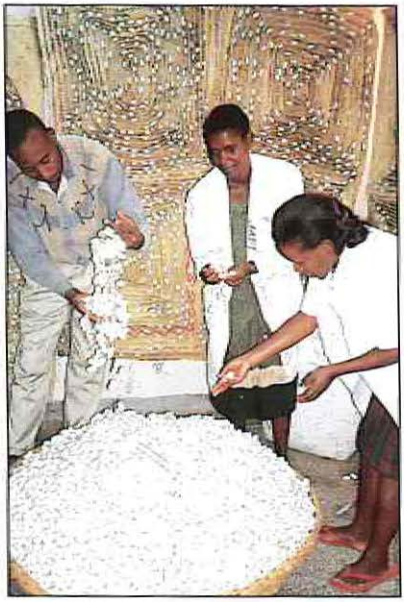


Fig. 13 – Mounted cocoons sorted for reeling

Fig. 14 – Silk reeling and re-reeling machine

Fig. 15 – Winding machine to transfer raw silk fibre to bobbins

Fig. 16 – Single and double twisting machine

Fig. 17 – Doubling single twisted yarn

Fig. 18 – Degummed, bleached and dyed silk yarn and bobbins for the preparation of warp

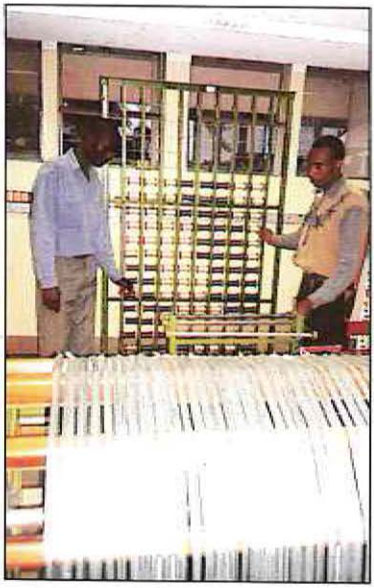


Fig. 19 – Creel of bobbins for warp preparation

Fig. 20 – Weaving silk cloth on a hand loom

Fig. 21 – Unfolding cloth from power loom beam

Fig. 22 – Screen printing of silk cloth

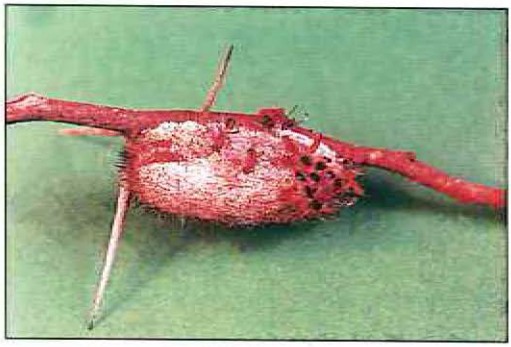
Fig. 23 – *Argema mimosae* on the lower leaf surface of *Sclerocarya birrea*

Fig. 24 – *Gonometa sp.* female moth laying an egg on the shell

Fig. 25 – Fifth instar larvae of *Argema mimosae*

Fig. 26 – Fifth instar larvae of *Gonometa sp.*

Figs. 27 a and b – *Gonometa sp.* cocoon showing damage by parasitoids



a – Hymenoptera

b – Diptera

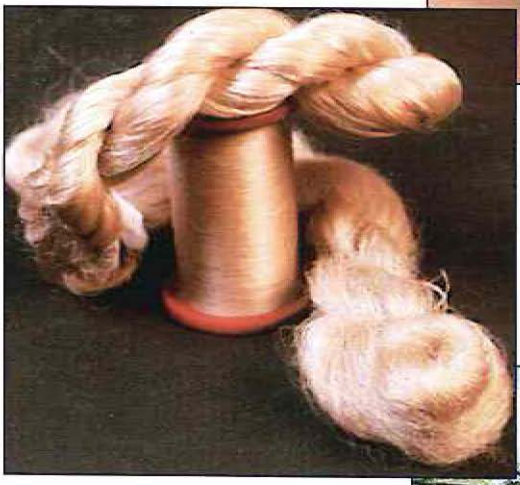


Fig. 28 – Silk fibre from *Gonometa sp.*

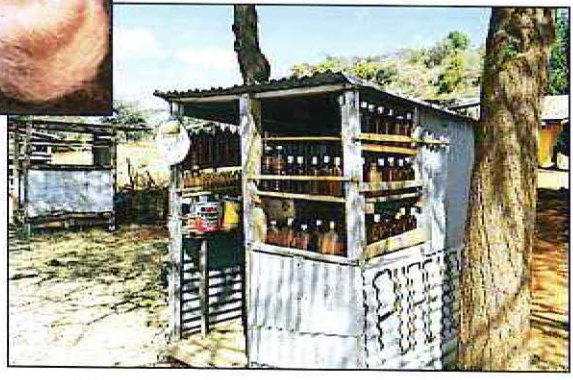


Fig. 29 – Local packaging and marketing of honey in Baringo

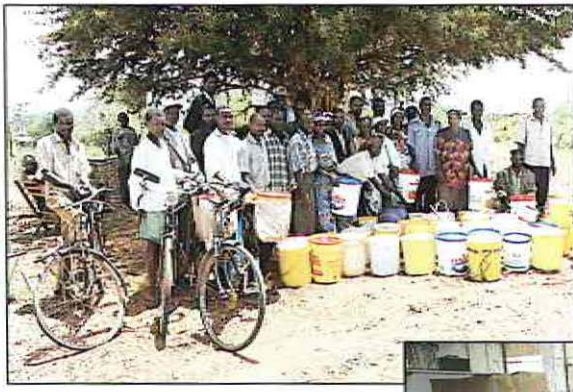


Fig. 30 – Collection of honeycomb from beekeepers in Mwingi district

Fig. 31 – Training of farmers from Mwingi district on honey harvesting, processing, Wax candle making and packaging at ICIPE

Fig. 32 – Honey processing and packaging laboratory

Fig. 36 – Sericulture farmers watch a silk reeling demonstration

CHAPTER IV

ECONOMICS OF AFRICAN WILD SILK FARMING

E.N. Kioko, S.K. Raina, F.K. Kiilu and D.M. Kimbu

Background

In East Africa biodiversity surveys in indigenous forests indicate there are at least sixty different silkmoth species in the wild. Preserving and utilising these silkmoths for the production of silk fibres will generate income for the resource-poor farmer, as well as conserve threatened natural forests (Kioko, *et al*, 2000).

In Kenya, two wild silkmoth species, *Argema mimosae* and *Gonometa sp.*, from two Lepidopteran families, Saturniidae and Lasiocampidae, respectively, were found, which produced silk fibre of high quality.

