THE EFFECTS OF FERTILIZERS AND MULBERRY (*Morus alba L.*) VARIETY ON COCOON AND SILK QUALITY IN KENYA

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DECLARATION

This Thesis is my original work and has not been presented for a degree in any other university

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This Thesis is submitted with our approval as university and ICIPE supervisors

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ABSTRACT

The study was carried out in two sites already with existing mulberry trees comprising three varieties, Kanva , Noi (Thailand), and Embu (local variety). The main objective of the study was to determine the effect of soil fertility and better mulberry varieties (grown locally) on cocoon and silk quality.

The study compared the growth and yield performance of the three mulberry varieties being used by farmers in silkworm rearing. It also involved comparisons of silk production using the three varieties and their quality response due to fertilizer (NPK) and manure treatments. These treatments were applied in 2 sites, ICIPE Farm at Kasarani and Thika government sericulture Farm.

Growth of mulberry varieties due to response of different treatments, NPK alone, NPK and manure, manure alone, and control (no manure and no fertilizer) was determined. Growth measurements were taken in terms of height of shoots; number of shoots, and number of leaves per shoot. Additionally leaf analysis was carried out to compare leaf quality in terms of crude protein and crude fibre due to the different varieties and treatments.

Groups of 50 silk worms were reared with leaf harvests from the different treatments. Larva weights were taken at 4thand 5th instars. After spinning semi wet cocoon weight, dry weight, shell weight, and pupa weight were taken. Silk quality was based on cocoon weight, shell weight, length and weight of silk filament.

These activities were done in two seasons, starting in the short rain season November 2004 to January 2005 and rearing in February 2005. The same procedure was repeated in the long rain season from March 2005 to July 2005 and rearing in August 2005, in order to evaluate the influence of seasonality on the parameters studied. Data was analyzed by Genestat statistical package using analysis of valiance (ANOVA) method. Means were separated by the least significant difference (LSD) according to Gomez and Gomez, 1984 at $p \leq 0.05$. The results showed that there were statistically significant effects of fertilizers and mulberry variety on mulberry growth performance, silkworm larva performance and consequently on cocoon weight and filament length. The cocoon weight was used to illustrate that there were significant effects of fertilizers and mulberry variety on economics of sericulture enterprise, fertilizer and manure giving higher gross margins than controls and Thailand variety giving higher gross margins than Embu variety.

1.0 INTRODUCTION

1.1 General

The World Bank estimates that 1.1 billion people are living on less than US$ 1 per day, and more than twice that number, are living on less than US $ 2 per day (Approtec, 2003-2004). Seventy five percent of the world's poor and undernourished live in rural areas of the developing world. According to the United Nations Food and Agriculture Organization (FAO), these people constitute the base of the pyramid in the socio-economic designation. There are 4 billion individuals who live primarily in developing countries whose annual per capita incomes fall below US$ 1500 (Approtec, 2003-2004). It has been suggested in this report that, if investors at the base of the pyramid could be helped, 200 million people would be lifted out of poverty forever. There is no faster way to develop except to pool our resources, our knowledge and our markets for the development of our economies. In view of this, growth will come from a strong agriculture – driven economy and agriculture will continue to have the greatest impact on food security and poverty in Africa for the sector is the primary engine of economic growth (Approtec, 2003-2004). Mulberry has the potential to play a valuable role in world agriculture. It is a versatile plant that can fulfill a number of roles in smallholder agricultural production. According to Singh *et al.,* (2005), it is estimated that approximately 1.2 billion hectares of land in the world is degraded, barren or marginal and this proportion is increasing every year. Mulberry can survive with rainfall ranging from between 400 - 4,500 mm per annum and optimum temperature 18-30^{0}C but survives beyond 48 or below 0 ^{0}C.

The cultivation of mulberry, a hardy plant that can thrive in most soils climates, diversifies on traditional cash crops. The rearing of the domestic silkworm, which feeds on mulberry, is profitable as economic returns to farm are more frequent than other crop production systems, since four to five silkw cocoon crops can be harvested annually (Raina, 2000; FAO, 1978).

Silkworm cocoon harvest can be maximized through the use of high yiel disease resistant bivoltine silkworm breeds, as well as the use of high yiel drought resistant mulberry varieties (Raina, 2000).

Since sericulture gives frequent returns and absorbs labour, efforts should concentrated on popularizing this industry. Kenya has quite a large area (7 classified as arid and semi arid. Part of this wasteland can be productively utili for sericulture industry by growing mulberry trees. In developing countries Kenya, planners may have to introduce sericulture industry to create gai employment in rural areas. The slow pace of expansion of sericulture industr non-traditional areas is due to absence of marketing facilities and the remunerative prices offered to the sericulturalists (Shri, 1988). Shri points out in the present day, we need to integrate sericulture in rural developmen developing countries.

In India where 80% of the population lives in villages and depend on agricul sericulture is the main activity. According to Shri, (1988), the governmen India has placed special emphasis on the development of sericulture in orde improve the economic conditions of the society. He also states that there is to include mulberry cultivation under the social forestry programme, Nati afforestation programme and other programmes of wasteland development to benefit the tribal and landless people in the different parts of the country. This is a leaf to borrow from, especially for the wasted lands in the semi arid areas of Kenya.

Since sericulture has a very short gestation period, income generation is frequent. Under tropical conditions, the first crop can be harvested from a mulberry plantation within a period of eight months from planting. From then on, 4 to 5 crops can be harvested every year. Further more, mulberry plant has a capacity to withstand adverse climatic conditions and it has been shown to be drought tolerant (Shri, 1988).

The domestication of mulberry, as the food for silkworm, must have started five thousand years ago as a requirement for silkworm rearing in sericulture (FAO, 1990). Historical evidence shows that silk was discovered in China and that the industry spread from there to other parts of the world. The earliest authentic reference to silk is to be found in the chronicles of Chou-king (2000 BC) where silk figured prominently in public ceremonies as a symbol of homage to the emperors (FAO, 1978). The silk industry originated in the province of Chan-Tong. For about 3000 years, silk production was confined and considered to be a national secret by the Chinese government and as an industry was not known in other countries (Saratchandra, 1999; FAO, 1978). When commercial relations were established between China and Persia, and later other countries, the technology spread and the export of raw silk and silk goods assumed great importance. By the first century BC markets as far as southern Europe began to receive silk fabrics made in the East. According to some sources such as FAO, (1978), the first country after China to learn the secret was Korea, in about 1200BC. In India it was introduced about 400 years ago and the industry flourished as an agro-industry till 1957 with an annual production of 2 million pounds of silk fibre. The industry later spread to Japan. During the later part of the 19th century Japan gave serious attention to the development of the industry, introducing the use of modern machinery and improved techniques and carrying out intensive research in sericulture (FAO, 1978)

1.2 Economic Importance

Mulberry sericulture is well suited for marginal small scale farmers, since it has several advantages over the other crops in the rural sector. According to Singh *et al.*, (2005) it is estimated that one hectare of irrigated mulberry generates employment for about 13 people starting from mulberry cultivation to trading throughout the year and that in value addition 48.3 percent goes to the farmer, 21.6 percent to traders and the rest to weavers, reelers, twisters and dyers (Lakshmanan *et al.,* 2000).

Silk has played an important role in the economic life of man ever since its discovery more than 4000 years ago and has been associated with the socio-economic life of many Asian and central Asian countries. Even today, despite the upcoming of man-made fibres, silk continues to reign supreme as the queen of textiles.

Sericulture today is practiced in industrially advanced countries such as Japan, and USSR as well as in countries such as China, India and South Korea which are now industrialized. In the developing countries, it is essentially a village based and welfare oriented industry capable of providing employment to large sections of the population. According to Saratchandra (1999), sericulture is an agro- based industry that is labour intensive and can provide employment to 13 persons per acre of mulberry garden. It is therefore well suited as a tool for rural employment and poverty alleviation in populous developing countries. The high manpower requirement, forced the industrialized countries either to reduce or discontinue with silk production, thereby enhancing the prospects of sericulture in developing countries (Saratchandra, 1999). For a long time sericulture had been considered as a subsidiary occupation in rural areas, recent technological developments have made it possible to practice sericulture on an intensive scale, producing greater profits than most of agricultural crops. Furthermore, since mulberry trees grow fast in great abundance, two to three cocoon crops in temperate zones and four to six cocoon crops in tropical areas can be raised in a year. It is therefore ideal and suited to Africa for income generation and self-employment in rural and semi-urban areas. It is an activity with great potential for increasing income in African rural areas and as a cottage based agro-industry.

Silk also plays an important role as a foreign exchange earner for many of the silk producing countries of the world. As an example, for a period of about 70 years preceding 2nd world war, silk used to lead in the list of Japan's exportable items, accounting for 30 to 50 % of her foreign exchange earnings. Recently with the export of raw silk from Japan falling drastically, other newly developing countries are looking to silk as a potential foreign exchange earner and have taken up programmes for sericulture development seriously (FAO, 1978)

1.3 World silk production

World silk production has roughly doubled during the last 30 years in spite of the availability of man-made fibres. China and Japan have been the main producers, together producing more than half of the world production each year. Chinese silk is highly prized throughout the world. Since 1949 silk making methods have been modernized in China and silk is of better quality. World silk production in 1940 was 59 million kg and by 1950 it had dropped to 19 million kg. By the mid 1980s it climbed to about 68 million kg (Vegan society, 2005). World production trends of raw silk reached nearly 100,000 tons in 1993. In contrast to strong declines in Japan and the republic of Korea to roughly 3900 and 500 tons respectively, China for the first time reached the 66000 tons and India raised its output to 14000 tons. Outside Asia, Brazilian output exceeded 2500 tons per year with USSR output lingering around 3000 tons yearly. Recently China experienced a striking decline in output to 59000 tons in 1996 (Lee, 1999) and according to vegan society (2005), by 2002 world production reached an astounding 134000 tons.

1.4 World silk consumption

Silk with its unmatched luxury, luster and elegance is known as ''the Queen of fabrics'' and is in high demand for the affluent (Saratchandra, 1999). Although silk accounts for less than 0.2 % of the total textile fibres in the world, being a low volume high value item has a multibillion dollar turnover in the international trade (Somayayi, 1995). Somayayi, 1995 indicates that silk and silk products have always been associated with luxury but today they have made great strides in reaching a greater population the world over. This trend is mainly because of the following factors:

(a) There is a new consumer group – the economically stronger young generation, blossoming in the western world.

(b) Rise in demand due to natural fibre-eco-friendly wave and

(c) Designers have made it possible to bring the silk goods within the reach of large middle-income groups.

Japan has the highest per capita consumption of silk in the world. It is the highest consumer of silk in the world. To meet this demand, it imports silk in all forms namely, raw silk, silk yarn, silk fabrics and western silk goods from not less than a dozen countries including India and China who take the lion share of the exports. Japanese market for western style garments may be large but silk producers of the developing countries may not penetrate this market due to high quality consciousness of the Japanese consumers (Somayayi, 1995).

Among the European countries the per capita consumption is highest in Germany followed by Switzerland and United Kingdom. In Western Europe, Germany, Italy, France, Switzerland, and United Kingdom are the leading exporters of silk goods. Germany was the largest and most important market for silk goods in 1995. The raw silk is mainly imported from China; silk weaving is concentrated in United Kingdom and Germany whereas the processing is in Milan and Como in Italy, Lyon in France and Zurich in Switzerland. The French city of Lyon has been producing highest quality silk fabrics since centuries. The French weaving industry is entirely dependent on imports particularly from China and Brazil, for raw silk. It also imports finished goods from China, Hong Kong, Italy and India (Somayayi, 1995).

China is the leading producer of silk in the world followed by India. Chinese silk export is hardly affected due to substantial increase in the production of raw silk, which takes care of local demand. The local market in China is rapidly increasing with rising standards of living. India, on the other hand, consumes 85% of the production internally in the form of Sarees.

1.5 Role of women in sericulture

Sericulture plays an important role in rural development and has a direct bearing on the social economic aspects of the society. It provides opportunities for stable and additional income to landless labour and marginal farmer families. It helps to generate opportunities for the diversification of labour use in integrated farming systems that help to combine the goals of nutrition and livelihoods security in development programmes. Sericulture does not involve hard labour and the technologies are very simple. According to Shri (1988), the International Tropical Sericulture congress (ITSC) recommended, that women should be involved at all levels of sericulture development. It is a home industry, making women fit very well in the industry. Further more, it greatly helps in income generation thereby facilitating for promotion of women economic empowerment (Shri, 1988).

1.6 Silk production in Africa

1.6.1 Sericulture history and background in Kenya

Kenya is one of the African countries where sericulture was introduced in 1904 but remained the business of a few individual farmers. In 1972 the Ministry of Agriculture (MOA) through the Government approached the Japan International Cooperation Agency (JICA) to assist in establishing the viability of sericulture in Kenya. Sericulture was then introduced in Kenya by the Japanese government in 1973 through a project. Initially they used locally grown mulberry varieties (used as ornamentals and for their berries, introduced in Kenya by the Italians during the first and Second World Wars) to rear the first lot of disease free egg-laying moths. They assisted in the introduction and establishment of more mulberry varieties (5 acres) and silkworm rearing in the sericulture station within Kenya Agricultural Research Institute (KARI), Thika centre facilities. The Sericulture project was organized into 8 rural silk centers in the country, namely Kirinyaga, Nyeri, Thika, Machakos, Baringo, Homabay, Bungoma and Murang'a. From Thika centre farmers received mulberry cuttings and bivoltine silkworm eggs, which are hatched and reared to produce silk cocoons. Research focusing on the suitability of local conditions for sericulture was done and it established that sericulture was viable with good returns and hence Kenya has potential since:

(i) Climatic conditions in Kenya are ideal for mulberry cultivation and equally suitable for rearing throughout the year, indeed up to 30 tons per hectare per year has been recorded in Thika centre (MOA, 1978).

(ii) There are no natural disasters e.g. severe frosts.

(iii) Silkworm can be reared in simple structures and equipment.

(iv) Cheap labour is available and

(v) Quality of cocoons was good with average cocoon filament of 1200metres (ICIPE, 2000).

In the eight silk centres, and with JICA's support, good harvests were realized as further proof that sericulture could be done successfully in Kenya. The activity picked up for some years but receded due to winding up of the project in 1982. The Ministry of Agriculture has continued with the work with very little external support (MOA TCP, 2000). Presently some of the areas still practicing sericulture include Turbo division (Sambut area), Laikipia district (Mutirithia area); Thika district (Kakuzi area); Murang'a district (Mathioya and Makuyu areas); Nakuru district (Lanet, Bahati and Elbugon areas); Nyeri district(Mweiga area); Lamu district (Mpeketoni area) (Officer in charge National sericulture station personal communication, 2005; ICIPE, 2000).

In 1992, ICIPE innovation Trust (I.I.T.), an autonomous non-profit organization was mandated to initiate sericulture pilot project in Kenya. The principal objective was to establish and promote a community-based sericulture industry in the country through demonstration and training. It has also played an important role in supplying of silkworm eggs. To date, this has continued in collaboration with the Ministry of Agriculture providing the necessary extension and technical back up to the farmers. It has moreover, provided one of the marketing outlets for the small-scale silk production farmers.

