JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF BIOLOGY

Evaluation of larval and cocoon Traits in some Mulberry Silkworm strains, *Bombyx mori L.* and yield potential of S13 Mulberry Variety under Bonga Condition, South Western Ethiopia.

By: Gezmu Seyoum

A Thesis Submitted To Department of Biology, College of Natural Science, Jimma University in Partial Fulfillment for the Requirement of Degree of Master of Science in Biology (Ecological and Systematic Zoology)

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Principal advisors: Delenasaw Yehuwalaw (PhD)

Co-Advisor: Abera Hailu (MSc)

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Declaration

I, the under signed, declare that this thesis is my sincere original work, has never been presented in Jimma University or other Universities, and that all the resources and materials used for the thesis have been dully acknowledged.

Name: Gezmu Seyoum

Signature___________________

Date _____________________

Place: Jimma University

Date of submission_________________

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List of Acronyms

BWYSPS: Bishaw WoldeYohannes Secondary and Preparatory School

EIAR: Ethiopian Institute of Agricultural Research

JARC: Jimma Agricultural Research Center

MARC: Melkasa Agricultural Research Center

RH: Relative Humidity

DFLs: Disease Free Layings

JH: Juvenile Hormone

PBA: Petiole Base to Apex

MBA: Midrib Base to Apex

LD: Leaf Diameter

Abstract

Recently a number of mulberry silkworm strains and mulberry varieties found in the world and a few of them are found in Ethiopia. However no sufficient information were available respecting *the variability in larval weight and cocoon traits among different mulberry silkworm strains, and on the yield potential of mulberry plants. Hence, this study was conducted on five mulberry silkworm races viz., yellow (multivoltine), Kenya-3,Kenya-5,Korea-1and China-2 (bivoltine) so as to evaluate for their weight in fifth instar mature larvae and quantitative cocoon traits ,and on the yield potential of S13 mulberry variety based on different growth parameters. Both the experiments for evaluation of variability in larval and cocoon traits among the mulberry Silkworm strains and yield potential of S13 mulberry variety were carried out in Bonga at B/W/S/P School compound. Highly significant ($p<0.05$)difference was observed in mean larval weight, cocoon weight, shell weight and pupa weight among four silk worm races viz.,Yellow,Kenya-3,Kenya-5 and Korea-1.But in Kenya-5 and China-2 no significant difference in mean larva, cocoon, shell and pupal weight was obtained. Of the five mulberry silkworm races the highest mean larval weight, cocoon weight, pupa weight and shell weight were obtained from Korea-1 silkworm race while the minimum mean larval weight, cocoon weight, pupa weight and shell weight were accounted by yellow race. From the results there was no significant difference ($p > 0.05$),) in mean shell ratio were obtained between (Yellow race and China-2), (Kenya-3 and Kenya-5),(Kenya-3 and Korea-1),(Kenya-5 and Korea-1) and (Korea-1 and China-2).However, the mean shell ratio among the following pairs (yellow and Kenya-3), (Yellow and Kenya-5) , (yellow and Korea-1), (Kenya-3 and China-2), (Kenya-5 and China-2) were significant difference ($p < 0.05$).The finding of this study also confirmed that the mean propagation, height , leaf size, leaf and shoot number in S13 mulberry variety showed an increasing trend at 45,60,90 and 120 days after planting .Thus, the propagation rate of S13 mulberry variety were achieved 56%, indicating for the adaptability to climatic condition of Bonga.*

1.Introduction

The silkworm, *B. mori* L. is an economically important insect comprises a large number of geographical races and inbred lines which show substantial variation in their qualitative and quantitative traits including body size, silk quality, fecundity, pathogen resistance, and heat tolerance (Nagaraju, 2002). Generally in the silkworm, traits such as cocoon shape, cocoon colour, silk fiber length, larval duration, together with many other ethological traits are used to differentiate varieties and selection of parental strains (Hussain, *et al*.,2010; Moorthy, *et al*.,2007).

There have been ample literatures stating the economic superiority of bivoltine mulberry silkworm races over multivoltine, and recently some mulberry silkworm strains of bivoltine and multivoltine were existing in Ethiopia. However, no sufficient study were carried out to evaluate the variability in larval weight, and cocoon traits of these mulberry silkworm strains.

Mulberry (Morus sp.) is a hardy deciduous perennial tree or shrub used as a food source for the domesticated silkworm *B.mori* (Aggarwal *et al.*,2004).Growth and development of silkworm *B. mori* L. is known to vary depending on the quality and quantity of mulberry leaf used as food source, which in turn indicated by commercial characteristics of cocoon crop (Nagaraju, 2002; Bari *et al*., 1989; Opender, *et al*., 1979).The use for high yielding varieties of mulberry is predominantly important for exploiting maximum benefit from silkworms. Furthermore, the development and economic production of sericulture largely and greatly depends on the metabolic modulations and physiological adaptability of silkworm, its genetic constitution (Chatterjee *et a*l., 1993; Thiagarajan *et al*.,1993).