Biology and population trends of wild silkmoths

A case study in Kenya

The biology and population fluctuations of two wild silkmoth species found in two different locations in Kenya were evaluated: *Argema mimosae* from Sultan Hamud (Fig. 23, page 54), and *Gonometa sp.* from Mwingi District (Fig. 24, page 54). Both wild silkmoth species have two generations per year. The emergence of the adult moth was synchronised with the sprouting of new leaves on the host plant. The bloom period was influenced by prevailing weather conditions.

The moth flight period of the first generation occurred between March and April 1998, and the flight period of the second generation occurred between September and November. The larval stages of *Gonometa sp.* and *Argema mimosae* required 50-70 days to complete the life cycle (Fig. 25 page 54 and Fig. 26, page 55), and during this time, the overall mortality of the larval instars due to parasites, predators, and other factors, was 84%. The major cause of mortality was egg and pupae parasitism (Figs. 27a and 27b, page 55). The incidence of parasitism of *Gonometa sp.* was decreased by 35-55% through the use of net sleeves. Local farmers require, and are learning wild silkworm rearing techniques, which will decrease silkworm losses due to natural enemies and increase productivity.

In Kenya, from Sultan Hamud and Mwingi District, the quality of silk produced from *Gonometa* and *Argema* cocoons was evaluated and compared favourably with the quality of silk produced from wild silkmoths elsewhere in the world (Akai, *et al*, 1997). Fresh field cocoons were collected and evaluated with respect to cocoon weight, size, and length (Tables 41 and 42) (Kioko, *et al*, 1999).

Table 41. Weight and size of cocoons of *Gonometa sp.* and *Argema mimosae* (means ± SD)

Species and sex	Cocoon weight (g)	Cocoon length (cm)	Cocoon width (cm)
Gonometa sp. females	8.45 ± 1.47	5.72 ± 0.35	2.39 ± 0.12
Gonometa sp. males	3.47 ± 0.53	3.99 ± 0.18	1.72 ± 0.16
A. mimosae females	6.04 ± 0.96	5.4 ± 0.45	2.43 ± 0.29
A. mimosae males	4.95 ± 1.3	3.92 ± 1.23	2.24 ± 0.96

Table 42. Comparison of cocoon weight, and cocoon shell weight and shell ratio % in *Gonometa sp.*

Sex	Cocoon weight	Cocoon shell weight	Shell ratio %
Females	8.5 ± 1.6	1.8 ± 0.4	21.9 ± 2.2
Males	2.8 ± 1.0	1.2 ± 0.7	35.1 ± 16.9

An examination of the silk cocoons indicated that *A. mimosae* cocoons were not reelable but could be spun. *Gonometa sp.* cocoons were easily reeled and gave a firm golden brown silk fibre (Fig. 28, page 55). Single cocoon reeling data indicated that 2325 female cocoons and 4,762 male cocoons were required for one kg raw silk. On average, 3544 *Gonometa sp.* cocoons were required for 1 kg of raw silk.

Economics of wild silk farming

In countries where rural communities depend on subsistence farming, wild silkmoth farming can be a supplementary activity for income generation while conserving biodiversity. To establish a wild silkmoth farm, it is necessary to identify a piece of land where silkworm host plants grow. There should be at least 500 plants. A 3 x 3m thatched hut is needed for seed cocoon storage. Seed cocoons are used to obtain moths, which lay eggs for the next rearing. To protect young silkworms from predators and parasites, fine net sleeves are requi[illegible] (Raina, *et al*, 1999).

For the production of silk cloth, farmers may sell their cocoons to a silk processing organisation, or form a cooperative that would purchase a manual reeling machine to process cocoons and a loom for weaving cloth.

Wild silkmoth farming

Before rearing starts, the rearing site and surrounding area should be cleared of weeds and bushes to reduce shelter for pests and predators. Wasp and ant nests should be removed from host plants. Natural pesticides, such as neem, should be sprinkled around the base of host trees to prevent attack by ants and other arthropods. In March, at the beginning of the long rains in Kenya, moths emerge and lay eggs. On average, one female lays 400 eggs. Of these, approximately 50% survive to the cocoon stage. A two-hectare plot containing 1000 host plants, should produce at least 200,000 disease free cocoons. The young instar larvae require tender leaves, whereas advanced larval stages prefer medium to mature leaves. In April to June, silkworms are reared on the trees in the field. In July, silk cocoons are harvested from the farm and preserved in a well-ventilated thatched mud hut. In October, the field is again prepared for distribution of young larvae (Table 43 opposite).

Table 43. Calendar of activities for farming of *Gonometa sp.* in Mwingi district of Kenya

Month	Activity
February	clearing fields and preparation of host plants
March/April	moth emergence and egg production
April/June	rearing
July	harvesting
September/October	clearing fields and preparation of host plants
October/November	moth emergence and egg production
November/January	rearing
February	harvesting

Using Mwingi, Kenya, as a case study, it was shown that 2 hectares (5 acres) of land contained 1,000 *Acacia* trees on which the wild silkworm *Gonometa sp.* thrived. One tree (with a canopy 8-10 cubic feet) could support up to 200 larvae. One thousand trees each supporting 200 cocoons, yields a total of 200,000 cocoons worth in total US $3,333. The value of each cocoon is US $0.0167. In this semi-arid region, there are two wild silkmoth crops a year, which yields an income of US $6,667/2 hectare/year (Tables 44 and 45).

Table 44. Calculated income in US dollars based on the data of one seasons per year (labour cost included)

Item	Expenditure (A)	Item	Income (B)
Maintenance of two hectare of 1000 host plant	10 days/season at US $1.66/day = US $16.7	Sale of cocoons	200 cocoons x 1000 trees = 200,000 cocoons/season. (1 cocoon @ 6.7 cents) or US $3,333
Eggs	$16.7	Net income	(B-A) 3,333-892 = $2441/season.
Hut	$ 66.66		
Training	$33.33		
Nets for early instar rearing	0.5 m/tree for 1000 = $625.00		
Labour for rearing	60 days/season =$50		
Total	**US $ 892)**		

Each family obtains US $1213 per season Each person gets US $152 per season

Two hectares supports 2 extended families each consisting of 8 people.

Table 45. Calculated income in US dollars based on the data of one season per year (labour cost not included as a family enterprise)

Cost (A)		Income (B)
Fixed cost	***Variable cost***	***Income for one season***
2 hectares (family land of 8 persons) with 1000 Acacia trees	Net sleeves* $616.66	Sale of 200000 cocoons = $333
Thatched hut $166.66	Eggs $16.7	A = $836.66
Training costs $33.3	laying bowls/cups $3.33	B = $3333.33)
Total $200.00	Total $636.66	Net Income (B-A) = $2497
		Household $1248.33/season
		Person gets $156.04/season

* Net sleeves can be reused in the second season.

To produce 1 kg of raw silk, 3,544 *Gonometa* cocoons are required. In one season, a two-hectare plot of land with 200,000 *Gonometa* cocoons will yield 56 kg of raw silk. The estimated selling price of raw silk is US $30/kg. The number of cocoons and revenue generated by each household is given in Tables 46 and 47.