1.6.2 Sericulture in Uganda

In Uganda sericulture was introduced in 1992 through the efforts of the government of Uganda and European Union silk sector development project. Uganda managed to export dry cocoons to Japan but due to uneconomical transportation of the voluminous cocoons the export market collapsed in 1997. The government approached ICIPE for assistance to save the collapsing silk industry. ICIPE intervened and established a complete post harvest unit at Kawanda campus, Kampala (ICPE, 2002-2003). According to this report the unit has a high production capacity for internal and external market outlets. Uganda has been exporting raw silk to South Africa and Egypt since 2002.

Through the ICIPE initiative, silk farmers from both Uganda and Kenya have been trained on different aspects of cocoon post harvest technologies and also organized into groups forming silk market places in Bushenyi in Uganda and Othoro in Kenya.

One of the constraints facing the upcoming sericulture sector in Africa is the dependency on Asian partners for regular supply of silkworm eggs. Delays in shipping also result in the spoilage of eggs and this results in a gap in cocoon production cycle. This problem has necessitated ICIPE to develop a strategy in establishing an African based egg grainage whose main objective is to breed, screen and develop silkworm races with high economic potential and adaptable to tropical African conditions, and to produce quality disease-free eggs at a reasonable cost to the farmer. This has been accomplished through the successful development of ICIPE 1 and ICIPE 11 races. This has improved the situation and hence improved the silk industry in Africa (ICIPE, 2002-2003). The grainage project has been supporting and supplying eggs to silk growers in Kenya, Uganda, Zambia, Zimbabwe, Ghana and South Africa.

1.6.3 Sericulture in Zambia

Sericulture was introduced in Zambia in 1985 and since then efforts have been made to develop and commercialize the industry. The country adopted Indian technology but not everything could be applied due to differences in climate and availability of resources such as, humidity, which is an important factor in rearing of silkworm (ICIPE, 2000).

1.6.4 Sericulture in Egypt

Egypt has produced silk since the early Islamic period, which has contributed a lot to the trade between eastern producer countries of Asia and the western consumer countries of Europe. During early 19^{th} century (around 1805) Mohammed Ali, the ruler of Egypt at the time, promoted the planting of mulberry trees which reached an astounding 3 million trees. These were cultivated along river Nile banks and since then sericulture began in Egypt giving about 4820 kg of raw silk. Much later on, the industry was not able to compete favourably with silk industry developed in other countries at the time, so it declined for years and developed again when a private sector factory for spinning and weaving silk fabrics was developed to facilitate exporting silk garments to the neighbouring countries such as Syria and Lebanon (Fwakia, 1999).

1.7 Some of the potentials for sericulture development in Africa.

African countries enjoy good climate for cultivation and rearing of silkworm, activities which can be done all round the year. The soils are suitable and the required labour is also available. The socio-economic conditions in the rural areas are also conducive for practicing sericulture as a profitable agro based rural cottage industry. Silk production in the world is still small compared to other natural and synthetic fibres, having a share of 0.2 %. Demand for silk is growing gradually but steadily at an average rate of 2-3 % per annum (Raje, 1999). Hence, the African countries have great opportunities and scope for introducing sericulture with comprehensive and renewed effort to create a new base for silk production.

1.8 The problems facing sericulture in Africa

According to ICIPE (2000), some of the constraints in Africa, facing sericulture include:-

(i) L ow leaf production due to none use of soil fertility inputs.

(ii) Irregular supply of eggs and silkworm adapted to our conditions. The hatchability of seed is sometimes affected by mishandling on transit.

(iii) Low productivity in cocoon production due to poor infrastructural facilities thus leading to inability of farmers to manipulate temperatures and humidity.

(iv) Lack of trained manpower and local training facilities to keep farmers abreast with modern technology. This leads to ineffective extension services to farmers.

(v) No specific marketing arrangements for cocoons and

(vi) Absence of cocoon processing facilities.

1.9 Problem statement

The quality of silk produced in terms of cocoon weight, filament length and weight has been wanting and this has reduced profit margins in this enterprise since prices are based on cocoon weight (ICIPE, 1993; MoA, 1978; 1983)

1.9.1 Justification

Kenyan sericulture is wholly on mulberry leaf rearing and mulberry varieties are used indiscriminately (Raina, 2000). Much as some varieties are suitable for fruit production, others are best for leaf production. Quader *et al.,* (1995), found that nutritional value of mulberry leaves is directly reflected on the larval growth and cocoon characters of *Bombyx mori* silkworm and varieties are different in this aspect. Silkworms fed with the quality improved mulberry leaf showed a higher larval weight, single cocoon weight, single shell weight, and filament length. Soils treated with phosphorus and potassium gave better yield of mulberry than without. Best yields were with the maximum doses of nitrogen (Rajanna and Dandin, 1994). At the same time, Sinha and Sakar, (1989) and Katiyar *et al.*, (1995) found that there was significant increase in leaf yield (20.5-35.2 % over control) with application of fertilizers.

However, our Kenyan varieties of mulberry have not been investigated to determine their varietal and performance differences in different soil fertility status in relation to their effect on quality of silk cocoons (personal communication by Raina in ICIPE, 2005). In this study, differences in silk quality due to use of manures and fertilizers, and selection of varieties were determined.

1.10 General objective

The overall objective of the study was to investigate the effect of fertilizers and mulberry variety selection on silk quality.

1.11 Specific objectives

(I) To identify the appropriate high yielding varieties among the three varieties.

(ii) To determine the best fertility treatment combination of the four treatments used, for high mulberry yield and quality

(iii) To determine the protein profile of the varieties, and due to the different fertility treatments.

(iv) To determine the impact of leaf quality on the economics of silk farming

2.0 LITERATURE REVIEW

2.1 Distribution of mulberry

The scientific name of mulberry is *Morus* species, a genus belonging to *moraceae* family of the *urticales* subclass. This is the genus associated with sericulture. It is allied to genus *Porousonetia a*nd *Ficus*.

Mulberry is both a temperate and a subtropical plant grown in many regions of the world, predominantly in Eastern, Southern and southeastern Asia, southern Europe, southern and northern America and parts of Africa (FAO, 1987).

In Africa it has been reported to occur in humid, sub humid and semi arid areas (Shayo, 1997).

2.2 Species

There are 35 species of *Morus*, which are broadly, classified as Dolichosty with long style and macromorus without style.

At present there are more than 1000 varieties of mulberry, which are being cultivated. Of these the most cultivated can be classified into 3 species:

i) *Morus bombycis* Koidz

ii*)* *Morus alba* Linn

iii) *Morus latifolia* Poilet

2.2.1 Morus bombycis Koidz (Yamaguwa)

The characteristic feature includes long style of female flower and brown or yellowish brown colour of the bark. While most of the leaves are lobed some varieties have entire leaves. The serrations in the leaves are somewhat acute and the leaf surface is poor in luster. The adaxial surface of the leaves is almost hairless but abaxial is scantly hairy. The winter buds are large and reddish brown in colour. Plants are usually dioecious and rarely monoecious and many of these are resistant to cold.

2.2.2 Morus alba Linn (Karayamaguwa)

The characteristic feature of these plants is the presence of extremely short or almost insignificant style in female flower and grey to white or grey brown colour of the bark. The leaves are entire or lobed, and serrations are blunt. The adaxial surface of the leaf is smooth and while some varieties are rich in luster, others are poor. Young leaves have hairs on the adaxial surface and as the leaves grow they gradually loose hair. When fruits mature they turn to black colour. The plants are either, monoecious or dioecious. The main varieties cultivated in Japan, Asia, Europe and America belong to this group and include 'Ichinose', 'Nezumikaeshi', 'Jumonji' 'Fukushimaoba', 'Tokowase' and 'Ichihei'.

2.2.3 Morus latifolia Poilet. (Roso)

The characteristic feature of this group is the absence of a style in the female flower. The Bark is smooth and pale brown in colour while the branches are highly flexible (they bend easily). The leaf tip is circular and serrations are blunt. Young leaves have upper distinct constrictions. The adaxial surface of the leaf is glabirous (without hairs). Usually the leaves are extremely shiny. This type originated from China and was imported to Japan in 1874 (Aruga, 1994).

2.3 Ploidy levels

Among the dominant varieties of mulberry, there are the usual diploid 2n=28 and triploid, 2n=42. There are also tetraploids and hexaploids, 'Keguwa' variety being a hexaploid.

Diploid 'Ichinose' variety was the most widely cultivated in Japan by 1954 (Aruga, 1994).

Triploids are today also widely cultivated and are considered to be very useful as silkworm feed as they grow fast. This is partially due to doubling of chromosomes and partially due to phenomenon of heterosis (Sikdar, 1990). Also as in the case with other plants, triploids of mulberry are sterile and so direct nutrients towards the formation of branches and leaves, which could otherwise be directed to formation of fruits and seeds, which is a profitable feature in sericulture. In support of this, Abdullaev, (1972) found that tetraploid forms yield 3.5 kg of leaves per tree more than the diploid forms.

In Kenya the varieties grown include 'Ex - Embu', 'Ex - Thika', 'Ex Ithanga', and 'Ex - Limuru'. These were brought by Italians during the 2nd world war (1939-1945) and have been named depending on the areas they were sourced from. Japanese also brought in other varieties during the JICA project period 1973-1982 and these include, 'Ichinose', 'Minamisakari', 'Kikuha', 'Rohashi', and 'Wasemidori' all from Japan, 'Noi' from Thailand, and 'Kanva 2' from India, (MOA, 1978).

2.4 Varieties grown in Kenya

2.4.1 'Noi' Ex –Thailand Variety

Amongst the varieties grown in Kenya, Noi Ex-Thailand variety does not produce fruits. It is a popular variety in Thailand since it has a high survival ratio (Sombat, 1971). Also from an experiment done by Chinchiem and Srisuwan, (1974a), 'Noi' variety showed some of the best agronomical characters such as longest shoot, high yield of leaves and is not highly susceptible to root rot (30-50% group). Additionally Karuhizo, (1978) indicated that 'Noi' variety showed better growth of shoots after base cut than other Japanese varieties. It also gave more abundant shoots hence better yield of leaves than the other Japanese varieties.

2.4.2 'Kanva 2' variety

This is one of the varieties that yield highest in Kenya. This variety gives a leaf yield of at least 21 tons of leaf per hectare (MOA, 1990). Besides giving 25 tons of leaf per hectare under the Indian environment, the quality of leaf obtained from this variety is superior with better nutritive and moisture content (Muneer, 1988). Under the same environment, the variety yields superior quality cocoons (Muneer, 1988; Krishnaswami, 1990) than other varieties tested. Krishnaswami, (1990) indicates that the variety thrives well both under dry as well as irrigated conditions.

2.4.3 'Ex - Embu' variety

In Kenya this variety has not been investigated but the Ministry of Agriculture reports that the variety thrives well in most parts of the country and has been found to have high leaf yields and drought tolerance characteristics (MOA, 1990; 1983; 1978).

2.4.4 Variety Differences

Various anatomical features of mulberry shoots differ according to the different varieties. These features of the shoots are closely related to the amount of leaves harvested and the quality of the leaves. Melikyan and Bayan, (1971) found that some varieties have thinner cuticles and also fewer cystoliths in the upper epidermis of the leaves than others and were therefore more palatable for silkworm.

The length and number of shoots are closely related to the amount of mulberry leaves harvested and these vary according to the varieties, pruning method, and climatic conditions. The number of shoots of a single stump is usually few for varieties that belong to roso group and more for the varieties that belong to *Morus bombycis* Koidz and *Morus alba* linn type (Aruga, 1994).

Machii and Katagiri, (1991), and Hafiz, (1992) demonstrated that there exists varietal differences in nutritive values of mulberry leaves used for rearing silkworms. Work done by Talyshinskii, (1980), shows that triploid and tetraploid forms have a greater potential for protein synthesis than their initial diploids. Additionally, work done by Plasksina *et al.,* (1977); showed that varieties of *Morus alba* had higher content of glycine, aspartic acid and serine than other species of *Morus*. Further, Plasksina *et al*., (1968), found that polyploid forms of mulberry have higher mannose content than diploid forms.

Mulberry shoots are of various colours. However, the colour depends upon the colour of the cells of epidermis, phellum, and phelloderm. The colour of the shoots differs according to mulberry variety but usually is classified into, black-brown, yellow-brown and reddish- brown, bluish-grey, dark-grey and green-grey. The variation in colours can be utilized in the selection of mulberry varieties during the seedling stage (Aruga, 1994).

Mulberry stems have lenticels and these are said to play the role of stomata. The number of lenticels per defined segment differs according to the variety. It is usually large in varieties belonging to *M. bombycis K*oidz. Lenticels initially are white but with ageing of the plant change to yellow and then to brown. On the other hand, the axillary buds are initially green in colour but as they mature change the colour to brown. The relative contents of Deoxyribose Nucleic Acid (DNA) and Ribose Nucleic Acid (RNA) in young growing leaves increased more rapidly in triploid and tetraploid than in diploid mulberry. Mature leaves of tetraploids however, contained less DNA and RNA (Ali-zade and Akhundova, 1970). Depending on coloration of lenticels and axillary buds, it is possible to roughly work out the degree of maturation of leaves. This feature is useful in selecting the leaves for rearing the young silkworm larvae (Aruga, 1994).

Morphology of mulberry leaf is never constant. It varies with different conditions. In a single stump of mulberry plant often a mixture of entire and lobed leaves are found. Changes are also found due to the position of leaf (phyllotaxy) or the stage of leaf growth.

Aruga, (1994) has shown that the water content of mulberry leaf is closely related to various environmental conditions, variety, stage of the growth, position of leaf along the branch, and climatic conditions. It ranges from between 65 and 83 percent. Usually water content decreases with the stage of growth of the leaves thereby decreasing storage time. Piao and Li, (1987) in their selection work found out that variety 'Yansang 59' had vigorous early growth and the leaves were abundant and of good quality. The variety stores well, and is suitable for rapidly growing close plantings.

The growth of roots depends on various conditions, such as mulberry variety, nature of soil, and depth of underground water. In most cases the roots can reach a depth of 3-4 m and at times have been found to reach a length of 15m (Aruga, 1994). The length of main root (tap root) depends on mulberry variety. Varieties belonging to *latifolia* type have thick and long roots, *bombycis* type have slender and long roots while *alba* have thick and short roots.

Various environmental factors determine the rate of absorption of water and nutrients. The moisture status of soil determines water absorption. If excessive, the air passages are blocked resulting in poor water absorption. If the moisture status is less absorption is decreased.

The temperature of the soil also determines water absorption. At cold temperature water absorption is extremely low. As it warms up in spring, water absorption gradually increases. Mulberry plants in dried soils have been found to increase the development of root hairs, as an adaptation to arid conditions.

Mulberry plants are perennial. One generation (cycle) of plants can survive for more than 10 years and at times even 30-40 years. Variety selection should be based on the suitability of the variety to regions of cultivation.