Goldsmith *et al*., (2005) has been reported that an estimated 4310 silkworm germ plasm strains are being reared worldwide. These races were varied in there rearing habitat, geographical distribution, number of molts that occur during larval growth, genetic recombination, number of generations produced in a year under natural conditions. Remarkable variation in growth and production performance were also depicted among different silkworm races reared in-door conditions. Hence, enormous effort were needed to evaluate the variability in larval weight and cocoon traits of 5 silkworm strains viz., China-2, Korea-1, Kenya-3 and Kenya-5 (Bivoltine) and yellow race (multivoltine) and the yield potential of S13 mulberry variety in the present study. Therefore, this study was aimed at finding out the variability in larval weight of fully grown fifth instar-larva, and cocoon traits among the five silkworm strains. This study was also aimed to determine the yield potential, viability and growth rate of S13mulberry variety. Moreover, this study were also aimed at determining the adaptability of S13 mulberry variety to the ecological condition of Bonga area.

1.1.Statement of the problem

Silkworm *B.mori* L. is an economically important insect used for silkworm rearing and silk production essentially a monophagous insect feeds solely on mulberry leaves (*Morus* spp.) as the sole natural food. Silkworm larval growth and development and cocoon crop yield are mainly influenced by yield and nutritional quality of mulberry (*Morus* spp.) leaf used as feed **(**Adolkar *et al*.,2007).Hence, that study was needed to evaluate the variability among five mulberry silkworm races in fully grown larvae and cocoon traits. The yield potential of S13 mulberry variety were also estimated. Therefore, the finding of this research exactly answered the following research questions.

- Among the silkworm strains used in the study which one was found to be superior in terms of larval weight and cocoon traits?
- Did the silk worm strains significantly varied in their larval weight and cocoon traits?
- Did the mulberry plant used in the present study considered as promising type under climatic conditions at Bonga in terms of yield potential and adaptability to new environment?

1.2. Significance of the study

This study was vitally important to promote the practice of silkworm rearing using the mulberry garden, which have already established in the study area, for the coming consecutive years. Silkworm, *B.mori* is being reared in door condition, ideal to demonstrate the body plan and life cycle and help students easier understanding of insects. Helpful to develop hands-on practice of silkworm rearing and management and thereby to ensure technology transfer. Provide valid information for potential farmers and investors need to work in the area. Moreover, the finding of this study believed to provide valid information to interested researchers and research centers while conducting research of the same topic for consecutive generations per annum.

1. 3. Objectives

1.3.1. General objective

The objectives of this study was to assess the weight of fifth instar larva and cocoon traits among the five mulberry silkworm strains, and the yield potential of S13 mulberry variety.

1.3.2. Specific objectives

- To determine the weight of mature larvae among mulberry silkworm races.
- To determine cocoon traits among mulberry silkworm races.
- To determine and compare shell ratio among five mulberry silkworm strains
- To estimate yield potential of mulberry variety used in the study depend on different mulberry growth parameters.
- To determine the viability potential of S13 mulberry variety.
- To assess growth rate of mulberry plant at different time intervals

2. Literature Review

2.1. Sericulture

Sericulture is the cultivation of silk through rearing of silkworm. It is an agro based industry. It involves the raising of food plants for silkworm ,rearing of silkworm for production of cocoon ,reeling and spinning of cocoon for production of yarn etc. for value added benefits such as processing and weaving .Sericulture is one of the major agro industry that plays an important role in uplifting rural economy and provides employment opportunity for the rural folk. It is a commercial enterprise capable of generating more income than any other commercial crop. On account of its economic importance and employment generation potential, special emphasis has been given for the development of sericulture industry (Umesh, 2001).The benefits of sericulture cannot be overemphasized .It provides gainful employment, economic development and improvement of the quality of life to the people in rural and semi-urban areas. It also plays an important role in antipoverty programs and prevents migration of rural people to urban area in search of employment. Apart from silk ,the mulberry plant which are cultivated for the purpose of providing food for the silkworms are rich in minerals and vitamins and from it herbal medicines are prepared. The pupae are rich in oil content and pupal oil is used in cosmetic industry and the remaining pupal cake is a rich source of protein (Tomotake *et al*., 2010). Silk production has the potential to make a valuable contribution to the economy of many countries where there is surplus labor, low costs of production and a willingness to adopt new technologies (Hajare *et al*., 2007).

In the view of its immense uses and output involving less input, time and energy, serious attention is needed to promote both the exploited and unexploited potential of sericulture throughout the country not only to earn foreign exchange but also alleviate poverty among rural community.