Table 46. The marginal physical product for cocoon production

Number of people employed	Cocoon production in cocoons/season	Output* of cocoons in numbers/season	Marginal physical product (MPP)/season	Average physical product (APP) in cocoons/season
0	0	0	0	0
1	78562	78562	78562	78562
2	132143	132143	53581	66072
3	200000	200000	67857	66667
4	250000	250000	50000	625000

* Output depends on favourable weather conditions

Table 47. Marginal Revenue Product for cocoon production (US $)

Number of people employed	Marginal physical product, MPP (cocoons/season)	Price of 1 cocoons (P)	Marginal revenue product MRP = MPP x P
0	0		
1	78562	$ 0.0167	1,309.36
2	53581	$ 0.0167	893.02
3	67857	$ 0.0167	1130.95
4	50000	$. 0.0167	835.00

The variable costs incurred in rearing wild silkworms include: cost of material for net sleeves (US $1.25 per m), egg laying cups (US $3.33/season), and seed cocoon for eggs (US $0.0167/tree. The fixed costs include the building of the rearing hut and land (US $1667 is assumed). Labour costs are not included as this is an activity for the farming family. The cost structures associated with wild silkmoth farming are given in Tables 48 and 49.

Table 48. Cost structure of the wild silk farm

Number of workers from a firm family	Total output of cocoons (Q) (cocoons/season)	Marginal Physical Product (MPP) (cocoons/season)	Average physical product (APP) (cocoons/season)	Fixed cost (FC) (US $)	Variable cost (CV) (US $)
0	0	0	0	200.00	0
1	78562	78562	78562	200.00	253.33
2	132143	53581	66072	200.00	426.45
3	200000	67857	66667	200.00	636.66
4	250000	0	625000	200.00	636.66

Table 49. Optimal profit from the wild silk farm (US $)

Number of people employed	Output of cocoons (Q)	Price of 1 cocoons (P)	Marginal revenue product MRP, MPP x P	Total revenue TR = P x Q	Total Cost TC=FC+VC (US $)	Total profit TP=TR-TC
1	78562	$0.0167	1,309.36	1309.36	453.33	856.03
2	132143	$0.0167	893.02	2202.38	626.45	1575.93
3	200000	$0.0167	1,130.95	3333.33	836.66	2496.67
4	250000	$0.0167	835	4166.67	836.66	3330.00675

Wise management of the natural resources and proper farm training to the farmers can conserve the habitat of the threatened silkmoth species and their utilisation for silk production can generate additional revenue.

CHAPTER V

MARKETING OF APICULTURE AND SERICULTURE PRODUCTS

THE BASIS OF MARKETING

D.M. Kimbu, S.K. Raina, V.V. Adolkar, E.N. Kioko

In East Africa, overexploitation of natural biological resources is a major threat to sustainability. Apiculture and sericulture are two activities that simultaneously protect the environment while generating income for the rural population. To sell honey, other bee products, and silk cloth there must be a willing consumer and a market where commodities can be sold for a profit which is in part, returned to the producer.

Marketing is that aspect of business which identifies unfilled needs and wants, defines and measures the magnitude of those needs, and determines how to supply those needs. Marketing is a link between a community's needs and an industry's response to those needs (Kotler, 1999).

In business, controllable variables include: product planning, pricing, distribution, promotion and marketing research. These variables can be manipulated to achieve marketing objectives. Non-controllable variables include environmental factors, such as economic, political, legal, geographical, social, competitive and technological circumstances, which facilitate or hinder the marketing of goods. These factors in turn, affect the controllable variables.

APICULTURAL MARKETING IN KENYA

In Kenya, the use of honey is widespread. It is used as a natural sweetener instead of sugar in baking and eating. Honey is used to brew an alcoholic drink consumed during traditional ceremonies. Honey is also a component of human and livestock medicine.

Regions where beekeeping is an habitual cultural activity were identified in Kenya and include: Kitui, Baringo, Mwingi, and Pokot. Two districts, Baringo and Mwingi, were selected as case studies to develop a honey marketing strategy. In these regions, beekeeping is done traditionally. The honey is harvested in a manner that results in high bee mortality, which weakens the colony. The honeycomb is crushed and the liquid sieved by squeezing, a process which contaminates the product with dead bees, pollen and honeycomb. The honey is then bottled and sold on the roadside by brokers (Fig. 29, page 55). Honey harvested in this manner does not meet the international standard and cannot be marketed. The honey ferments early and becomes unfit for human consumption. Thus, traditional beekeepers would benefit economically by learning modern methods of apiculture, which would enhance the quality and quantity of honey produced.

The saleability of honey is a reflection of its quality, which in turn is affected by the flora from which the honey is derived. Some flowering plants produce dark honey, which generally commands a lower price than lighter coloured honey. To maximise profit, honey packers could blend honeys of different grades (from different floral origins) to produce a light coloured honey.

The yield of honey and other hive products is a consequence of environmental conditions which include: ambient temperature, humidity, forage, soil fertility, wind, and rainfall. These factors are uncontrollable and affect the secretion of nectar of flowering plants, which in turn affects honey flow. For this reason, from year to year, the yield of honey is neither consistent nor predictable.

However, honey yields are maximised when hives are maintained at their maximum strength. In a healthy hive, productive queens are used, appropriate supplementary feeding is provided, and the brood is maintained in a stress free state.

Generating the product, in this case honey, is the initial step in marketing. If the production of honey is high and exceeds the local demand, the surplus product can be profitably marketed.

To sell honey, it must first be transported to the market. In Kenya, beekeepers are scattered in the countryside, and it is difficult to transport honey to locations where it will be sold. The current export market is competitive and importing countries have strict quality requirements concerning honey flavour, colour, biochemical consistency, and floral origin.

Table 50. ICIPE standard Price for purchase of honey from beekeepers

Type of honey	Amount in US $/kg
Comb honey from Traditional hive	$1.33
Comb honey from Langstroth hive	$1.67
Good refined liquid honey	$2.00

To assist with marketing, ICIPE buys honey from rural beekeepers (Table 50). While the price for sealed honeycomb is fixed, the price is reduced if the combs are old or broken.

To introduce modern beekeeping to rural Kenya, ICIPE organized a number of self-help groups in Baringo (Radat), Uasin Gishu (Eldoret) and Mwingi Districts, in Kenya. The production of honey in these regions, and the money generate is shown in Fig. 30 (page 56) and Table 51. (*Note:* In the process of selling ICIPE processed honey on behalf of beekeepers, the selling price varied from year to year.)

It is difficult for Kenya to export honey because of the high cost of honey collection, transport and storage, which raises the export price. In addition, the inconsistent and irregular supply of honey causes a serious marketing problem.

Organization, coordination and training

Beekeepers scattered across every district in Kenya were mobilised and educated by ICIPE apiculturists on the importance of forming groups for the collection of honey and the transfer of information and technology. Methods for marketing products without using middlemen and brokers were introduced. The rural beekeepers received one day training in the laboratory, and in their fields.