Mulberry plants grow in tropical and temperate regions. There are many varieties of mulberry grown in Kenya, some local and others exotic brought in from Japan and other Asian countries. Each variety has its own characteristic features. Although they have differences depending on the variety, mulberry plants are relatively resistant to various environmental hazards (Aruga, 1994). As in the case for other agricultural crops, the harvest of quality mulberry leaf is strongly dependent on the genetic factors as well as the fertility of the soil. However, for quality silk production, high protein content of the mulberry leaf is required. From research done in India, it has been demonstrated without reasonable doubt that improvement of leaf quality has a direct positive correlation on silk quality. Improvement of cocoon quality, in silk production is dependent on silkworm feed. Miao, (2000) confirmed that the use of high protein diet effectively increased the quality of cocoon shell. This was demonstrated by the use of supplemental diets besides mulberry leaf, of soy protein and blood meal. The investigation also demonstrated that the silkworm (*Bombyx mori)* prefers mulberry leaf and that its digestibility has been found to be excellent compared to other supplemental diets (Miao, 2000). Furthermore, mulberry provides the silkworm with feeding inducers (such as Morin), vitamins and other growth factors (Miao, 2000). Any substitute for mulberry introduced as artificial diet (supplemental diet) should be similar to mulberry in nutritional value and has to be palatable to the silkworm

(Miao, 2000). Mulberry leaf is an excellent food for silkworm but is limited by seasons, varieties and management (Aruga, 1994). Quader *et al*., (1995) found out that nutritional value of mulberry leaves was directly reflected on the larval growth and cocoon characters of *Bombyx mori* silkworm. When fed with improved quality mulberry leaf it resulted in a higher larval weight, single cocoon weight, single shell weight, and filament length.

Soils treated with phosphorus and potassium gave better yield of mulberry leaves than without. Best leaf yields were with the maximum doses of nitrogen (Rajanna and Dandin, 1994). In addition, Sinha and Sarkar, (1989) and Katiyar *et al*., (1995) found that there was significant increase in leaf yield of range (20.5-35.2 % over control) with application of fertilizers.

Varietal differences in the nutritive value of mulberry leaves were examined with special emphasis on nitrogen and amino acid content. Production efficiency of cocoon shell of silkworms (*Bombyx mori*) was compared among several varieties. The results indicated that there were high correlations between production efficiency of cocoon shell (PECs) and nitrogen content as well as between PECS and amino acids content including methionine, histidine, and Threonine. The first two are restriction amino acids for the growth of silkworms and the last amino acid is required for the synthesis of silk protein (Hirano, 1982). Verma and Kushwaha, (1970) found that silk worm *Bombyx Mori* grew better giving heavier cocoons and longer silk filaments on the exotic variety 'Catteneo' than on two other exotic varieties and a local one. 'Catteneo' and 'Burnese 2' varieties had lower starch content and higher mineral contents than the local variety, 'Tsukasakhu'. Hirano, (1982) also found that varieties differ in leaf crude protein content but not in amount of ribulose 1, 5-diphosphate carboxylase.

2.5 Climate and soils suitable for mulberry production

Mulberry plants usually grow from 150^0 N to 10^0 S latitude and are mostly distributed in the northern hemisphere. The plant is hardy and capable of thriving under a variety of agro-climatic conditions. It is adapted to warm-temperate to tropical conditions. The plant is found within the altitude from sea level to 4000m above sea level. When it is well established, mulberry grows well at a temperature range of 20-30^0C with a capability to sustain wide variations in the climate (Saratchandra, 1999). They flourish in regions with high temperature and humidity and in areas with effective soil depth of 50cm or more. The soil has to be light to medium textured without hardpan or high ground water table or stagnant water within 80cm of surface. At the same time, it is also sensitive, responding extremely well to optimum agricultural inputs but showing practically no growth when plant nutrients and moisture begin to operate as limiting factors. This is evident from the fact that under the poor rainfall conditions of 625-750mm prevailing in south India (Tropical conditions), the current leaf yield is of the order of only 3,000-3,500 kgs per hectare whereas under assured irrigation and appropriate fertilizer application it can be stepped up to 30,000 kgs per hectare (Krishnaswami, 1990). Mulberry under tropical conditions gives continuous growth almost throughout the year because of optimum temperature conditions and good sunshine (Krishnaswami, 1990).

2.5.1 Use of Fertilizers and manures in mulberry

Over several hundred years, mulberry species and varieties have been selected and improved to feed the silkworm, and these have high nutritional demands for the high yield performance. The aim has been to produce greater quantities of leaves of high quality under a wide range of conditions. The frequency of harvesting and the planting density increases overall biomass yields. The system results in increased biomass production due to increased photosynthetically active radiation (PAR) interception (Kinama *et al.*, 2007). Thus, the issue of maintenance of soil fertility, and plant persistence become important as huge quantities of nutrients are extracted from the soil in the biomass under the cut and carry system (Sanchez, 2000).

The importance of application of fertilizers and manures for increased productivity, both in quality and quantity of mulberry leaves has been well recognized. It has been realized that for any increase in leaf yield of mulberry per unit area of land, the native soil fertility alone cannot be relied upon and so application of fertilizers and manures is inevitable. Of the three major elements, Nitrogen, phosphorus and potassium, nitrogen is the most important and vital for increased production.

In Kenya, Ikombo, (1984), revealed that most of the soils in semi arid areas of eastern Kenya are deficient in N, P, Cu, and Zn and are also quite low in organic matter content. Other areas are not exceptional due to over cropping over a long period of time. Under these conditions, the maintenance and improvement of soil fertility becomes fundamental in most areas. Gachimbi *et al.*, 2005 found out that there are negative nutrient balances in the high and low potential agricultural production areas of Kenya. This indicates the need of improved soil fertility for enhanced crop yields.

2.5.2 Mulberry leaf quality

The mulberry leaf is the exclusive food of the silkworm *Bombyx mori*. It is essential that the mulberry leaves are not only in abundant supply but are also of good and suitable quality. Leaf quality has much to do with the success of silkworm rearing and the quality of the cocoon produced. The leaf quality is influenced by various factors such as soil, pruning, fertilizers, and rainfall (FAO, 1987).

Succulent leaves, which have attained full size and grown on loamy fertile soils contain more water and protein, and are very suited for feeding silkworm larvae. The composition of leaves varies with variety, degree of maturity and the type of soil in which the plants are grown. Dwivedi, (1988), showed that mulberry leaves are rich in protein and calcium and have high content of ether extract and low content of crude fibre.

2.5.3. Influence of NPK - nutrients on mulberry growth.

2.5.3.1 Nitrogen

Nitrogen is a constituent of protein and therefore a constituent of every living cell (Reisenauer, 1978). Being a basic nutrient in the biosynthesis of proteins, amino acids, chlorophyll and alkaloids, if deficient in plants the vegetative growth is stunted, leaves dry up and are shed prematurely (Sridharas *et al.,* 1995). Nitrogen deficiency reduces the protein content of the leaves, thereby reducing the nutritive value of leaves. When nitrogen is supplied in optimum quantity, the plants put forth vigorous vegetative growth; the leaves enlarge in size, become deep dark green indicating an increase in chlorophyll content. Thus nitrogen increases the vegetative growth, number, size and weight of leaves. Leaves become more succulent and their maturity is delayed, and all these translate into higher yields of leaves (Aruga, 1994; FAO, 1976).

Some leafy vegetable crops like spinach and kales also have high demand for nitrogen with yield increases recorded for additional amounts of nutrient (Domitov and Rankov, 1971; Mija and Nowosielski, 1971; Edmund *et al.*, 1977).

Plants absorb nitrogen from the soil as ammonium (NH_4^+) or nitrate (NO_3^-) ions. However, nitrate (NO_3^-) nitrogen is preferred over the ammonium nitrogen (NH_4^+) (Barber, 1974).

2.5.3.2 Phosphorus

Phosphorus is a constituent of cell nucleus, essential for cell division and development of meristematic tissues in the growing regions. In mulberry, the symptoms of phosphorus deficiency are not readily recognized by visual observation and are less characteristic than those of nitrogen deficiency. In general phosphorus deficiency causes stunted growth with small and very dark green leaves and the older leaves turn reddish purple (FAO, 1976). It is absorbed primarily as a monovalent phosphate anion (H_2PO^{4-}). Maturity of plants is often delayed in plants containing abundant phosphate. If excess phosphorous is provided, root growth is increased relative to shoot growth (Salisbury and Ross, 1986).

2.5.3.3 Potassium

Potassium influences the development of woody parts of the stem. It is essential both for photosynthesis and translocation of starch. When potassium is deficient the older leaves became mottled and chlorotic with necrotic symptoms along the margins. It is absorbed as K_2O ions. Potassium deficient crops develop weak stems and their roots become more easily infected with root rotting organisms leading to lodging of plants (Salisbury and Ross, 1986).

2.5.4 Balanced use of fertilizers

Instead of applying each nutrient separately, fertilizers containing NPK are recommended (FAO, 1978). The FAO report recommends that compound fertilizers are applied as basal doses and the straight fertilizers containing nitrogen are applied in split dose as top dressing in order to meet the full requirements of the plant. In Kenya compound fertilizers are preferred to the straight fertilizers due to the high cost of inorganic straight fertilizers and the cost of labour in application. The preferred fertilizer is the NPK 17:17:17. Experience from Ministry of agriculture has shown that this fertilizer is mostly used for tree crops especially in coffee, oranges and many other fruit tree crops. It is applied by making shallow bands between the plants where the crop is at a close spacing and around the plants where the crop is widely spaced.

2.5.4.1 Influence of fertilizers on the yield and quality of leaves

Leaf productivity is the major parameter to assess the harvest of green cocoon and raw silk productivity. The relationship between the amount of three-element fertilizer and the mulberry harvest is an important aspect of the study in

Moriculture. The status of growth of the mulberry determines the amount of leaves harvested due to amount of leaves and shoots produced in a year. In fact, the stability in growth of silkworm crop greatly depends on the mulberry leaves particularly the quality of the mulberry leaves (Aruga, 1994; Mishara *et al.*, 1996).

Among the nutrients in fertilizers, Nitrogen has the greatest influence on the quality of mulberry leaves. With the increased supply of nitrogen the percentage of crude protein in the leaves increases while the percentage of sugars, phosphoric acid, potash and lime slightly decreases. The leaves become more succulent and their maturity is delayed. With increased application of phosphate, potash and lime, the nitrogen of leaves decreases. Mulberry leaf protein is the source for the silkworm to biosynthesize the silk which is made up of two proteins, fibroin and sericin. Nearly 70 % of the silk proteins produced by a silk worm are directly derived from the proteins of the mulberry leaves (FAO, 1987; Aruga, 1994).

The supply of mulberry leaves of high nutritive value is essential for healthy growth of silkworm larvae and leads to a good production of high quality cocoons. From the study done by Aruga (1994), mulberry fertilizer should have 23% of nitrogen, 11% of phosphate and 17% of potassium. This is a general recommendation, which needs modification depending on various soil conditions. Krishnaswami (1990), indicated that in addition to bulk organic manure, chemical fertilizer should also be applied at the rate of 100kg N, 50kgP and 50kg K per hectare per annum applied into two equal split doses. This should be applied close to the plant on either sides along the rows and the fertilizer incorporated well into the soil. The use of unbalanced ratios of nitrogen, phosphorus and potassium leads to imbalance of nutritional factors and is eventually reflected in loss of yields (Subbaswamy *et al.*, 1995). They pointed out that neglect of application of organic manures and increased dependence on chemical fertilizers has led to micro nutrient deficiency. After all, health and yield of mulberry depends much on sixteen micronutrient elements in soil. Subbaswamy *et al.*, (1995) showed that availability of some of them like zinc in soil not only ensures good mulberry yield but also avoids to a greater extent the use of growth regulators. To produce leaves of high yield and good quality special attention must be paid to balanced NPK fertilization. Mulberry is a nitrate loving plant and so favourable conditions are required to promote nitrification and long-term supply of nitrate – Nitrogen.

Fertilizer practices in S.E Asia have shown that less inorganic fertilizers are applied to mulberry than in countries like Japan and China but use organic manures, such as rice straw, cut grass, sugarcane waste, Fowl droppings and cattle dung. In Sulawesi, Indonesia most sericulture farmers have been reluctant to use fertilizers in mulberry fields but dressings of urea (providing a total of 100kg per hectare per year of N) gave a remarkable leaf yield increase in the fertilizer demonstration and field trials (Subbaswamy *et al.*, 1995).

2.6 Manure and leaf quality

In order to maintain good quality of mulberry leaves, it is essential to apply sufficient quantity of manure. In this regard, 20,000 kg (20 Metric Tons) of manure for an area of one hectare should be applied (Aruga, 1994). Manures applied should be like the compost or farm yard manure and this should be applied immediately after pruning and inter-cultivation and thoroughly incorporated into the soil (Krishnaswami, 1990). The two methods of application are broadcasting and localized placement (FAO, 1987).

When manure is supplied, the leaves have higher water and protein content but are poor in carbohydrate and fibre content (Aruga, 1994). In an experiment conducted by Chinchiem and Srisuwan (1974b), better growth of shoots indicated by length of longest shoot were found in plots that had double the amount of NPK (NPK= 48:24:32 to 96:48:64) followed by plots with manure (compost) + NPK. High yield of leaves also corresponded to plots with longest shoots, in all of them, the best being compost +NPK (Chinchiem and Srisuwan, 1974b).

The chemical composition of cattle manure is influenced by diet, storage and handling conditions, (Fassen *et al*., 1987; Murwira *et al*., 1993) cited in Amolo, (1995). These factors account for some of the variations in manure composition reported from different sources. Fresh and aerobically decomposed manure have low nitrogen effects on the soil whatever their source. This is because the fresh manure has higher carbon to nitrogen (C: N) ratio and would therefore decompose slowly on incorporation into the soil. The aerobically decomposed manure has lost significant amount of nitrogen through de-nitrification as aeration increases due to oxygen supply. Nevertheless, it remains a most valuable soil organic resource for resource poor small-scale farmers. Furthermore, crops do respond well to manure application at the rates of 22.5 to 37.5 tons per hectare (Amolo, 1995; Ikombo, 1984).

The harvested amount of leaf is closely related to the number of plants in an area-spacing of the plants. The spacing adopted for mulberry is 1.5m x 0.7m, which gives 10,000 plants per hectare. If the spacing is closer than this, there's insufficient sunlight, aeration, and rapid growth of pathological organisms and quality of leaves deteriorates. The amount of leaf harvested is also closely related to the amount of manure or fertilizer used. Usually the amount of leaf harvested shows an increasing trend along with an increase in the fertilizer applied (Aruga, 1994).

2.7 Constituents of mulberry leaves

The constituents of mulberry leaves vary considerably depending on the type of mulberry plants or the species. The general trend is that the leaves of *Morus bombycis* have lower water content as compared to the mulberry leaves of other species. However, this species of mulberry is rich in protein and carbohydrates (Aruga, 1994).

Among the volatile constituents of mulberry leaves there is a special substance, which acts as an attractant for silkworm larvae (Aruga, 1994). Mulberry leaves contain various substances required for the nutrition of silkworm. Singh *et al.*, (2005) notes that the preferential food value of mulberry leaf for silkworm larvae is attributed to the presence of three stimulant factors in it, an attractant, a biting factor and a swallowing factor. The substances that attract the larvae to leaves have been identified as citral, linalyl acetate, linalol, terpinyl acetate and hexanol. Sitesterol (approx. 0.2 percent in leaves) together with some sterols and water-soluble substances is the main factor that stimulates the biting action.