In selected districts, ICIPE established centres where beekeepers in the field could transport their honey for collection. At these centres, the beekeepers received practical training on methods to harvest comb honey from traditional hives without contaminating the honey with bees, brood and pollen combs. The beekeepers were given clean plastic containers for storing honey for transport.

ICIPE established a honey collection schedule at these centres. On a given day, beekeepers in the surrounding area were instructed to deliver their honey to the centre for payment. At the centre, the honey was inspected for quality, and weighed. The beekeeper was paid immediately for the amount of honey produced.

There were numerous difficulties with this system. Some beekeepers were transporting as much as 100 kg of honey a distance of 20 km by foot, bicycle, or donkey. In some instances, ICIPE staff were unable to reach the collection centre and beekeepers could not sell their honey. In other instances, during good seasons when a lot of honey was collected, the money was spent before all beekeepers were paid.

To address these problems, beekeepers will be assisted in constructing honey storage facilities at the collection centres. Thus, the beekeeper can drop his honey at the centre and receive a receipt which can be honoured at a later date. Beekeepers throughout Kenya were encouraged to form co-operatives as a means to collect and distribute their honey.

Table 51. Beekeepers Production in the field in 1997 – 2000

Date	Group & Location	Type of honey purchased	Qty/kg	Amount (US $)	Sales (US $)	Gross profit (US $)
Aug-Oct 1997	Imba beekeepers S.H.G, Mwingi	Comb	377.5	490		
June 1997	Mathyakani Joint S.H.G, Mwingi	Comb	333.25	444		
Oct 1997	Sambut S.H.G, Eldoret	Comb	62.50	83		
Sub-Total			**773.25**	**1017**	**1209**	**192**
Feb 1998	Imba beekeepers S.H.G, Mwingi	Comb	15.00	20		
Mar 1998	Katuuni beekeepers S.H.G, Mwingi	Comb	9.00	11		
Mar 1998	Kathiani beekeepers S.H.G, Mwingi	Comb	9.00	11		
Mar-Apr 1998	Baringo beekeepers S.H.G, Baringo	Liquid	4165.00	8,281		
Mar-Dec 1998	Sambuti beekeepers S.H.G, Eldoret	Comb	74.50	99		
Nov 1998	ABESO, Arusha, Tanzania,	Comb	138.50	200		
Sub-Total			**4411.00**	**8622**	**10494**	**1872**
Jan-Feb 1999	Baringo beekeepers S.H.G, Baringo	Liquid	510.50	672		
Feb-May 1999	Mathyakani Joint S.H.G, Mwingi	Comb	647.00	863		
Mar 1999	Embu beekeepers S.H.G, Embu	Comb	13.00	17		
Apr-May 1999	Katuuni Beekeepers S.H.G, Mwingi	Comb	1214.00	1619		
Mar-May 1999	Imba beekeepers S.H.G, Mwingi	Comb	858.00	1144		
Apr-May 1999	Kathiani beekeepers S.H.G, Mwingi	Comb	1615.00	2153		
Apr-July 1999	Ngaani Beekeepers S.H.G, Mwingi	Comb	1936.50	2582		
Apr-May, 1999	Itiva Nzou Beekeepers S.H.G, Mwingi	Comb	1363.50	1818		
Sub-Total			**8156.50**	**10868**	**28720**	**17852**
June 2000	Embu beekeepers S.H.G, Embu	Comb	59.75	80		
Feb-Apr 2000	Mathyakani Joint S.H.G, Mwingi	Comb	422.50	553		
Feb-Apr 2000	Katuuni Beekeepers S.H.G, Mwingi	Comb	571.00	761		
Feb-Apr 2000	Imba beekeepers S.H.G, Mwingi	Comb	473.00	631		
Feb-Apr 2000	Kathiani beekeepers S.H.G, Mwingi	Comb	1153.25	1538		
Feb-Apr 2000	Ngaani Beekeepers S.H.G, Mwingi	Comb	1497.00	1996		
Feb-Apr 2000	Itiva Nzou Beekeepers S.H.G, Mwingi	Comb	1127.00	1503		
June 2000	Kathiani beekeepers S.H.G, Mwingi	Comb	424.00	565		
Sub-Total			**5245.25**	**7627**	**13113**	**5486**
TOTAL			**18,586.00**	**28134**	**53536**	**25402**

From June 1997 – 2000, beekeeper groups produced 18.586 tonnes of honey comb. The data were collected from six different groups in Mwingi district and one group from Baringo, Embu, Eldoret districts, Kenya, Arusha in Tanzania and Kampala in Uganda. The total amount of honey produced in four years then valued US $28,134. Total sales for 4 years processed honey was US $53,536. Total revenue generated was US $25,402.

Post-collection processing

ICIPE has established a processing unit for comb honey. Collected honeycombs are brought to ICIPE and examined, weighed and stored. For processing, combs are placed in frames, which are fitted to an extraction machine, which removes honey from the combs. The extracted honey is heated to 40°C in a water jacketed processing drum for one hour. The liquid is refined by sieving until it is clear. It is then bottled and labelled for sale (Fig. 31, page 56).

The beeswax of the empty combs is refined and used in candle manufacturing (Fig. 31, page 56).

Each batch of honey processed is tested for quality at the control laboratory. The honey is examined for moisture, free acid, pH, simple sugar, and enzyme content. These levels are listed on the container label. The label also contains the floral type that provided the source of bee nectar. The honey is bottled in containers that hold 470 gm, and in bulk (Fig. 32, page 56).

Locally, honey consumption is very high and it is sold to individuals and supermarkets. There is a need for honey in the production of yoghurt and baked goods. The international market is open but table honey production in Kenya is less than the large quantity of industrial grade honey produced.

ICIPE has developed a strategy to produce, process, and market honey, which entails mobilising beekeepers to form co-operatives. ICIPE has been training beekeepers from these co-operatives in harvesting, processing and marketing of honey so that the technology can be taken over by the local beekeepers themselves. In four years time, the co-operative will achieve self-sufficiency in these initiatives, so that ICIPE will no longer be involved (Fig. 33 opposite).

Pricing of honey

The value of honey and other hive products is influenced both by production and market factors. Consumer demand is affected by honey quality, price, competition, and consumer income. Managers exert a positive influence on profit by maintaining a high quality product. Domestic honey prices are closely correlated with export (large quantity) market prices. When setting the price of honey for sale, a number of parameters must be considered, which include: labour, start-up and running costs, product transport costs, and demand.

To enhance the efficiency of honey production, co-operatives in rural areas can be established which would transfer information and new technology to small land-holders, as well as improve means to collect and transport honey for commercial sale. The employment of local people (capacity building), and the use of local materials and natural resources, will serve to protect the environment and improve the standard of living of subsistence farmers.

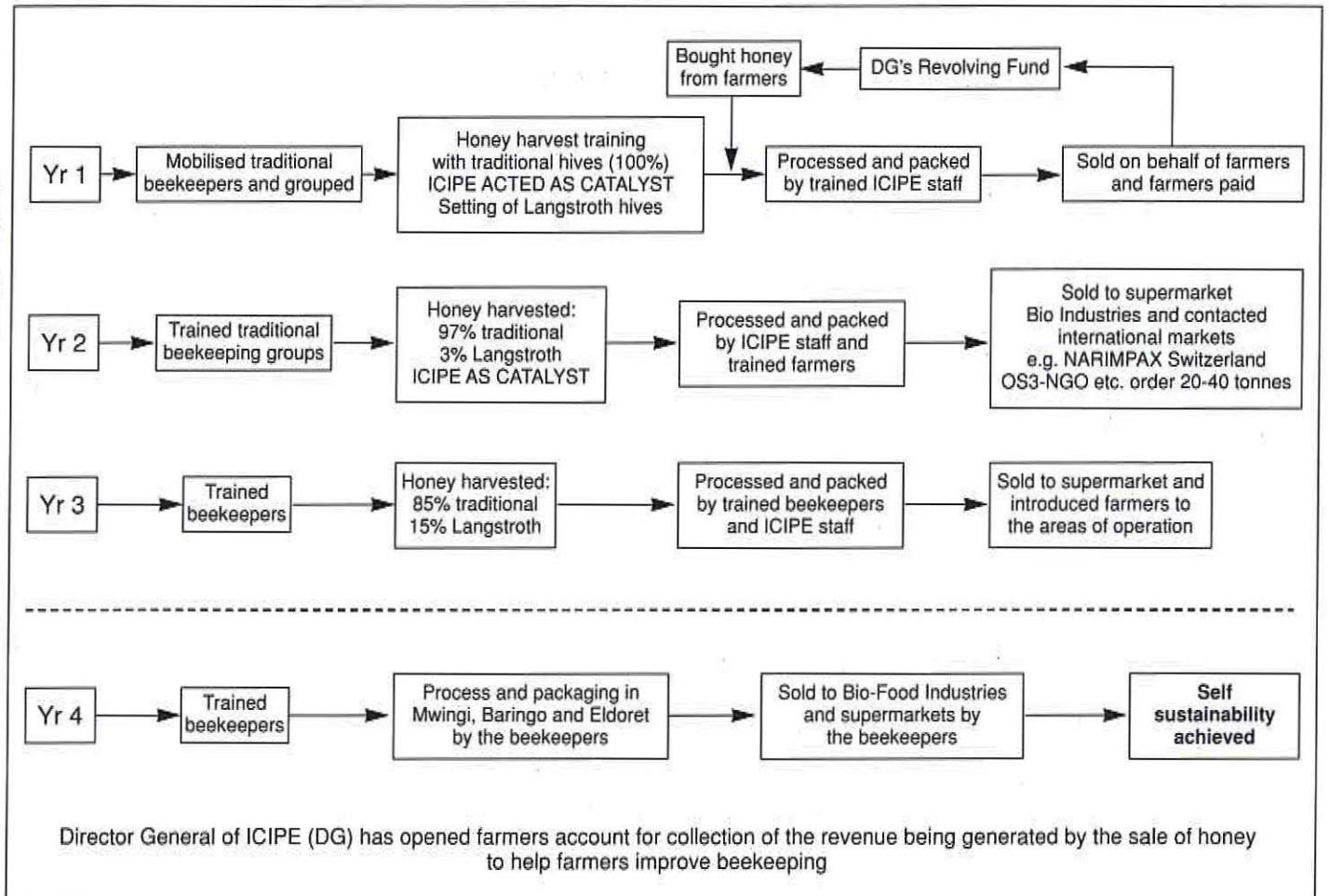


Fig. 33 – Marketing strategy for beekeeping; ICIPE model

Marketing – Strength, Weakness, Opportunity, and Threat – Analysis (SWOT Analysis)

Strength: The success of producing a commodity for high profit depends upon a number of factors. The expertise of the producers determines the quality and quantity of product harvested. Capacity building, or the empowerment of local rural farmers to learn and apply new apiculture technology, increases producer strength. It is also important to find a steady, willing market that accepts and sells honey. Such markets may include local grocers, supermarkets, bakeries, hotels, airline companies, and international exporters. Low production costs and high quality products strengthen honey marketability.

Weakness: A number of factors negatively affect honey sales. A dearth of beekeepers, poor equipment, a lack of apicultural experience, too few extension staff, an absence of centralised honey collection centres and low start-up funds all inhibit honey production. The successful marketing of honey is hampered by low quality product, inadequate transport, and insecurity in rural regions. The sustainability of apiculture through the seasons is inhibited by poor capacity building and an over-dependence on outside funding and expertise.

Opportunities: Opportunities in honey production and marketing are those areas which can be positively exploited to increase honey saleability. Currently, Kenya needs more trained apiculturists capable of raising bees to produce a high quality honey and a high quantity of hive products. More co-operatives need to be established to get apiculturists together to share information and equipment.

Threats: Any new industry is threatened by instability. The withdrawal of external funding and assistance can impede production and squander limited resources and funds spent on establishing apiaries. Climatic catastrophes such as too much or too little rain, can have a disastrous effect on honey production and farmer moral. High productivity of honey and hive products which then have no market and go to waste, also threatens a fledgling enterprise. These issues need to be addressed to galvanise rural farmers into becoming apiculturists (Reid and McCaw, 1994).

SERICULTURE IN EAST AFRICA

Introduction

Sericulture is a new technology for most of the African continent. While the cultivation of mulberry and the production of silk cocoons are agricultural practices, the reeling and spinning of raw silk are cottage-based industries. From egg-rearing to silk cloth production there is a long chain of specialised operations that provide employment for a large number of people (Fig. 36, page 56).

The marketing of silk cloth as a luxury commodity in Africa presents unique challenges. The local market is limited to wealthy Africans, Europeans and Asians. Thus, for maximum profitability, silk cloth of export quality for the international market needs to be produced. There is a current demand for high quality raw silk in the world market, which provides an opportunity for Africa to penetrate the international silk business. Improved sericulture technologies practised by rural farmers for the production of high quality silk cloth will generate additional income and protect dwindling natural resources.

Research and evaluation

Mulberry silk farming

Mulberry silk farming is a newly introduced technology in Kenya and East Africa. Since it is not a traditional practice, there is not much local expertise. There is also little government assistance to the sericulturist, and limited markets for silk products. Scientists at ICIPE have been working in Kenya to address these constraints. Regions throughout the country that are suitable for the growing of mulberry and silkworms were identified and found to be widespread in the western, central, and eastern parts of the country.

Mulberry silk farming involves a variety of activities, which include: growing mulberry bushes, rearing silkmoths, processing silk fibres, and producing silk cloth. Technical advances have been made in rearing disease-free plants and worms, and processing and protecting silk cocoons. These practices have collectively produced a higher quantity and quality of silk. Introducing these advances to rural farmers will improve silkworm production and augment income generation.