2.8 Cocoons and raw silk

2.8.1 Importance of quality of cocoons

The cocoon is the raw material used for reeling raw silk. It is in fact a protective shell made up of a continuous and long proteinaceous silk filament spun by the mature silk worm before pupation for self-protection from adverse climatic factors and natural enemies. Economics of reeling and the quality of reeled product depend largely on the quality of cocoons used for reeling and therefore it is of vital importance that the cocoon quality should be good (FAO, 1987). Testing regulations indicates that, cocoon classification is done on the basis of quality and reel ability grades. Quality grade of raw silk is determined by the uniformity in size of the thread and by the frequency of distribution of knots in it. Hence in evaluating the quality of cocoons, priority is given to the length of silk bave available per casting, as longer length ensures better evenness. Next to be considered, as a quality measurement is the denier. Good quality cocoon need not necessarily be large in size but it should be firm and compact and this conforms to the weight (FAO, 1972). It should be uniform in shape and size as far as possible, rich in silk content, contain less of floss but more of easily reel able silk.

2.8.2 Raw silk Testing and classification

In Sericulturally advanced countries, raw silk is tested and graded according to specified and accepted standards before marketing. This has been considered important so as to establish silk conditioning and testing institutions. These conduct qualitative tests but also determine the actual mercantile weight of raw silk by subjecting raw silk to a process called conditioning. Classification depends upon scientific methods of testing samples properly drawn from lots of raw silk tendered for testing.

The quality of raw silk depends on a combination of factors like quality of cocoons, reeling technique, the type of machinery and equipments used and the skill of operatives. The results of testing provide scope for scientific investigation into the causes for defective aspects as well as the superior aspects of raw silk (FAO, 1972).

2.8.3 Factors that influence cocoon and silk quality

Silk fibre is a liquid protein produced from the silk glands of silkworm that hardens upon exposure to air. The fibre consists of two proteins, fibroin (80 %), and sericin (20%) (Raina, 2000). The worm internally adds layer after layer to complete this protective covering. The resulting cocoon is in essence a silk fibre is obtainable through reeling process (ICIPE, 2002-2003). It has been found that accumulation of protein in larva depends largely on the proteins in the leaves (FAO, 1987; Aruga, 1994).

Apart from the nature of silkworm, climatic conditions, management of silkworm rearing and quality of leaves influence the quality of cocoon which form the raw material for silk production (Nadiger *et al.*, 1988).

High humidity in rainy season coupled with wrong rearing practices influence the quality of cocoon and result in low price and less returns (Benchamin, 1995). Benchamin (1995) noted that feeding the silkworm on good quality mulberry leaves alone is not enough to ensure good quality cocoons. There are other factors that count and these include:

(i) Rearing humidity

(ii) Rearing temperature

These two factors should be controlled to optimum levels depending on silkworm developmental stages:

(iii) Rearing hygiene. This should be provided at all times of rearing silkworm.

(iv) Mounting and spinning care. The silkworm should be picked up at correct maturity (colour changes from white to an opaque translucence and shrink slightly in size) (Raina, 2004) and mounted on to suitable frames for spinning cocoons, avoiding wasting of silk, ensuring uniform drying of silk filament and providing correct spacing to form cocoons. High humidity characteristics of rainy seasons, is not at all ideal for spinning.

2.8.4. Quality of raw silk.

As earlier stated, the quality of raw silk depends upon a combination of factors like the quality of cocoons, reeling technique, the type of machinery and equipments used and the skill of operatives. Testing provides scope for scientific investigation into causes for the defective aspects as well as the superior aspects of raw silk. The investigations would lead to evolving remedial measures to avoid recurrence of defects and also measures for further improvement of the quality and thus help to follow a system of quality control of production and marketing (FAO, 1987).

Selection of cocoons must be done very carefully otherwise serious losses may be incurred in the reeling enterprise. Selective purchase of cocoons in an open-air market is extremely difficult and becomes imperfect particularly in the absence of determined standards of quality for cocoons and standard method of testing for classifying cocoons into grades. In sericulturally advanced countries, on the other hand, where the cocoons produced are of good and uniform quality, the cocoon trade has been systematized by the introduction of standards of quality for cocoons and uniform methods of cocoon testing which includes test reeling (FAO, 1987).

2.9 Other uses of mulberry

In Kenya, mulberry tree is widely known for its fruits. The fruits can be made into jams and juices. Mulberry has made new advances worldwide as a forage plant because of its high protein content and high digestibility (Shayo, 1997). It has also been planted and used as multi-purpose tree for animal fodder, soil conservation, landscaping and for wood fuel as it regenerates very fast. In Asian countries and Tanzania it is also used for vegetable and for medicinal purposes (infusion is made from dry leaves as herbal teas), and basketry (Shayo, 1997; Omar, 1998).

3.0 MATERIALS AND METHODS

3.1 Experimental sites.

The experiments were conducted at two sites, ICIPE commercial insects mulberry farm within Duduville facilities at Kasarani, Nairobi and at Ministry of Agriculture sericulture farm within Kenya Agricultural Research Institute (KARI) Thika centre. These sites were with already existing mulberry trees which were meant for training, variety conservation and supply of planting materials for the farmers.

3.1.1 Thika Experimental site

The farm it at 1548 m above sea level, longitude of $37^0$04'E and Latitude 0^0.59'S. It has a temperature regime of between 25.1^0 C maximum and 13.7^0 C minimum. The coolest months are in May, June, July and August. The hottest months are in December, January and in February. It has a bimodal rainfall pattern, long rains and short rains, averaging 1060 mm per annum. It has a relative humidity of 60 percent (at 15.00 hrs local time 3 pm) (Kenya Soil Survey D22, 1982; Table 33).

The soils are dark red to dark reddish brown with textures varying from friable clay to gravelly clay (Kenya soil survey D22, 1982).

The experimental plots were 14m x 7.5m ('Thailand' variety), 14m x 7.5m ('Embu' variety), and 14m x 7.5m ('Kanva 2' variety).

Management regime before the experiment:

History of manure application was done but not consistently on yearly basis. Also fertilizers used were NPK 17:17:17; 23:23:0 and Calcium Ammonium Nitrate.

Weeding and pruning.

Manual weeding was done once a season. Grammaxone herbicide was also used in the farm to control the weeds.

Pruning of mulberry trees was done just before every rainy season. Medium-cut tree training method was adopted in the farm where by the pruning point on the main trunk is around 30 cm from the ground.

3.1.2 ICIPE Experimental site

The farm is at 1610 m above sea level, longitude of 36.89'E degrees and Latitude -1.22'S degrees. It has a temperature regime of between 27.8^{0}C maximum and 11.5^0 C minimum. The coolest months are in May, June, July and August while the hottest months are in December, January and in February. It has a bimodal rainfall pattern, with long rains and short rains averaging 850 mm per annum (ICIPE, 2000-2003).

The soils are shallow, yellow-brown to yellow red, friable clays overlaying a Laterite Horizon. Low in humus and with slight seasonal impeded drainage. (ICIPE, 2000- 2003)

The experimental plots sizes were 7m x 28m ('Thailand' variety), 9m x 24m ('Embu' variety), and 10m x 24m ('Kanva 2' variety).

Management regime before the experiment

The manure used was mostly left over wastes from sericulture lab composted in the farm. Mostly used inorganic fertilizers are NPK 20:20:0 and Calcium Ammonium Nitrate.

Weeding and prunning

Weeding was done once a season. Pruning is done mostly before the start of rainy seasons. Medium-cut tree training method was also adopted where by the pruning point on the main trunk is 30 cm from the ground.

3.2 Experiments

There were three experiments; Mulberry fertilizer response evaluation experiment, silkworm-rearing experiment and raw silk reeling experiment. These were done at the two sites.

3.2.1 Determination of effects of fertilizer and mulberry variety on plant growth

Experiment materials

In this experiment, the experimental materials included:

i) Plots of already existing mulberry trees of 'Embu', 'Kanva2', 'Thailand' varieties in the two sites.

ii) Fertilizer NPK 17:17:17

iii) Well-decomposed cattle Manure was collected from Government veterinary farm in Ngong.

3.2.2 Experiment Procedure in the two sites

The experiment was conducted in two seasons, starting during the short rainy season (SR) October to December 2004 and again in long rain season (LR) April to July 2005.

During the dry season, the plots were weeded and all mulberry plants were pruned to the height of 30 cm (medium- cut pruning system which is practiced at the farms) from the ground at both sites. The mulberry trees were at a spacing of 1.5m between the rows and 0.7m within the rows. Then furrows were dug 15 cm deep mid way between the plants in preparation for fertilizer application. The initial land preparation was done by weeding the already existing mulberry trees. Representative soil samples were taken (at 30cm soil depth), a sample per the Variety block, and these were analyzed for the macronutrients Nitrogen, Phosphorus and Potassium (NPK) and micronutrients copper, iron, manganese, and zinc.

Random allocation of manure and fertilizer treatments on the plots per variety block was done and labeled accordingly. The experimental design adopted at both sites was split plot in a Randomized Complete Block design (RCBD) with locations as blocking factors, each variety as main plot treatment and fertilizer-manure treatment as subplot treatment. At every site there were 3 main plot treatment of the three varieties and four sub plot treatments in every main plot. So each main plot of each variety was divided into four subplots, for the four treatments. These plots were marked and assigned treatments randomly. The treatments were applied on already prepared trenches mid way between the plants, which is a method of fertilizer application practiced in the farms.

The treatments applied were:

(a) Control – No manure and no fertilizer

(b) 1 kg Manure + 25g NPK 17:17:17 per tree per season

(c) 2 kg Manure per tree per season

(d) 50g NPK 17:17:17 per tree per season

For Manure alone treatment, it was applied at 4 kg per tree per year (2kg per tree per rainy season) and Fertilizer at 100g per tree per year for NPK alone treatment i.e. 50 g per tree per rainy season (adopted a generalized recommendation for Mulberry trees (Aruga, 1994) and also the practice in these farms). For the NPK+Manure treatment half the rates of manure and fertilizer was applied. i.e 1kg manure and 25 g fertilizer applied per tree per season. This was undertaken to determine the effect of reduced fertilizer application on mulberry quality and quantity and eventually silk quality.

These fertilizer treatments were done during short rains from October to December and long rains from March to July. The plots were treated once before each rainy season and left to sprout. Growth measurements were taken at 90 days after treatments, once every season and at both sites. This included measurement of the 4 longest shoots from different plants per sub-plot, and then assessing the number of shoots per stump. These aspects determine the quantity of leaf available for harvesting. Leaf samples were taken from the different lots harvested for initial silkworm feeding for chemical composition analysis on crude protein, crude fibre, dry matter and moisture content, constituents that determine leaf quality.

3.3 Methods used in Soil Analysis

Soil samples collected from each main plot and manures used were analyzed for both macronutrients and micronutrients at Soil Science department of University of Nairobi (see appendix 8.2 for methods used for soil analysis).

3.4 Methods used in Leaf chemical analysis

Leaf samples were taken from the lots that were being fed to the different groups of silkworms, and packed in labeled polythene bags. These were analyzed at

KARI Thika animal feed analysis Laboratory. (See appendix 8.1, for methods used for leaf chemical analysis).

3.5 Determination of effects of fertilizers and mulberry variety on silkworm performance

3.5.1. Rearing experiment materials

The experimental materials used included:

i) Silkworm eggs (ICIPE II race) 3 disease free layings (dfl) per site per season

ii) Sprouted Mulberry Leaves from the three varieties per season per site

iii) Rearing facilities and accessories at the two site laboratories

3.5.2 Procedure

The procedure below was followed at both sites and in the two seasons.

The experimental design was as in mulberry experiment, a split plot in RCBD with locations as blocking factors, each variety, a main plot and fertilizer-manure treatments as subplots.

Every season before feeding commenced, leaf sampling was done for chemical composition analysis. At every site three disease free layings (dfls) of ICIPE 11 race were incubated for 10-11 days to hatch. Feeding commenced in January 2005 (short rain season) and July 2005 (long rain season) when the trees were 90 days after fertilizer-manure treatments. Every time, the rearing houses and accessories had to be disinfected with formalin in readiness for silkworm rearing. The trays were marked as the plots indicating the variety and the treatments (as in the mulberry plots). After hatching the worms were brushed and divided into three variety-marked trays. These were fed adlibitum with the leaves corresponding to the three varieties. Bed cleaning was done after every moult to observe and maintain hygiene. In their 3rd instar every variety group of worms was divided into four groups of 50 worms each, to correspond to the fertilizer and manure treatment plots and every tray labeled accordingly. This is the stage when silk glands develop. Feeding continued through 3rd, 4th and 5th instars. Dusting of the worms with lime after every bed cleaning was done to ensure disinfection and reduce disease incidences. Larval weights were determined at 4th instar, day 4, by weighing a random sample of 30 worms from each group and weights of individual worms recorded in the already prepared register. Again at the 5th instar day 1 and 5th instar day 5 weighing was done and weights of randomly picked 30 individual worms recorded in the register. Feeding stopped at 5th in-star day 8 when the groups started spinning and cocooning mountage frames were provided. They were left to spin for eight days before cocoons were harvested. From the harvested fresh cocoons, random samples of 30 cocoons were weighed from each group. These samples were then dried separately. Then 20 randomly picked cocoons of each group were weighed, cut to separate the pupa and the shell. Pupa and shell were then weighed separately, thus giving measurements on; cocoon weight, pupae weight, and Shell weight. All measurements were recorded on prepared data registers

3.6 Determination of effects of fertilizers and mulberry variety on cocoon characters and raw silk

Cocoon reeling experiment

The objective of silk reeling is to unwind the filament of which the cocoon is formed in order to obtain the silk yarn. The silk filament is a continuous thread of great strength measuring from 500-1500 metres in length. Single filaments are too thin for utilization. For production purposes, several filaments are combined with a slight twist into one strand. The filament is reeled into raw silk after the sericin or the gum holding the cocoon together is dissolved. This is done by boiling the cocoons in hot water. The cooking technique has evolved along with the evolution of the reeling technology (FAO ASB 42, 1980).

3.6.1 Reeling procedure

The remaining 10 cocoons of each group were placed in hot water (90^0C) and boiled separately for 10 minutes. During the boiling, 1-1.5 % of the sericin gum is removed. The remaining 18-19 % gummy proteins are essential for further post cocoon operations (Raina, 2004). Brushing with a hand brush was done to get free ends to start unwinding. Each cocoon was reeled singly on a single cocoon reeling machine. Unwinding of the cocoon was done until the inner case is reached. The length of each cocoon filament was recorded from the machine. After the 10 cocoons were reeled these were removed from the machine, weighed and recorded.

3.7 Data analysis

All the data collected was analyzed by Genstat statistical package using analysis of variance (ANOVA) procedure. Means were separated by the least significant difference (LSD) at $p \leq 0.05$ (Gomez and Gomez, 1984; Steele and Torie, 1980).

4.0 RESULTS

4.1 Soil analysis results

4.1.1 Macronutrients

Table 1: showing the macronutrient content of the manure and soil samples collected from the two sites.