Production of silk cocoons and marketing

A silk cocoon is the product of mulberry silk farming. Environmental conditions such as rainfall, temperature and humidity, affect mulberry growth and silk cocoon production. A silk cocoon harvest can be maximised through the use of high yield, disease resistant, bivoltine silkworm breeds, as well as the use of high yield, drought resistant mulberry varieties.

Despite new technology, the yield of silk cocoons produced per season is unpredictable. In a good season, a large number of cocoons may be produced, whereas in a bad season, the number of cocoons produced may be low. The seasonal fluctuation in silk cocoon production negatively affects the industry, which in turn, negatively affects cocoon saleability. To promote the practice of sericulture, ICIPE stabilised its price of purchase for locally grown cocoons. However purchase prices did depend upon cocoon quality (Table 52, page 70).

Table 52. Cost of silk cocoons based on grades

Particulars	Grade	Cost/kg (US $)	Cost/ton (US $)
Wet/Fresh Cocoons	A	4.17	4,167
	B	3.33	3,333
	C	2.50	2,500
Dry Cocoons	A	4.17 x 2.5	4,167 x 2.5
	B	3.33 x 2.5	3,330 x 2.5
	C	2.50 x 2.5	2,500 x 2.5

To introduce sericulture in East Africa ICIPE has organized a number of self-help groups through collaboration with government extension and national programmes. The production of silk cocoons by farmers in Kenya and Uganda and processed material by ICIPE during training of farming community is highlighted in Tables 53 and 54.

Table 53. Production of silk cocoon, fibre and finished products and development of marketing outlet for sericulture farmers in East Africa.

Purchase of silk Cocoons	Unit	Unit cost/kg (US $)	Total cost (US $)
KENYA			
1998	100 kg	4.1	410.00
1999	300 kg	4.1	1230.00
2000	600 kg	3.6	2160.00
UGANDA			
1998	300 kg	4.1	1230.00
1999	700 kg	4.1	2870.00
			7900.00
	SALE OF SILK FABRIC		
	1998		
SHIRTS	37	28.00	1036.00
SCARVES	18	10.00	180.00
MATERIAL	7 metres	5.8	41.00
	1999		
SHIRTS	5	26.00	132.00
SCARVES	10	5.4	54.00
MATERIAL	161.75 metres	10.00	1612.00
	2000		
SHIRTS	3	33.3	100.0
SCARVES	6	16.00	96.00
MATERIAL (Plain/Dyed/Screen Printed)	103.5 metres	14.4	1485.7
			4736.7

Table 54. Farmers stock in hand (silk cocoon, fibre and fabric)

Particulars	Kg/metres	Cost (US $)
Silk cocoons	519	2128.00
Raw silk(untwisted fibre)	19	665.00
Twisted yarn	86	3440.00
Bleached /dyed silk yarn	17	65.00
CLOTH	135	1350.00
		8348.00

NOTE: **a** Expenditure on raw material (silk cocoons) = US $7900.00

b Income from sale (silk garments and cloth) = US $4736.7

c Current stock in hand (cocoon, fibre and fabric) = US $8348.00

GROSS PROFIT = (b + c - a)

= US $4736.7 + 8348.0 - 900.0

= US $5184.7

Organization, co-ordination and training

ICIPE developed a strategy to market cocoon and silk products. To enhance capacity building among farmers, trained sericulturists went to the field to educate rural people on the growing of mulberry and production of silk cocoons. To stimulate the industry, for two seasons, farmers were given one to two boxes of silkworms (25,000 – 50,000) free of charge to rear. After the first year, the farmers were charged 10% of their production profit for seed material.

In Kenya, in the Bondo District and the Central Province, sericulturists established strong links with silk farmers and provided training. A central meeting place was selected where experienced sericulturists and farmers could get together to solve problems and transfer new technology.

In the Nyeri district of Kenya, two centres were established at Naru-Moru and Laikipia. In these centres, farmers grow mulberry and bring leaves from their fields to where the silkworm rearing takes place. There are currently approximately 20 farmers associated with each centre. Through training, it is envisaged that the farmers will eventually rear silkworms independently on their own farms.

The production of silk cocoons in Kenya was 500 kg in 1998-99. With modern technology, 360 kg of cocoons should be produced on a one-acre farm in one year. Through increased awareness and training these centres plan to produce to 2 to 3 tons of cocoons a year.

Post-cocoon operations

Silk cocoons are purchased from the farmer groups in wet form or dry form. The cost of the cocoons is fixed on the basis of quality, which is determined by visual examination, cocoon weight and filament length. The farmers are paid immediately for their produce.

The cocoons are then transported to the sericulture laboratory at ICIPE (efforts are being made to establish reeling centres in the areas where the cocoons are produced). Dried cocoons are stored in cotton or gunny bags and placed in a dry and well-ventilated room. The wet cocoons are passed through dryers and stored once they are completely dry. Correct storage of cocoons is important to avoid mould and mechanical damage.

Cocoon processing

Currently, most silk cocoons produced in Kenya are processed at the sericulture facility at ICIPE. In this process, the silk filament, which comprises the cocoon is unwound. The filaments are re-reeled, and silk hanks are prepared for weaving into silk cloth.

ICIPE houses two reeling machines, one is cottage based and the other is a semiautomatic machine with a re-reeling capability. The semiautomatic reeler can process 10.5 kg of fresh cocoons per day. The reeled filament is re-reeled onto standard diamond reels and made into skeins. A bale (60 kg) or 6 loose skeins (1kg) can be sold on the international market.

To make silk cloth, the twisted, doubled yarn is degummed, bleached, and dyed, then warped and woven the yarn is processed without degumming to the cloth stage and bleached afterwards. A power loom or hand loom is used to weave the yarn into cloth, which is then sold on the local or world market.

A five-year model for mulberry silk farming in Kenya is shown in Fig. 34, page 73. Within this time frame, farmers throughout the region will receive training on silkworm rearing, as well as cocoon harvesting and silk fibre processing. Within five years, the silk farmers should become self sufficient and ICIPE will no longer play an active role in commercial sericulture.

Wild Silk Strategy

Wild silk research has been completed although farming has not yet reached a marketable level. Efforts are at hand to mobilise the farmers groups and initiate large scale wild silk cocoon production. The first validation trial has been conducted in Mwingi district with 6 farmers groups and result are awaited. A model for wild silkmoth farming is shown in Fig. 35, page 74.

Pricing of silk

The price of silk products is influenced by the local industry and the international market. The demand for silk is a function of its price, consumer income, competition and quality. Managers enhance silk product profitability by maintaining silk fabric quality.

The quality of the silk cocoon and silk cloth produced, depends upon mulberry variety and silkworm race used. The multivoltine silkworm always produces cocoons of low quality, whereas the bivoltine races yield a higher quality silk. Many inexperienced sericulturists loose their cocoon crop during fifth-stage larvae due to disease outbreak.

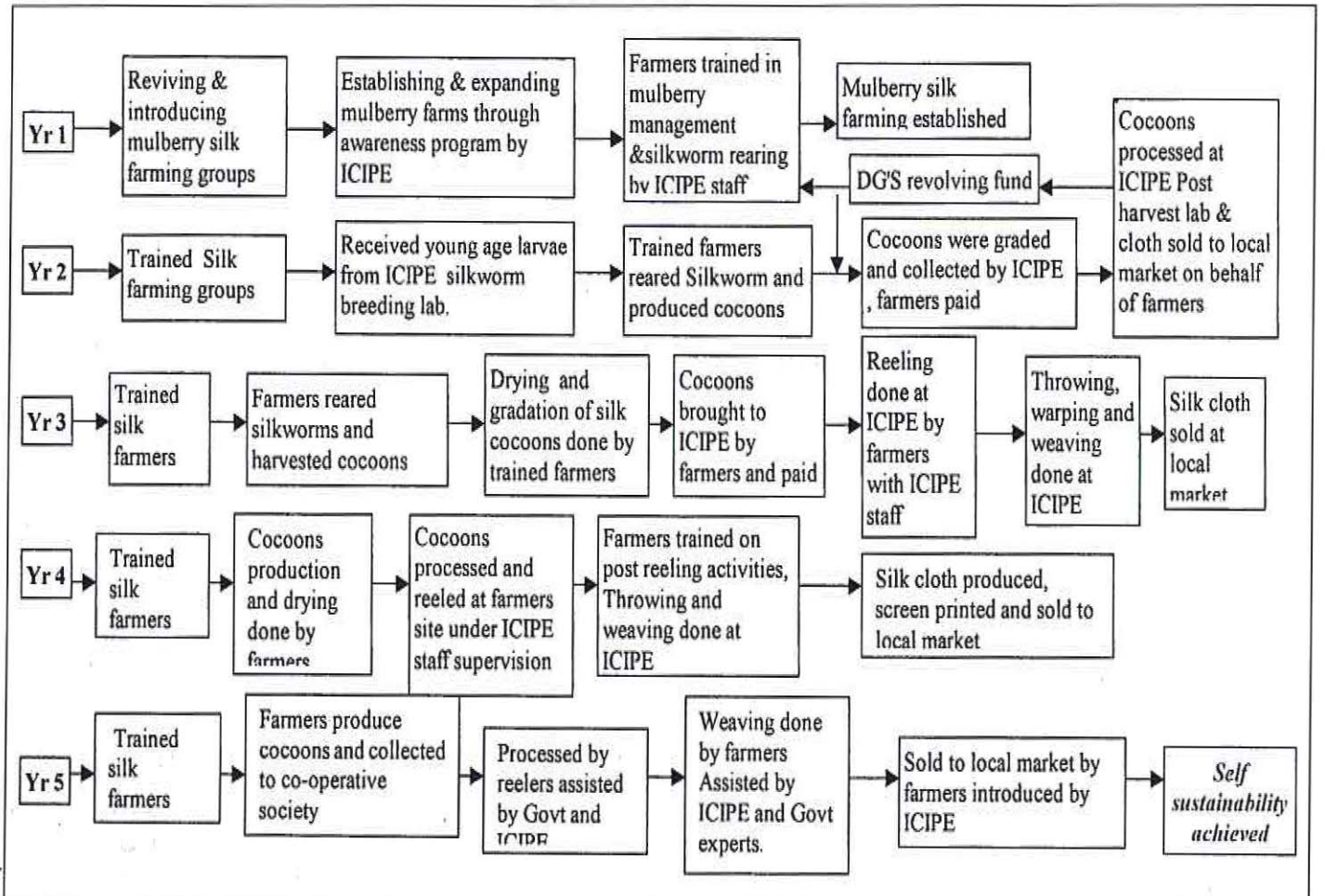


Fig. 34 – Marketing strategy for mulberry silk farming; ICIPE model

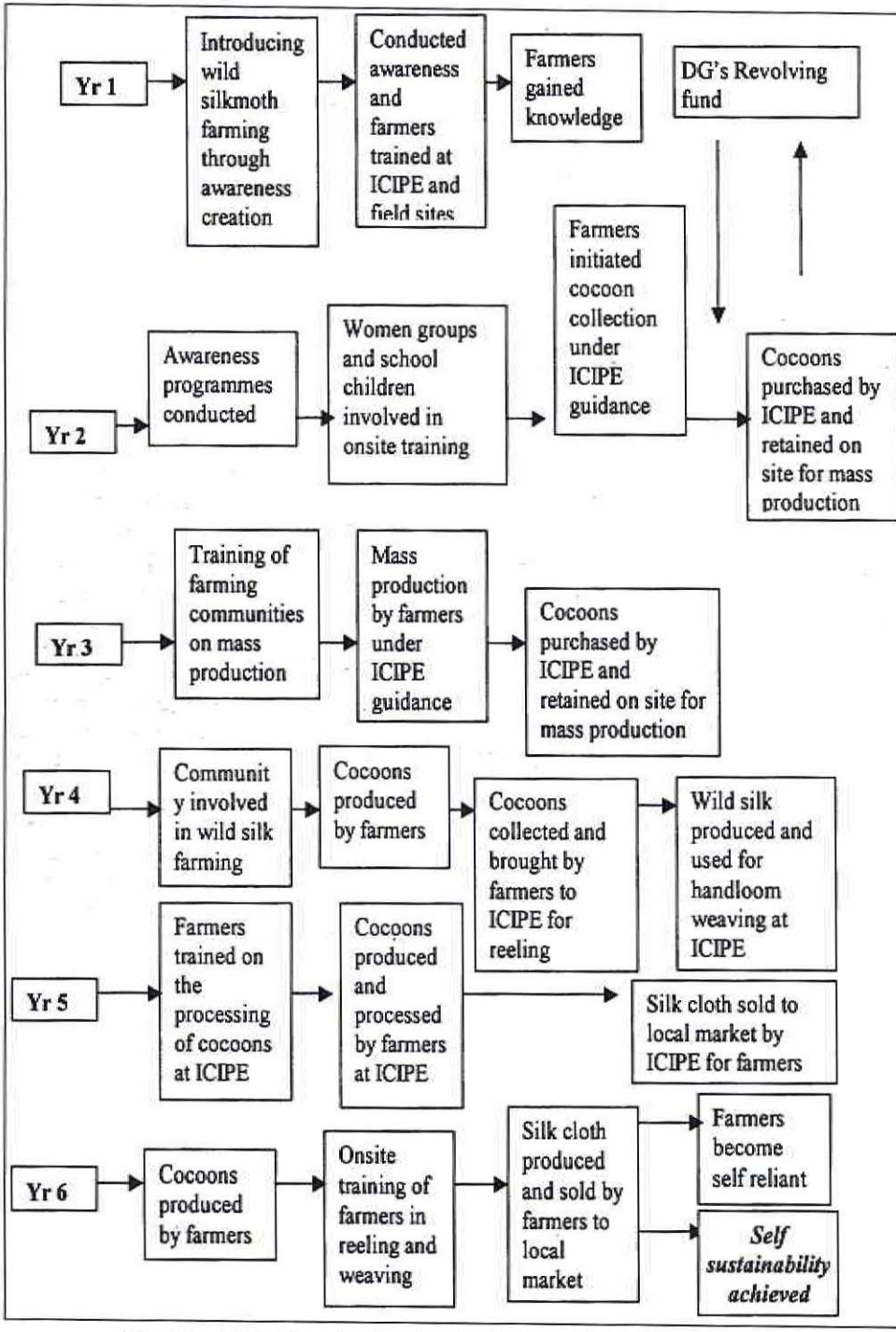


Fig. 35 – Marketing strategy for wild silkmoth farming; ICIPE model

Also after mounting when the cocoons are not dried earlier, emerging moths pierce the cocoon and render it useless for reeling. For high profitability the silk cloth and the manufacturing process must yield a finished product that is of high quality and commands consumer demand. Currently, ICIPE has bought silk cocoons and sold silk fabric at world market prices.

Marketing – Strength, Weakness, Opportunity And Threat – Analysis (SWOT Analysis)

Strength: The saleability of cocoons and silk cloth depends upon the experience of rural sericulturists producing a marketable product. Here, training, extension service, and back-stopping support, bolster and improve silkworm farming. Identifying a ready international market where silk products may be sold, also provides an important incentive for cocoon production.

Weakness: Constraints of silk marketing include a lack of willing rural sericulturists, low awareness of the potential returns of silkworm farming and inexperience with sericultural techniques. At the moment, there is no grainage facility in Africa where silkworm eggs are produced. There is also a negligible number of post-cocoon harvest processing units on the continent. Where sericulture is undertaken, there is often inadequate cocoon storage facilities and problems transporting cocoons for processing.