		Cmol/kg							%		ppm
Location	Main plot	pH H_2O	pH 0.01M $CaCl_2$	Na	K	Ca	Mg	CEC	C	N	P
Thika	Thailand	6.8	5.6	0.001	0.55	4.35	4.1 **	11.7	3.8 *	0.72**	30.0
Thika	Embu	7.2 **	6.3	0.001	0.55	5.55	4.5 **	15.4	4.8	0.66 **	10.0
Thika	Kanva	7.0	6.6	0.004	0.55	1.80 *	3.5	8.7	3.7 *	0.63 **	10.0
ICIPE	Thailand	7.5 **	6.8	0.4	0.45	9.1 **	5.6 **	18.5	1.7 *	0.21	9.0
ICIPE	Embu	7.8 **	6.6	0.5	0.30	8.5 **	7.1 **	25.8 **	2.7 *	0.31	2.1
ICIPE	Kanva	7.7 **	7.2	0.5	0.30	5.10	3.0	13.6	2.8 *	0.25	50.0
	Manure	7.8 **	6.5	0.45	1.90 **	6.70	187.5 **	28.8 **	14.8 **	1.6 **	3.500

** High levels * Low levels

The analyzed soil results were compared with the summary given in Tropical soil manual, Landon, 1991 (Table 2) and rated as low, high and very high levels as indicated above (Table 1). The results from table 1 showed that soils from ICIPE had higher pH levels as compared to Thika soils. ICIPE soils had higher levels of CEC and high levels of calcium (Ca), magnesium (Mg) and lower levels of carbon, nitrogen and phosphorus compared to Thika soils. Table 1 again showed that Thika soils had higher amounts of potassium compared to ICIPE soils. ICIPE soils on the other hand had higher amounts of sodium (Na).

Table 2: Showing high and low levels of macronutrients.

Rating	pH (H_2O)	Na	K	Ca	Mg	CEC	C	N	P
Units		Me/100g soil	Me/100g soil	Me/100g soil	Me/100g soil	Me/100g soil	% by weight	% by weight	ppm
Very High	>8.5					>40			
High	>7.0	>1	>0.6	>10	>4.0	>25	>10	>0.5	
low	<5.5		<0.2	<4	<0.5	<5	<4	<0.2	

Source: Booker Tropical Soil Manual (Landon, 1991)

4.1.2 Micronutrients

Table 3: Showing micronutrients of the soil samples collected from Thika and ICIPE sites (in ppm).

Location	Main plot	Cu	Fe	Mn	Zn
Thika	Thailand	8.0	60.0	240.0	40.0
Thika	Embu	4.0	50.0	180.0	40.0
Thika	Kanva	3.0	90.0	180.0	40.0
ICIPE	Thailand	15.0	300.0	250.0	30.0
ICIPE	Embu	15.0	310.0	380.0	30.0
ICIPE	Kanva	9.0	290.0	280.0	30.0
	Manure	2.4	470.0	710.0	130.0

Micronutrients results (Table 3) were also compared with summary in Booker tropical soil manual by Landon, 1991 (Table 4) and the following observations rated as toxic or deficient levels.

Soils from the two sites did not have toxic or deficient levels of macronutrients but ICIPE soils were found to have higher levels of iron (Fe), manganese (Mn) and copper (Cu) than Thika soils. Thika soils on the other hand had higher amounts of zinc (Zn) than ICIPE soils. The manure used also had high levels of Fe, Mn and Zn.

4.1.3 Deficiency and Toxic levels

Table 4: Showing the deficiency and toxic levels of micronutrients (in ppm).

	Cu	Fe	Mn	Zn
Deficiency levels	<0.2	<4.5	<9	<7.5
Toxic Levels	>200	>500	>10,000	>900

Source: Booker Tropical soil manual, 1991

4.2 Effects of fertilizers and mulberry variety on plant growth performance.

4.2.1 Length of mulberry shoots

In the 1st season (SR), the interaction (combined effects) between treatments and variety was found significant (P=0.0018). Thus the effect of fertilizer/manure input depended on the variety (Table 5). For 'Embu' and 'Thailand' varieties, manure and NPK applications gave longest shoots compared to other treatments. As for 'Kanva' variety, NPK and control treatments gave longer shoots than 'Kanva' variety treatments. 'Embu' variety gave the most effect of the fertilizer/manure application (Table 5).

Table 5: Influence of fertilizer and Mulberry variety on the shoot length of mulberry in the 1st season at Thika and ICIPE (Shoot length in cm).

Treatments	Embu	Kanva	Thailand
Control	84^{c}	87^{bc}	64^{d}
Manure	111^{a}	78^{c}	81^{c}
NPK	103^{ab}	88^{bc}	91^{bc}
NPK+Manure	96^{bc}	83^{c}	81c

SE (V*T) = 4.0215 **LSD = 23.96**

In the 2nd season (LR), the interaction between treatments and variety was also found significant (P<0.001). In this season, 'Embu' variety with manure gave longer shoots compared to its other treatments. For 'Thailand' variety, NPK, and NPK+ Manure treatments had significantly longer shoots than other treatments. As for 'Kanva' variety manure and NPK+ manure gave longer shoots than other treatments. In this season,' Thailand' variety showed the most of effect of fertilizer/manure application followed by 'Kanva' variety (Table 6).

Table 6: Influence of fertilizer and Mulberry variety on the shoot length of mulberry in the 2nd season (Shoot length in cm) at Thika and ICIPE.

	Variety		
Treatment	Embu	Kanva	Thailand
Control	92.8^{e}	105.9^{d}	103.1^{d}
Manure	121.8^{ab}	129.8^{a}	$118b^{c}$
NPK	110.5^{cd}	108.3^{d}	129.6^{a}
NPK+Manure	110.1^{cd}	128^{a}	125.6^{ab}

SE (V*T) = 3.1 LSD = 8.58

In this season interaction between location and variety was found to be significant (P< 0.001). Thika plots were observed to have longer shoots than those at ICIPE site (Table 7).

Table 7: Influence of location and Mulberry variety on shoot length of mulberry in the 2nd season (Shoot length in cm) at Thika and ICIPE.

	Location	
Variety	ICIPE	Thika
Embu	104.1^{d}	113.4^{c}
Kanva	103.3^{d}	132.7^{a}
Thailand	116.6^{bc}	121.6^{b}

SE (L*V) = 2.2   LSD = 6.07

4.2.2 Number of mulberry shoots.

In the 1st season (SR) interaction between treatment and variety was found not significant. Thus the effect of fertilizer/manure treatment did not depend on variety for number of shoots. However, single factor for variety was significant ($P<0.001$), 'Embu' variety having the highest number of shoots. In 2nd season (LR), the interaction between treatment and variety was not also significant, but interaction was significant between location and variety ($P< 0.005$) (Table 8) with 'Embu' variety at Thika site having the most number of shoots. Interaction between location and treatment was found to be significant ($P<0.05$) with Thika site giving the highest number of shoots for 'Embu' variety with NPK treatment (Table 9).

Table 8: Influence of location and Mulberry variety on shoot numbers of mulberry in the 2nd season (LR) at Thika and ICIPE.

Variety	Location	
	ICIPE	Thika
Embu	25.4^{c}	49.8^{a}
Kanva	24.8^{c}	35.3^{b}
Thailand	21^{c}	38.3^{b}

SE (V*L) = 2.0 LSD = 5.71

Table 9: Influence of fertilizers and location on shoot numbers of mulberry in the 2nd season (LR) at Thika and ICIPE.

Treatment	Location	
	ICIPE	Thika
Control	19.4^{d}	40^{b}
Manure	22.4^{d}	40^{b}
NPK	23.5^{cd}	46.8^{a}
NPK+Manure	29.7^{c}	37.6^{b}

SE (T*L) = 2.3 LSD = 6.60

4.3 Effect of fertilizers and mulberry variety on silkworm larva performance.

4.3.1 4th instar larval weight

During 1st season (SR) interaction between treatment and variety was found significant (P=0.0001) for 4th instar larva weight. Thus, 'Embu' variety with manure and manure +NPK treatments had higher mean weights than its other treatments. For 'Kanva' variety, there was no significant difference in weight among the treatments. For 'Thailand' variety, there was significant difference in larva weight between fertilizer/manure treatment and its control (Table 10).

Table 10: Influence of fertilizers and Mulberry varieties on 4th instar larva weight in the 1st season (SR) at Thika and ICIPE.

	Variety		
Treatment	Embu	Kanva	Thailand
Control	0.518f	0.661cd	0.672cd
Manure	0.635d	0.686bc	0.726ab
NPK	0.567e	0.691bc	0.739a
NPK+Manure	0.635d	0.676cd	0.728ab

SE (V*T) = 0.01 LSD = 0.04

In 2nd season (LR) interaction between treatment and location was found significant (P=0.0007) on the 4th instar larva weight with manure treatment in ICIPE having the highest 4th instar larva weight. (Table11). There was also significant interaction between location and variety (P=0.0000) 'Thailand' variety in ICIPE location having higher mean weight than other varieties (Table 12).

Table 11: Influence of fertilizers and location on 4th instar larva weight (gms) in the 2nd season (LR) at Thika and ICIPE.

	Location	
Treatment	ICIPE	THIKA
CONTROL	0.638d	0.596e
MANURE	0.72a	0.645cd
NPK	0.699ab	0.632de
NPK+MANURE	0.678bc	0.681bc

SE (L*T) = 0.01 LSD = 0.03

Table 12: Influence of location and mulberry varieties on 4th instar larva weight (gms) in the 2nd season (LR) at Thika and ICIPE.

	Location	
Variety	ICIPE	THIKA
EMBU	0.566e	0.611d
KANVA	0.712b	0.646c
Thailand	0.774a	0.659c

SE (L*V) = 0.01 LSD= 0.03

4.3.2 5th instar larva weight

In 1st season (SR), interaction between treatment and variety was significant (P=0.0135) at both sites with 'Embu' variety with NPK+Manure and manure treatments in Thika having higher larval weight (Table 13) and 'Thailand' variety with manure treatment in ICIPE having higher 5th instar larva weight (Table 14).

Table 13: Influence of fertilizers and mulberry varieties on 5th instar larva weight (gms) in the 1st season (SR) at Thika site.

Treatment	Embu	Kanva	Thailand
Control	1.833^{bc}	1.97^{b}	1.731^{c}
Manure	2.239^{a}	2.153^{a}	1.826^{bc}
NPK	1.926^{b}	1.85^{bc}	1.687^{c}
NPK+Manure	2.204^{a}	1.985^{b}	1.663^{c}

SE (V*T) = 0.0470 **LSD= 0.280**

Table 14: Influence of fertilizers and mulberry varieties on 5th instar larva weight (gms) in the 1st season at ICIPE site.

Treatment	Embu	Kanva	Thailand
Control	1.325^{de}	1.288^{e}	1.498^{b}
Manure	1.518^{b}	1.342^{de}	1.611^{a}
NPK	1.418^{c}	1.343^{de}	1.398^{cd}
NPK+Manure	1.334^{de}	1.393^{cd}	1.552^{b}

SE (V*T) = 0.0183 **LSD = 0.109**

However, in 2nd season (LR), interaction between treatment and variety, locations pooled was found significant (P=0.00000), 'Thailand' variety with NPK+ manure treatments and 'Kanva' variety with NPK+ Manure having higher mean weights than other treatments (Table 15).

Table 15: Influence of fertilizers and mulberry varieties on 5^{th} instar larva weight (gms) in the 2nd season both Thika and ICIPE locations pooled.

Treatment	Embu	Kanva	Thailand
Control	2.239^{g}	2.818^{e}	2.742^{e}
Manure	2.864^{de}	2.945^{d}	3.251^{b}
NPK	2.447^{f}	3.185^{bc}	3.12^{c}
NPK+Manure	2.955^{d}	3.407^{a}	3.285^{ab}

SE (V*T) = 0.04 LSD = 0.12

In this season (LR) there was also significant interaction between variety and location (P=0.0000) with ' Kanva' variety in Thika location having the highest mean weight among the other varieties (Table 16). There was also significant interaction between treatment and location with NPK+Manure treatment in Thika location having the highest mean weight (Table 17).

Table 16: Influence of location and mulberry varieties on 5^{th} instar larval weight (gms) in the 2^{nd} season (LR) at Thika and ICIPE.

	Location	
Variety	ICIPE	THIKA
EMBU	2.227^{f}	3.025^{c}
KANVA	2.762^{e}	3.415^{a}
THAILAND	3.261^{b}	2.938^{d}

SE (L*V) = 0.03 LSD = 0.09

Table 17: Influence of fertilizers and location on 5^{th} instar larval weight (gms) in the 2^{nd} season (LR) at Thika and ICIPE.

	Location		
Treatment	ICIPE	THIKA	Mean
CONTROL	2.457^{d}	2.742^{c}	2.600
MANURE	2.712^{c}	3.327^{a}	3.020
NPK	2.747^{c}	3.087^{b}	2.917
NPK+MANURE	3.083^{b}	3.347^{a}	3.215
Mean	2.750	3.126	

SE (L*T) = 0.04 LSD = 0.10

4.4 Effect of fertilizers and mulberry variety on cocoon characters.

4.4.1 Semi dry cocoon weight

During 1st season (SR), interaction between treatments and variety was not significant but single factor of variety was significant (P=0.0000) with 'Kanva' and 'Thailand' varieties with NPK+Manure treatment having higher mean weight of 1.351 and 1.341, respectively (Table 18).

Table 18: Influence of fertilizers and Mulberry varieties on cocoon semi dry weight (gms) in 1st season (SR) at Thika and ICIPE.

Treatment	Embu	Kanva	Thailand
Control	1.175	1.323	1.282
Manure	1.199	1.269	1.296
NPK	1.216	1.300	1.251
NPK+Manure	1.151	1.351	1.341

SE (V*T) = 0.0381 LSD= 0.227

In the 2nd season (LR), interaction between treatment and variety was significant (P=0.0051), 'Kanva' and 'Thailand' with NPK+Manure having higher weights in both sites than other treatments (Table 19).

Table 19: Influence of fertilizers and Mulberry varieties on cocoon semi dry weight (gms) in the 2nd season (LR) at Thika and ICIPE.

Treatment	Variety		
	Embu	Kanva	Thailand
Control	1.3^{g}	1.5^{cde}	1.5^{cde}
Manure	1.4^{f}	1.5^{c}	1.7^{b}
NPK	1.4^{e}	1.5^{cd}	1.7^{ab}
NPK+Manure	1.5d^{e}	1.7^{ab}	1.7^{a}

SE (T*V) = 0.03 LSD = 0.07

4.4.2 Dry cocoon weight

It was only in the 2nd season (LR) that there were significant interactions between variety and location (P=0.0000), and treatment and variety (P=0.0276). 'Kanva' variety in Thika location and 'Thailand' variety in ICIPE location had higher dry cocoon mean weights than 'Embu' variety (Table 20).

Table 20: Influence of Mulberry variety and location on cocoon dry weight (gms) in the 2nd season (LR) at Thika and ICIPE.

Variety	Location	
	ICIPE	THIKA
Embu	0.523^{c}	0.612^{b}
Kanva	0.62^{b}	0.696^{a}
Thailand	0.683^{a}	0.632^{b}

SE (V*L) = 0.01 LSD = 0.03

Treatment and variety had significant interaction (P=0.0276), 'Kanva' and 'Thailand' varieties had higher dry cocoon mean weight than other treatments, NPK+ Manure gave higher dry cocoon weight than other treatments (Table21).

Table 21: Influence of fertilizers and Mulberry varieties on dry cocoon weight (gms) (Pooled for both Thika and ICIPE sites) in the 2nd season (LR).

Treatment	Variety			Mean
	Embu	Kanva	Thailand	
Control	0.504^{e}	0.628^{cd}	0.579^{d}	0.570
MANURE	0.593^{d}	0.631^{cd}	0.68^{d}	0.635
NPK	0.586^{d}	0.656^{bc}	0.666^{abc}	0.636
NPK+MANURE	0.588^{d}	0.718^{a}	0.705^{ab}	0.670
Mean	0.567	0.658	0.657	

SE (V*T) = 0.02 LSD = 0.05

4.4.3 Cocoon shell weight

During the 1st season (SR), interaction between treatment and variety was not significant (P=0.0541). Single factors were not also significant. However, in the 2nd season (LR), the interaction between treatment and variety was not significant (P=0.1309) but single factors were significant (P=0.0000) for variety and (P=0.0491) for fertilizer treatment, 'Kanva' and 'Thailand' varieties with NPK+Manure treatment having the highest shell weight (Table 22).

Table 22: Influence of fertilizers and Mulberry variety on cocoon shell weight (gms) in the 2nd season (LR) at Thika and ICIPE.

Treatment	Embu	Kanva	Thailand
Control	0.262	0.280	0.287
Manure	0.243	0.248	0.269
NPK	0.258	0.244	0.284
NPK+Manure	0.251	0.280	0.276

SE (V*T) = 0.0076 LSD = 0.045

4.4.4 Cocoon filament length

In both seasons interaction between treatment and variety was significant (P=0.0000). 'Thailand' variety with NPK+ Manure had highest filament length (857.3 metres) (Table 23).

In other varieties also NPK+Manure treatment gave the highest filament length amongst treatments (Table 23).

Table 23 : Influence of fertilizers and Mulberry varieties on filament length (metres) at Thika and ICIPE.

	Variety		
Treatment	Embu	Kanva	Thailand
Control	786.7[bc]	686[d]	692.2[d]
Manure	698[d]	763.1[c]	764.1[c]
NPK	760.1[c]	756.1[c]	824.9[ab]
NPK+Manure	791.5[bc]	838.2[ab]	857.3[a]

SE (T*V) = 19.5 LSD = 54.3

Interaction between seasons and location was significant (P=0.0000) with 1st season (SR) at ICIPE having highest mean length (Table 24).

Table 24 : Influence of location and seasons on cocoon filament length (in metres) at Thika and ICIPE.

	Season	
Location	1	2
ICIPE	816.2[a]	784.9[ab]
THIKA	705[c]	766.6[b]

SE (L*S) = 11.3 LSD = 31.4

Treatment versus season was also found significant (P=0.0221), NPK+Manure and NPK treatments having the highest mean lengths (Table 25).

Table 25: Influence of fertilizers and seasons on cocoon filament length (in metres) at Thika and ICIPE.

Treatment	Season		Mean
	1	2	
Control	731.9[b]	711.3[b]	721.6
MANURE	731.1[b]	752.4[b]	741.7
NPK	745.4[b]	815.3[a]	780.3
NPK+MANURE	833.9[a]	824[a]	829.0
Mean	760.6	775.7	

SE (T*S) = 16.0 LSD = 44.3

4.5 Effect of fertilizers and mulberry variety on leaf nutrient composition.

Leaf samples were taken at 90 days after fertilizer treatments and were analyzed at Kenya Agricultural Research institute (KARI) Laboratory within Thika centre. Results of the analysis are in Appendix Tables 33 for the 1st season (SR) and Table 34 for the 2nd season (LR).

4.5.1 Crude protein percentage (% cp)

In the 1st season (SR), interaction between treatment and location was not significant but single factors were significant (P=0.0218), S.E. 0.8223 and LSD 2.631 for treatment. 'Thailand' variety had highest mean % CP in Thika. Manure and NPK+ Manure treatments gave higher mean % CP compared to other treatments (Table 26).

Table 26: Influence of fertilizers and location on %Crude protein in the 1st season (LR) at Thika and ICIPE.

	ICIPE			Thika			Mean
Treatment	Embu	Kanva	Thailand	Embu	Kanva	Thailand	
Control	19.27	19.05	18.84	21.40	20.55	21.83	20.16
Manure	21.83	18.19	17.33	20.76	19.91	23.17	20.20
Manure+NPK	19.06	21.09	23.76	20.76	20.12	21.94	21.12
NPK	19.48	17.55	19.70	19.69	17.98	21.83	19.37
Mean	19.91	18.97	19.91	20.65	19.64	22.19	20.21

S.E. (T*L) = 0.8223 LSD = 2.631

4.5.2 Crude fibre percentage (%CF)

In 1st season (SR), the interaction between treatments and variety was significant (P=0.0295), Embu variety having the highest mean % crude fibre in both sites. NPK treatment has highest mean % crude fibre (Table 27).

However, in the 2nd season (LR), interaction between all factors was not significant (Table 28).

Table 27: Influence of fertilizers and varieties on % crude fibre in the 1st season (SR) at Thika and ICIPE.

	ICIPE			Thika			Mean
Treatment	Embu	Kanva	Thailand	Embu	Kanva	Thailand	
Control	13.99	13.87	16.52	18.10	16.38	13.00	15.31
Manure	13.82	13.51	15.71	18.34	18.48	15.25	15.85
NPK+Manure	15.42	14.05	13.29	17.25	17.41	16.75	15.70
NPK	15.55	16.75	16.61	17.41	18.13	17.00	16.91
Mean	14.70	14.55	15.53	17.78	17.60	15.50	15.94

SE (T*V) = 0.78 LSD = 2.50

Table 28: Influence of fertilizers and location on % crude fibre in the 2nd season (LR) at Thika and ICIPE.

Treatment	ICIPE	Thika	Mean
Control	10.8	10.9	10.9
Manure	11.6	10.6	11.1
NPK	12.0	10.8	11.4
NPK+Manure	12.3	11.5	11.9
Mean	11.7	10.9	11.3

S.E. (T*L) = 0.2726 LSD = 1.658

There were no statistical significant differences with other constituents analyzed which had the following means (Tables 29 and 30).

Table 29: Influence of fertilizers and varieties on % moisture content in the 1st season (SR) at Thika and ICIPE.

	ICIPE			Thika			Mean
Treatment	Embu	Kanva	Thailand	Embu	Kanva	Thailand	
Control	69.62	67.14	68.87	73.40	68.88	66.75	69.11
Manure	72.23	67.42	62.63	68.90	67.70	71.43	68.39
NPK+Manure	56.44	69.80	53.03	68.60	70.03	70.68	64.76
NPK	70.41	66.65	60.34	68.25	67.33	69.48	67.08
Mean	67.18	67.75	61.22	69.79	68.49	69.59	67.33

Table 30: Influence of fertilizers and varieties on % Dry matter in the 1st season (SR) at Thika and ICIPE.

	ICIPE			Thika			Mean
Treatment	Embu	Kanva	Thailand	Embu	Kanva	Thailand	
Control	30.38	32.86	31.13	26.60	31.12	33.25	30.89
Manure	27.78	32.58	37.37	31.10	32.30	28.58	31.62
Manure+NPK	43.56	30.20	46.97	31.40	29.97	29.32	35.24
NPK	29.60	33.35	39.66	31.75	32.67	30.52	32.93
Mean	32.83	32.25	38.78	30.21	31.52	30.42	32.67

In Table 30 there was no significant difference in dry matter content between all the treatments but manure + NPK treatment had the highest dry matter content.

5.0 DISCUSSION

From the soil analysis results (Table1) ICIPE soils were higher in pH, Na, Ca, Mg and lower in organic carbon and nitrogen. The soils had higher levels of iron (Fe) than Thika soils. According to management regime the plots rarely got organic manures and the leaf remnants (wastes) from the silkworm rearing is very insignificant for the three acre farm. The farm was also prone to water-logging leading to high pH and high accumulation of the minerals like Na, and Fe. pH levels affect the availability of both macronutrients and micronutrients (Landon, 1991). High pH values may render nitrogen unavailable due to reduced bacterial nitrogen fixation. At high pH levels and in presence of calcium, phosphate ions are converted to calcium phosphate rendering phosphate unavailable to the plant. Boron may attain toxic levels at high pH.

Thika soils were high in zinc micronutrient (Table 3). Subbaswamy *et al.,* 1995, found that availability of some micronutrients like Zn not only ensures good mulberry yield but also avoids to a greater extent the use of growth regulators. This suggests a possibility why the mulberry crop in Thika did better than in ICIPE (Table 3).

Ministry of Agriculture final reports on fertilizer use recommendation (MoA FuR, 1987), indicates that areas on the east of Thika and Ruiru towns which includes both ICIPE and Thika experimental sites lie on plateaus and high level structural plains and soils in these areas are developed on basic igneous rocks. These soils include Eutric- Nitisols (RB3) class of soils. In most of these areas, the soils are well drained, extremely deep, dusky red to dark reddish brown, friable clay.

(A few pockets are poorly drained and are of dark clays). The soils have a predominantly moderate angular blocky structure and a very high porosity. Referring to soil analysis done in these reports, soils in these areas contain only low to moderate amounts of total nitrogen. They also have wide C/N ratios that indicate a very low N supplying capacity and so a moderate N supply from the soil should be assumed. Available phosphorus also is low to moderate. Potassium status is moderate to high. Quantities of magnesium are fairly moderate in amounts. Calcium is on average, levels are low to moderate; manganese is well within the adequate range, Zinc is low to moderate and copper is available in high amounts. This compares very well with the soil analysis results of this project except for a few which show low or high amounts, and these could be related to the management regimes in these sites.

5.1 Effects of fertilizers and mulberry variety on plant growth performance

5.1.1 Length of shoots

Mulberry shoot length and number are closely related to the amount of mulberry leaf harvests and so it is an important parameter for consideration (Aruga, 1994).

Embu variety was found to have significantly higher mean length of mulberry shoots than other varieties in the 1^{st} season (SR) (Table 5). From the rainfall data (Appendix Table 33 and Fig 2), 1st season (SR) had lower mean rainfall with a range of 78.2 to 98.6 mm within the months of October and December 2004 compared to 2^{nd} season (LR) with a rainfall range of 50.0 to 259.2 mm within the months of March and May 2005 . Maximum temperatures were ranging from 26.2 to 25.4 ^{0}C within the months of October to December and 28.9 to 23 ^{0}C within the months of March to June (Appendix Table 33 and Fig 1). Humidity was ranging from 78 to 81 % within the months of October to December and 80 to 85 % within the months of March to June (Appendix Table 33 and Fig 3). During the first season (SR), Embu variety did better in shoot length than other varieties despite the low rainfall (Table 5). In the 2nd season (LR) when weather conditions were not limiting, Thailand and Kanva varieties did better than Embu variety (Table 6). This to some extent supports the report by the Ministry of Agriculture (MOA, 1983) that Embu variety is drought tolerant. Despite the low rainfall and high evaporation rates of 145.2 to 155.1mm within the months of October to December, when potential evapo-transpiration was higher than rainfall (Appendix Table 33 and Fig 4), the growth performance of this variety proved to be better than of other two varieties.

Decline in soil fertility is a major problem contributing to low yield in many crops. Debele, (1999) indicates that it is particularly serious in tropical and sub tropical regions where many soils lack adequate plant nutrients and organic matter, and intense rainfall erode top soils. Recommendations on soil improvement treatments are therefore necessary so as to up scale yield of crops.

In Tables 5 and 9, NPK treatment gave higher shoot length and numbers, respectively. With low rainfall as it was in 1st season (SR), readily available nutrients in NPK were rapidly utilized by the mulberry crop giving higher length of the shoots than with manure treatments. However, in 2nd season (LR) where higher rainfall, humidity, and lower temperatures prevailed, Thailand variety and with NPK and NPK+ manure had higher lengths of shoots. This confirms the findings of Karuhizo, (1978) and Chinchiem and Srisuwan, (1974a) that found that Noi (Thailand) variety showed better growth of shoots after base cut than other Japanese varieties. Further more unutilized manure applied in 1st season (SR) in this latter plot was an added advantage to manure treatment plots in the 2nd season (LR). Farmyard manure has slow release of nutrients and there is no way the crop could utilize all the benefits in one or two seasons. Thika plots generally had longer shoots than ICIPE ones (Table 7). This could be attributed to better soil fertility (high N, C, P, K and more favourable pH, Mn and Na levels) that existed before treatments (Table 1). High levels of iron and manganese in ICIPE soils could have contributed to lower growth performance of ICIPE crop than in Thika.

5.1.2 Number of shoots

There were significant interaction between location and variety and also between location and treatments (Tables 8 and 9, respectively). Thika site gave a higher number of shoots in Embu variety and with NPK treatment in both 1st and 2nd seasons (Tables 8 and 9). This could be attributed to age of the trees since Thika trees (15 years) were older than ICIPE trees (10 years). Age of trees is a factor that influences the size of trunk and hence the area where shoot buds arise. The other factor that could have influenced is the soil fertility. Soil analysis results showed that ICIPE soils were lower in C and N than Thika soils (Table 1).

It was noted in the course of the field observations that except for mulberry plots that received manures, all others in the 1st season (SR) were showing signs of wilting at the peak of daily temperatures in the short rainy season especially in the months of January and February which had highest figures for evaporation and had most hours of sunshine. (See weather data Appendix Table 33 and Fig 4). The exception was attributed to improved water holding capacity due to manures in the manure treated plots. However, in 2^{nd} season (LR), plots that received both fertilizers and manures had lower brown leaf spot and powdery mildews diseases' incidences than the controls, except Thailand variety that showed high tolerance. This could have been due to improved nutrition which resulted in faster growth and enhanced disease resistance. Kanva and Embu varieties showed high vulnerability to these diseases especially in the cold months of June, July, and August.

5.2 Effects of fertilizers and mulberry variety on silkworm performance

5.2.1 4^{th} instar larval weight

During 1^{st} season (SR), Embu variety with manure treatments had higher mean weight (Table 10). It was observed that plots with manure did not show signs of wilting. This is in line with findings by Ikombo (1984) (with maize). Leaves from his manure plots stayed fresh longer after plucking (harvesting). This longer period of freshness gave the larvae longer time of feeding on them since larva has less appetite for wilted leaves. Manure increases water-holding capacity of the soil thereby giving the plants moisture reserves during the low rainfall season (Table 10). In the 2^{nd} season (LR), where moisture was not limiting, Thailand variety with NPK gave higher mean weight (Tables 11 and 12). When 1^{st} season (SR) larva performance is compared with 2^{nd} season's (LR), 2^{nd} season (LR) seems to be better. This is because much as larva performance is determined by leaf quantity and quality, it is also determined by temperatures and humidity, the optimal temperature range being 20-28^{0}C and humidity range of 65-85 % depending on larval stage (Raina, 2004). This 2nd season (LR) favoured the rearing in July-August when temperature was lowest (12.8min -22.5^{0}C max) and humidity highest (56-86%) (Appendix Table 33).

Higher temperatures combined with lower humidity also makes the leaves wither faster rendering them unpalatable to the larva hence the lower larva growth performance in the 1st season (SR).

5.2.2 5th instar larval weight

This is the last larval stage of silkworm. It is in this stage that the larvae gain most of the weight after accumulating the silk content that forms the cocoons. This weight is important as it relates to the size and weight of the resultant cocoons.