Opportunities: Numerous opportunities for improving sericulture exist in Kenya and Africa as a whole. The agricultural and climatic conditions in many regions throughout the continent are favourable for silkworm farming. With adequate training and transfer of information, small-holders and poor farming communities can undertake sericulture as an agro-based cottage industry. Sericulturists at ICIPE are promoting this endeavour by introducing silkworm farming to rural farmers in Kenya. Advances and applications in the complete sericulture technology, which range from silkworm egg-rearing to silk cloth production, will provide extensive employment opportunities and substantial income generation to resource-poor farmers.

Threats: The fledgling sericulture industry in Kenya is vulnerable to inadequate funding, lack of applied expertise, and insufficient support from the government and private sector. Climatic hindrances also threaten the industry, as droughts and flooding endanger the food source on which the silkworms feed. The absence of a steady market for silk export would delay remuneration and deter the small-holder from practising rural sericulture. These threats must be addressed in order to generate stability and profitability in the industry.

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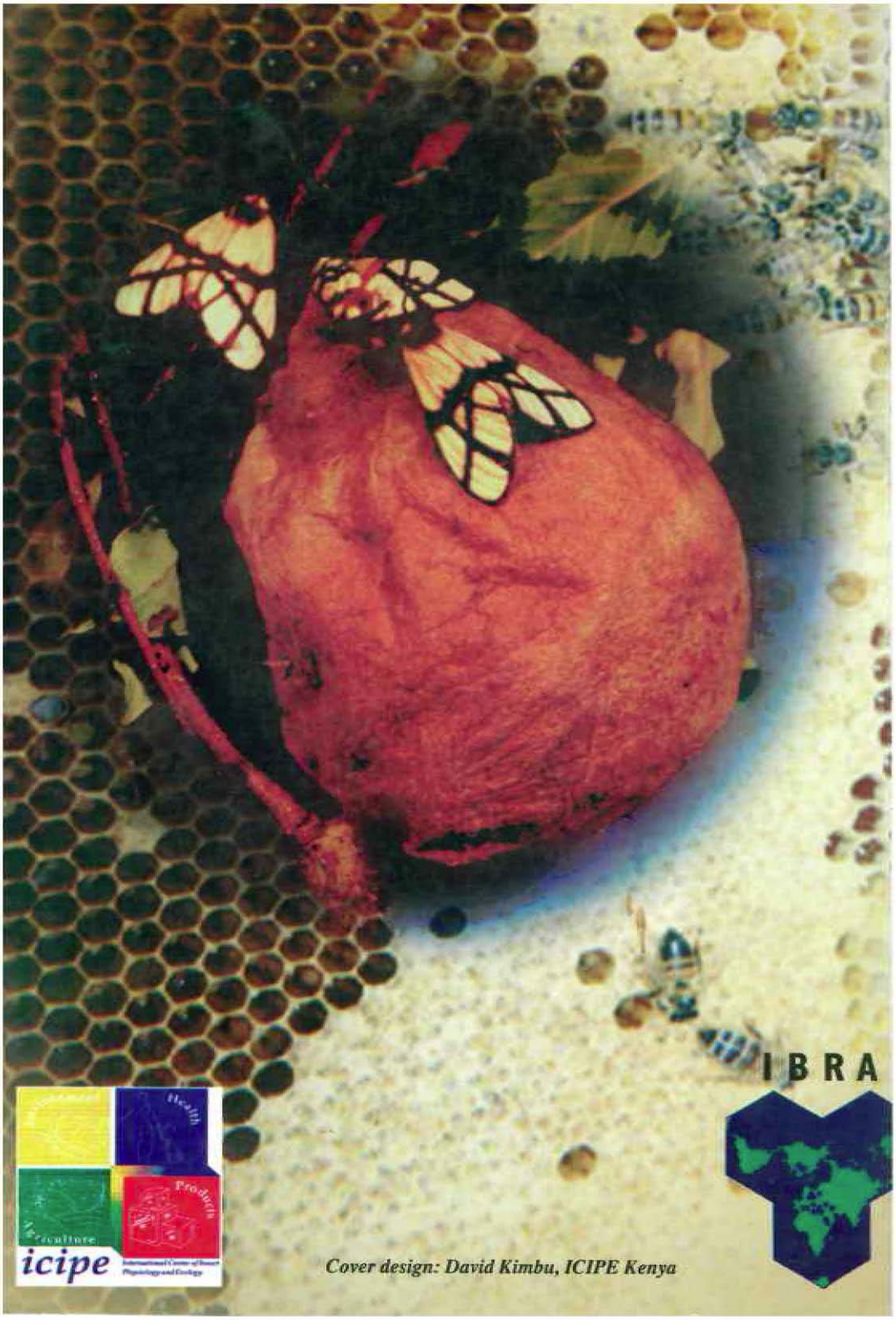

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