The results in Table 13 indicate that during the 1st season (SR) Embu variety in Thika gave higher weights than other varieties. Manure treatments in all varieties gave better weights than other treatments (Table 13). This could be due to the fact that manures contain a complete range of nutrients. At ICIPE, Thailand variety gave higher weight than other varieties. In the leaf analysis results, Thailand variety gave higher mean % crude protein than other varieties. Manure treatments also gave high mean % crude protein (Appendix Tables 31 and 32). Generally, manure treatments gave highest larval weight among the treatments (Table 14). High crude protein in leaves meant healthy silkworm and high accumulation of silk protein in silk gland of the silkworm hence heavier weights.

During 2nd season (LR) when moisture was not limiting, Thailand and Kanva varieties with manure and NPK+ manure were found to have higher mean weights than Embu treatments (Table 15). At the same time, Thika plots did better than ICIPE plots (Table 16). Manure and manure +NPK plots also gave highest larval weights (Table17). This could be due to favourable, temperatures and humidity (Appendix Table 33 for rainfall pattern) that prevailed resulting to better larval growth and also well-distributed and sufficient rainfall for good crop performance in addition to these nutrients. Thailand variety being tolerant to leaf spot and powdery mildew gave better leaves than those other varieties. Moreover, manure applied in 1st season (SR) in NPK+Manure plots gave more assimilates in 2nd season (LR) and in addition to nutrients in NPK applied; the crop had better performance than in 1st season (SR).

5.3 Effects of fertilizers and mulberry variety on cocoon characters

5.3.1 Cocoon weights

Semi dry cocoon weight is an important aspect as this is harvesting and selling weight of cocoons in this country and determines the gross output of sericulture enterprise.

In the 1st season (SR) single factors of variety were significant, Kanva and Thailand varieties with NPK+ Manure having higher mean weights (Table 18). During 2nd season (LR), interaction between treatments and variety was significant Kanva and Thailand varieties with NPK+Manure treatment having the highest semi dry weight (Table 19). It was observed that the higher the larval weight the higher the cocoon weights (compare Tables 11, 15, 16 and 19, 20, 21).

This was attributed to crop performance and quality of leaves. High quality of leaves is related to high mean percentage crude protein, dry matter, moisture content and low crude fibre of the leaves and this greatly influences the health of silkworm larvae, and finally the resultant weight of cocoons (Aruga, 1994).

5.3.2 Shell weight

In both seasons interaction between treatment and variety was not significant but single factors were. Kanva and Thailand varieties with NPK +manure had higher shell mean weight (Table 22). This is again attributed to quality crop and healthy larva performance giving a heavier shell. Also high % CP in leaves from these treatments gave higher silk content thus heavier shells (compare Tables 22 and 26).

This is an important feature of the cocoon for judging the cocoon quality and silk content

(Aruga, 1994) Hisao indicates that, $\frac{\text{shell weight} \times 100}{\text{Total cocoon weight}}$ = Cocoon Layer Ratio.

Cocoon layer Ratio is termed as Cocoon Yield.

5.3.3 Filament length

Again it has been observed that in both seasons Thailand variety with NPK +Manure gave longer filaments (Tables 23 and 25). Seasonality was also found significant during the 2nd season having higher filament length of 775.7 metres than 1st season (SR) (Table 24). Mulberry leaf protein is the source for silkworm to biosynthesis the silk. So treatments that had high % crude protein showed longer filament length (Compare Tables 23 and 26).

Seasonality also was found to have some effect on weight of filament with 2nd season (LR) having higher mean weight (Tables 24 and 25). This is attributed to better environmental conditions, temperature, humidity and rainfall in addition to fertilizer and manure applications (Table 33). This led to better crop and larva performance giving higher filament mean lengths and weights. .

5.4 Effects of fertilizer and mulberry variety on protein profile of leaf feed

Leaf analysis in 2^{nd} season (LR) shows that leaves from Thailand variety at both sites had highest % crude protein. NPK+ Manure treatment had the highest % crude protein (Table 26). This high % mean protein favoured the larvae growth. Thika plots gave higher % crude protein. From Table 1, Thika soils had higher levels of nitrogen and micronutrient Zinc and this contributed to enhanced leaf quality. This supports Aruga, (1994) that harvests of quality mulberry leaf were strongly dependent on genetic factors as well as the fertility of the soil. When nitrogen is increased, crude protein is increased while decreasing the crude fibre giving high quality leaves and this favours the growth of the larva.

As far as crude fibre is concerned, Embu variety gave highest % crude fibre. NPK treatment gave also highest % crude fibre compared to all other treatments (Tables 27 and 28). High crude fibre contributes to unpalatability of the leaf feed. This is supported by the general lower larva weights in Embu treatments than of other varieties (Tables 10 and 15).

5.5 Effect of fertilizers and mulberry variety on Economics of sericulture

The initial wealth of Asian countries originated with the silk trade. The profitability of any enterprise is the key to its success, thus the evaluation of marketing strategies, product quality enhancement and the sustainability of production should be addressed.

Rearing of the domesticated silkworm, which feeds on mulberry, is more profitable than growing most cash crops since economic returns are higher than other crop production systems as 4 to 5 silkworm cocoon crops can be harvested annually (Raina, 2000). Raina, (2000) indicates that, the output in sericulture can be measured in module units. A module unit is the amount of silk cocoons or silk cloth produced in a given time. To find the initial cost required to produce a unit product, an average cost (AC) is determined.

$$AC = \frac{\text{Total cost}}{\text{Output}}$$

The gross output for an enterprise is calculated based on quantities harvested multiplied by its unit price. Variable cost is deducted from gross output leaving a gross margin. Fixed costs are completely ignored in this form of analysis because they are shared throughout the period of production (Norman *et al.,* 1985).

The unit price in sericulture depends on the grades of the cocoons. Weight of cocoon is an important factor in determining the grades and therefore the price of the cocoons. There are four (4) grades and prices as follows (Raina, 2000):

Grade	number of cocoons per kg	Price ($)	Price (Ksh)
A	500-599	4.20	300
B	600-699	3.30	250
C	700-799	2.50	200
D	800 and above	0.30	21

Source: The Economics of Apiculture and Sericulture modules for income Generation in Africa, 2000.

Note: Grades in this table are referred to in the following gross margins illustrations.

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As long as the unit price of the product is higher than the average variable cost, the enterprise makes a profit. Since, the variable costs in sericulture are very low, this makes the profits high. These include mainly labour, cost of eggs, and the disinfectants used to sterilize the rearing room.

For an illustration based on the mean weight of cocoons obtained from Embu control and Thailand NPK, with mean weights 1.3g and 1.7g per cocoon, respectively (Table 19) suggests that with the number of cocoons held constant, the NPK will have more kilograms for the same number of cocoons.

Variable Costs in sericulture enterprise per ¼ of an acre of mulberry

Labour for weeding and rearing (28 days) @ksh200........... 5,600

Cost of 2 cases of eggs (each has 20,000 eggs)................. .1,000

Disinfectants and miscellaneous costs............................. 1,000

1 Bag Fertilizer enough for ¼ of an acre (1000 trees) 1,700

Total 9,300

Thailand variety with NPK treatment -cocoon mean weight of 1.7g (588 cocoons /kg)

40000 cocoons x 1.7g...................68000g =68kg

From the table above, this is A grade with a price of Ksh 300 per Kg of semi dry cocoons.

68kg will give a gross output of Ksh 20,400 per month.

Total variable cost=Ksh 9,300

Therefore giving a gross margin of Ksh 11,100

Thailand variety with control treatment- cocoon means weight 1.5g (667 cocoons/kg)

40000 cocoons x 1.5g…………………60000g=60kgs

This is in B grade with a price of Ksh 250 per Kg of semi dry cocoons.

60 Kg will give Ksh 15,000 per month (gross output)

Total variable cost = Ksh 7,600

Therefore giving a gross margin of Ksh 7,400

Embu Variety with NPK treatment – cocoon mean weight 1.4g (714 cocoons/kg)

40000 cocoons x 1.4g…………..56000g =56 kg

This is in C grade with a price of ksh 200 per kg of semi dry cocoons.

56 kg will give Ksh 11,200 per month (gross output)

Total variable cost = Ksh 9,300

Therefore giving a gross margin of Ksh 1,900

Embu variety with Control treatment- cocoon means weight 1.3g (769 cocoons /kg)

40000 cocoons x 1.3…………………52000g =52kg

This is also C grade has a price of Ksh 200 per kg of semi dry cocoons.

52kg will give Ksh 10,400 per month (gross output)

Total variable cost = Ksh 7,600

Therefore giving a gross margin of Ksh 2,800

From the results of illustrations above, it shows that management decisions in terms of choice of variety and use of soil fertility inputs determines the yield of cocoon and consequently the productivity of sericulture enterprise. It shows that Thailand variety with NPK giving a mean weight of 1.7grams had the highest gross margin of Ksh11, 000, where as Embu variety with NPK gave a mean weight of 1.4 grams resulting to a gross margin of Ksh 1,900. However, Thailand variety without any input (control) gave a mean weight of 1.5 grams giving a gross margin of Ksh 7,400; whereas Embu variety without any input (control) gave a mean weight of 1.3 grams thus giving a gross margin of Ksh 2,800. These comparisons indicate that although this experiment is limited on two seasons and the two sites, given same growing conditions Thailand variety yields better than Embu variety. Moreover, Embu variety with NPK does not yield better than Thailand variety with control treatment.

When these weights are compared with average cocoon weight of what the sericulture farmers get, it shows that most farmers use very little or no inputs as their average weight ranges from 0.9-1.5grams (MoA, 2004). Also it is important to note that most farmers are from marginal areas and therefore mulberry trees grown are mostly of Embu variety.

However, sericulture enterprise competes very well with other agricultural crop enterprises. This is especially so in marginal areas of this country where there is lack of income generating activities (Nguluu at al., 1997). Mulberry tree being drought tolerant offers an enterprise for diversification in these areas. When comparison of sericulture enterprise and other crops like maize is done reference made from MoA fmgt, (1989), indicates that maize grown in low rainfall (400-800mm) and with inputs yields 12 bags per acre. Using current price per bag of Ksh 1,000, this gives a gross output of Ksh 12,000 per acre. When variable costs are considered from this figure, the resultant gross margin would compare very well with the illustration on Embu variety with NPK which gives gross margin of Ksh 2,800 per ¼ acre, thus giving Ksh7,600 per acre. Further more sericulture enterprise gives output after one month compared to five months in maize enterprise.

6.0 CONCLUSION AND RECOMMENDATIONS

The overall conclusions from the study indicated that soil fertility in sericulture is a limiting factor, when controls are compared with the other three treatments in general mulberry crop performance (Tables 5, 6 and 9). It has been found that mulberry quality and quantity is of paramount importance to the performance of the silk worm larva. The pooled results further indicate that NPK + Manure treatment seemed to be the best fertility combination when rainfall factor was not limiting. These results have also been reported by Chinchiem and Srisuwan 1974b). However, where rainfall is limiting, NPK seems to give better yield response due to readily available nutrients. For sustained high yield of mulberry leaves, regular Nitrogen fertilization is necessary either from farm yard manure or in mineral form. When mineral nitrogen is applied, it should be supplemented with mulch and other organic amendments to protect the top soil during heavy rains and to maintain its high humus content.

Manure on the other hand is important as it improves on water holding capacity of the soil. It should be considered in mulberry production to improve on this aspect and the soil texture. Furthermore most farmers keep animals and or can use compost manures. In addition manure provides macro and micronutrients as slow assimilates thereby raising the nutrient status of the soil which are not provided for in NPK inorganic fertilizers (Table 1-manure results).

As far as varieties were concerned, again recommendation for a variety will depend on climate and weather patterns of the seasons in the areas. Shri, (1988) indicates that mulberry plant has a capacity to withstand adverse climatic conditions and has been proved to be drought tolerant. However, in this investigation Embu variety conforms to this since it has been observed to persist low rainfall conditions, and this conforms to the Ministry of Agriculture findings (MOA, 1983), that it is drought tolerant. Where rainfall is not limiting, Kanva and Thailand varieties seems to perform better than Embu variety in quantities (shoot length and number) and quality given by leaf analysis (Appendix Tables 31 and 32) and silkworm larva performance (Tables 10, 13 and 15).

From the illustration of gross margins, it can be concluded that quality and quantity management of mulberry crop is of paramount importance through variety selection and soil fertility consideration so as to safeguard the profit margins of sericulture enterprise. The illustration concluded that where climatic conditions are favourable; Thailand should be a variety of choice. Kanva variety should be second in priority. Where there is low rainfall, Embu variety should be a variety to recommend.

Again Thailand variety has shown tolerance for brown leaf spot and powdery mildew (as observed in 2^{nd} season). In areas with heavy rainfall and high temperatures where these diseases are prevalent, Thailand should be a choice variety. But in areas with low rainfall (semi arid areas) Embu variety should be recommended.

As far as silkworm rearing in semi arid areas is concerned, the farmer should be able to moderate temperatures and humidity in both rearing room and storage of leaves so as to maintain high silkworm performance. Experience gained in rearing of silk worm, has it that high temperatures and low humidity conditions can be moderated by spreading wet gunny bags or wet newspapers in the room or literally pouring water on the floor. This lowers the temperatures and raises the humidity in the rearing room, important conditions in silkworm rearing. At the same time storing leaves in polythene bags and sprinkling water on leaves make them stay fresh longer.

FUTURE SCOPE OF RESEARCH

1) There is need to investigate how these varieties will perform (in quality and quantity) at different rates of NPK or with different rates of foliar fertilizer.

2) Investigate how these varieties perform in cold (for instance Njambini and Limuru areas) and very dry environments (North Eastern province) of this country.

3) Investigate on the types and amounts of Amino Acids in the different mulberry varieties.

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8.0 APPENDIX

8.1 LEAF ANALYSIS

8.1.1 Determination of crude protein

KJELDAHL METHOD

Procedure

Weighed samples from each sub plot were oven dried and ground separately. Approximately 0.2gm of each ground sample was weighed and put in 100 ml kjeldahl flask giving a total of 24 flasks. Approximately 1.7 mg of selenium was added to the flasks folloed by 10 ml concentrated sulphuric acid. A blank containing the H_2SO_4 and catalyst was also prepared. The flasks were heated over burner in the hood in inclined position. Then using digestion block until the colour became pale green. It was continued for another hour to ensure complete conversion of nitrate to ammonia sulphate when the solution became clear. the digest was allowed to cool. Then it was diluted with 20ml distilled water in small amounts ensuring complete mixing. Contents were then transferred to 100ml graduated volumetric flasks and diluted with distilled water up to 80ml and to 100ml after cooling.

Then distillation was carried out using micro-kjedahl nitrogen distillation apparatus using an aliquot of 5ml of diluted digest in each case.

!00ml of 1% boric acid was measured into conical flask and 5-6 drops of mixed indicator added. Distillation was carried out and steam generated by boiling water on a hot plate. 5ml of the digest was pippetted and delivered into a reaction chamber followed by 5ml of sodium hydroxide (46%w/v). A conical flask containing 10ml boric acid were placed at the delivery ensuring tip of condenser was beneath the surface of liquid. The indicator solution became green. The reaction mixture was removed by sunction, rinsed well with distilled water before distillation of the next digest.

All boric solutions were titrated with standardized 0.01M HCL. End point reached when colour changed from green to pink.

Calculation of results

Based on stoichiometric relation involved in the titration 1ml of 0.01 M HCL is equivalent to 0.14 mg of nitrogen present in ammonia. From the volume of standard HCL used in titration and after substracting the titre value for the blank, the amount of nitrogen can be calculated and multiplied by 6.25 a conversion factor used for plant materials

$$\% CP = \frac{(\text{mean titre x molarity of acid x Mwt of dilution x conversion factor}) \text{ x } 100}{\text{Aliquot x } 1000 \text{ x wt}}$$

Where

% CP = percent crude protein

Aliquot = 5ml of diluted digest

M = molarity of Hydrochloric acid (0.01M)

Mwt =Molecular weight of Nitrogen (14)

wt = weight of sample taken (0.2 gm)

Conversion factor = 6.25

From this calculation the results of crude protein percentage were derived

8.1.2 Determination of crude Fibre

Principle

Crude fibre is the organic residue which remains after digestion of the sample with 1.25% sulphuric acid and 1.25 sodium hydroxide solution.

Procedure

Approximately 2 gm of ground dried mulberry leaves was transferred into a 600ml reflux beaker. 200ml near boiling 1.25% H_2SO_4 solution was added. Meanwhile a 1litre conical flask was used to boil distilled water used to keep level of mixture above 150ml.

Beakers were placed on the digestion apparatus at 5 minute intervals and boiled for exactly 30 minutes rotating beaker periodically to remove solids adhering to the sides. The acid mixture was filtered through the filtration apparatus washing with near boiling distilled water. A piece of muslin cloth was fitted on the buchner funnel, distilled water poured on it followed by the acid mixture and draining of by application of the suction. Residue from the funnel was washed with distilled and then filtered into a crucible, dried in the oven at 100^0C and weighed. The material was then ashed in the muffle furnace at 60^0C and cooled in a dessicator before weighing. The weights were subjected to calculation:

$$\% CF = \frac{(w2-w1)}{w3} \times 100$$

Where

w1 = weight of crucible + ashed sample (gm)

w2 = weight of crucible + fibre (gm)

w3 = weight of sample taken

CF = crude fibre

8.1.3 Determination of dry matter

Simplest means of determining dry matter is to place the test material in an oven and leave it until all the free water has evaporated under temperatures 100-105^{0}C.

Procedure

Dry matter on wet samples is done at lower temperature to avoid burning and change of colour. Mulberry leaves were weighed on a piece of aluminium foil, put on a drying oven at 60^{0}c for three days. These were then weighed, and final weighing taken when the weight became constant.

$$\% \, DM = \frac{w3 - w1}{w2 - w1} \times 100$$

where

w1 = weight of empty foil (gm)

w2 = weight of foil + wet sample

w3 = weight of foil + dry sample

w2 –w1 = weight of sample in gm

8.1.4 Determination of moisture

Percentage moisture is determined by calculating the difference between 100 and the already calculated % DM. Thus,

% moisture = 100- % DM

Table 31: Showing leaf nutrient composition of the leaf samples from the different fertilizer treatments at Thika and ICIPE in the 1st season (SR).

Location	Variety	Treatment	%Crude protein	%Crude fibre	%Moisture content	% Dry matter
ICIPE	Thailand	Control	18.84	16.52	68.87	31.13
ICIPE	Thailand	NPK	19.7	16.61	60.34	39.66
ICIPE	Thailand	Manure	17.33	15.71	62.63	37.37
ICIPE	Thailand	Manure+ NPK	23.76	13.29	53.03	46.97
ICIPE	Embu	Control	19.27	13.99	69.62	30.38
ICIPE	Embu	NPK	19.48	15.55	70.41	29.6
ICIPE	Embu	Manure	21.83	13.82	72.23	27.78
ICIPE	Embu	Manure+ NPK	19.06	15.42	56.44	43.56
ICIPE	Kanva	Control	19.05	13.87	67.14	32.86
ICIPE	Kanva	NPK	17.55	16.75	66.65	33.35
ICIPE	Kanva	Manure	18.19	13.51	67.42	32.58
ICIPE	Kanva	Manure+ NPK	21.09	14.05	69.8	30.2
THIKA	Thailand	Control	21.83	13	66.75	33.25
THIKA	Thailand	NPK	21.83	17	69.48	30.52
THIKA	Thailand	Manure	23.17	15.25	71.43	28.58
THIKA	Thailand	Manure+ NPK	21.94	16.75	70.68	29.32
THIKA	Embu	Control	21.4	18.1	73.4	26.6
THIKA	Embu	NPK	19.69	17.41	68.25	31.75
THIKA	Embu	Manure	20.76	18.34	68.9	31.1
THIKA	Embu	Manure+ NPK	20.76	17.25	68.6	31.4
THIKA	Kanva	Control	20.55	16.38	68.88	31.12
THIKA	Kanva	NPK	17.98	18.13	67.33	32.67
THIKA	Kanva	Manure	19.91	18.48	67.7	32.3
THIKA	Kanva	Manure+ NPK	20.12	17.41	70.03	29.97

Table 32: Showing leaf nutrient composition of the leaf samples from the different fertilizer treatments at Thika and ICIPE in the 2nd season (LR).

Location	Variety	Treatment	%Crude protein	%Crude fibre	%Moisture content	% Dry matter
ICIPE	Thailand	Control	19.97	9.25	71.95	28.05
ICIPE	Thailand	NPK	19.74	13.75	73.43	26.57
ICIPE	Thailand	Manure	25.21	11.75	72.69	27.31
ICIPE	Thailand	Manure+ NPK	22.82	11.25	72.2	27.79
ICIPE	Embu	Control	16.48	10.53	65.77	34.23
ICIPE	Embu	NPK	17.76	12.75	70.4	29.6
ICIPE	Embu	Manure	18.07	11.4	73.89	26.11
ICIPE	Embu	Manure+ NPK	18.07	12.25	69.4	30.6
ICIPE	Kanva	Control	16.49	12.75	70.38	29.62
ICIPE	Kanva	NPK	17.6	9.5	69.86	30.14
ICIPE	Kanva	Manure	18.79	11.5	69.52	30.48
ICIPE	Kanva	Manure+ NPK	24.25	13.43	72.82	27.18
THIKA	Thailand	Control	19.59	8.45	6190	38.1
THIKA	Thailand	NPK	26.15	11.5	75.47	24.53
THIKA	Thailand	Manure	24.49	9.25	76.13	23.87
THIKA	Thailand	Manure+ NPK	27.8	8.36	75.75	24.25
THIKA	Embu	Control	16.65	12.25	73.41	26.59
THIKA	Embu	NPK	19.02	11.5	78.31	21.69
THIKA	Embu	Manure	19.5	13.04	76.51	23.49
THIKA	Embu	Manure+ NPK	22.36	16	77.44	22.56
THIKA	Kanva	Control	20.92	12	77.13	22.87
THIKA	Kanva	NPK	20.69	9.5	77.97	22.03
THIKA	Kanva	Manure	19.26	9.5	73.72	26.28
THIKA	Kanva	Manure+ NPK	22.36	10	76.94	23.06

8.2 SOIL ANALYSIS

Methods of soil analysis used are as described In: Methods of soil analysis 1982. Part 2: Chemical and microbiological properties Second Edition.Edited by A.L. Page et al., (1982).

8.2.1 Soil pH

The pH of the soil was determined using one part of soil to two parts of water. 10 gms of soil was mixed with 20 mls of deionised water. The soil water mixture was allowed to come to equilibrium and shaking or stirring it at intervals for about 20 minutes. It was then allowed to settle so as to give a layer of fairly clear solution above a layer of soil suspension. Then, a ph meter with glass electrodes was adjusted accordingly and the Reference electrode lowered into the clear layer and the pH is read on the meter.

8.2.2 Determination of Nitrogen

Wet digestion was done in which 5gms of air dried soil sample was digested using concentrated sulphuric acid so as to convert all the nitrogen to ammonium. Selenium catalyst is used to promote oxidation of organic matter. Distillation and titration was done as per the Kjedahl method to determine the ammonium in the digest.

Calculation of % N

$$\% N = \frac{\text{ml acid(titre) x 5(wt of soil) x.0.14 (mg N)} \quad \text{x } 100}{\text{wt of soil (in mg)}}$$

8.2.3 Determination of Phosphorus and potassium

This was done using Spectroscopy method. Readings were taken from the spectrophotometer.

8.2.4 Determination of bases (Na, K, Ca, Mg)

Used Leaching method by using 1N ammonium acetate at pH 7.0.

8.2.5 Determination of CEC

Done by leaching with 1N KCL at pH 2.5 and distillation, then titrating with H_2SO_4

8.2.6 Determination of micronutrients

This was done by extraction using 1gm of soil to 10mls of 0.1M HCl. Shaking for 1 hour. Then filtered solution was taken for reading in Atomic Absorption Spectrophotometer (Page et al., (1982); Landon, 1991).

8.3 Weather data for the two seasons of the experiments. Aug- 2004- Sept.2005

Appendix Table 33: Monthly means weather data for Thika for the two seasons.

	Temperature		Rainfall		Relative **Humidity**		Sunshine	Wind speed
Month and year	Max ^0C	Min ^0C	Total **Rainfall** **mm**	Evaporation **mm**	At 9.00am %	At **3.00pm** %	Hrs per day	Km per day
Aug-04	23.8	12.6	trace	110.5	80	49	42	60.2
Sept-04	27.0	13.8	20.9	152.4	77	41	6.4	88.0
Oct-04	26.2	15.2	78.2	145.2	78	45	6.2	107.5
Nov-04	24.8	15.6	93.3	115.8	85	59	6.4	105
Dec-04	25.4	14.7	98.6	155.1	81	55	8.7	121.8
Jan-05	27.2	13.6	21.4	93.9	70	39	9.8	102.4
Feb-05	28.6	13.3	25.1	186.1	68	35	9.5	114.9
Mar-05	28.9	15.8	50.0	195.3	80	38	8.4	110.1
Apri-05	26.7	15.9	245.1	152.1	81	51	7.4	93.5
May-05	25.3	16.0	259.2	123.7	83	58	6.1	101.1
June-05	23.0	14.2	15.3	74.5	85	53	3.6	60.8
July-05	21.9	12.8	7.5	72.9	86	58	2.7	55.7
Aug-05	22.5	12.8	1.9	87.9	82	56	3.4	80.5
Sept-05	25.2	13.6	5.5	124.0	80	45	4.7	82.7

Monthly mean data from Kenya Agricultural Research Institute, Thika Meteological Sub- Station

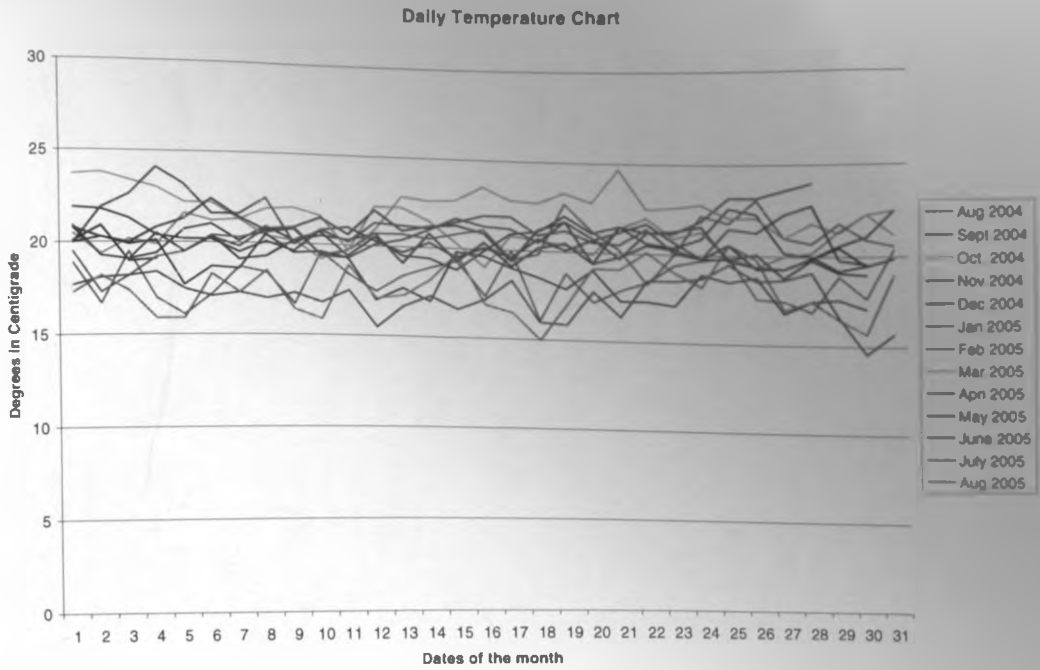

Fig: 1- Daily temperature in degrees Centigrade at Thika

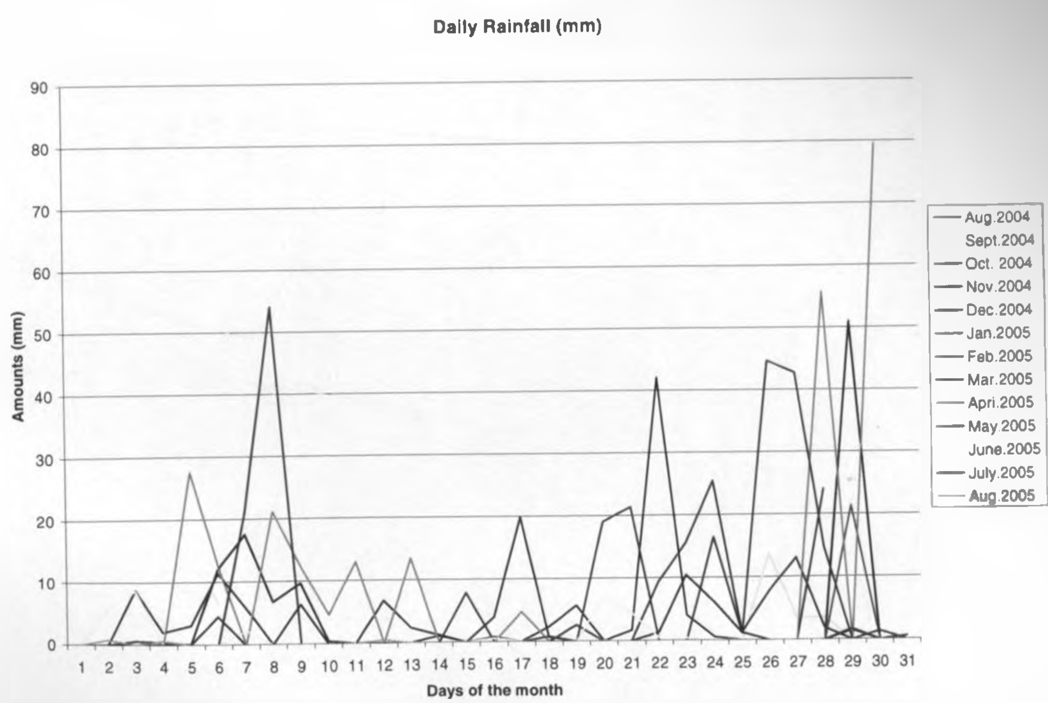

Fig: 2- Daily rainfall in millimeters at Thika