Silk originating in the spittle of an insect is a natural fibrous substance and is obtained from pupal nests or cocoons spun by larvae known as silkworm, preferred over all other types of fibres due to its remarkable properties like water absorbency, heat resistance, dyeing efficiency, and luster (Fenemore and Parkash, 1992; Ahmed and Muzaffar, 1987). Silk is a natural protein fiber. It contains about 75% actual fibre fibrion and 25% of sericin gummy protein that holds filaments. These filaments are about 1000 to 1300 yards in length and can be as long as 3000 yards (Mathew, 1996). Silk has benefited man not only by producing fabrics due to its lighter weight, suppleness, luster, grace, durability, dyability and tenacity but also used in making artificial blood vessels, surgical sutures, electrical insulation materials and tyre linings (Ahmed, 1990).

Siddiqui (1988)reported that silkworm was considered as a treasure house from head to foot because nothing gets waste in sericulture; the byproducts such as mulberry shoots serve as fire wood and fuel, the left over larvae and excreta as manure, cattle feed and in the production of biogas, reeled out pupae and used male moths as poultry feed and in the manufacturing of certain medicines and amino acids; mulberry roots and bark in preparing anti-hypertension drugs.

2.2. Mulberry sericulture

About 92.20% of the silk produced in the world is obtained from mulberry silkworm *B.mori* L. reared solely on mulberry leaves (*Morus spp*.).It is also a confirmed fact that, around 60% of total cost of cocoon production goes towards mulberry production alone in sericulture (Chaudhary and Giridhar,1987).Silk the"Queen of textiles" an outcome of sericulture activities has a number of applications. Increasingly practiced under a variety of agro-climatic conditions, this agro-based industry provides livelihood to a million people including farmers, reelers, spinners and weavers. In Kenya, the sericulture industry is un upcoming enterprise that is increasingly being perceived as a promising alternative source of income generation for rural small-scale farmers (Adolkar *et al*.,2007). Sampatharaj and Saxena (1986) have been also reported that mulberry sericulture industry employed more than six million people in India.

2.2.1. Mulberry silkworm

Silkworm larvae, *B. mori* L. (Lepidoptera: Bombycidae) is an important economic insect which is used as a tool to convert leaf protein into silk (Rahmathulla,2012)..The silkworm *B. mori* L.is a monophagus insect, cherishing on its sole food plant i.e., mulberry. The industrial and commercial use of silk, the historical and economic importance of production and its application in all over the world finely contributed to the silkworm promotion as a powerful laboratory model for the basic research in biology (Singh, 2012).

2.2.2. Taxonomy of silkworms

Silkworms belongs to Kingdom : Animalia ; Phylum: Arthropoda ;Class: Insecta ; Order: Lepidoptera ;Family: Bombycidae (include mulberry silkworm species, such as:*Bombyx mandarina* ,the wild race and *B.mori* the domestic one. Insects mainly belong to two families.viz., Saturnidae and Bombycidae which spine silk fiber. Today's domestic silkworms are all descended from an initial stock of *B.mandarina*, the wild silk moth (Yoshitake, 1968).

2.2.3. Biology of mulberry silkworm

2.2.3.1. The life cycle of silkworm

All species of silkworm have four stages in their life cycle namely eggs, larvae, pupae and adults. The egg stage generally lasts for 10 days and the larvae life is 25 to 30 days. This is the most active period in the life cycle of the insect where it accumulates nutrients required for its physiological activity at the later stage. At the end of the larval life, these silkworms build a silken abode (the cocoon).They enter the pupae stage in the cocoon and emerge out as moths (Dandin , 2000).

2.2.3.2. Molting and Metamorphosis

Insect molting and metamorphosis are regulated by two classes of hormones: ecdystroides and Juvenile hormones (JH) (Gilbert *et al*., 2002;1996).The interplay of ecdystroides and JH serves to orchestrate the progression from one developmental stage to the next, with ecdytroides initiating the molting process and JH regulating the quality of molt. These hormones together cause the shade off old skin and enhance larval growth from one stage to another (plate.1)

Plate1.Silkworm molting

The five successive larval instars are behaviorally and morphologically separated by ecdysis (molting).The larva is called caterpillar. It has soft cylindrical body with head and short thoracic legs. Silkworm caterpillars have six real legs, plus five pairs of pseudo pods (false legs) on the rear of the body. The very rear is split and used for grasping twigs and leaves. Its body has head, thorax and abdomen. *B.mori* larva has three pairs of thoracic legs and five pairs of abdominal legs are lost during larval to pupal metamorphosis (Palopolibdom, 2001;Gopinatan *et al*.,1997;Veno*et al*.,1995). It has biting and chewing mouth parts. It feeds on mulberry leaves. It molts for four times. Its salivary glands are modified into silk glands. Silk glands rapidly reaches their peak mass by the pre-pupal stages, are used to spine the cocoon at pupation, then rapidly catabolized during metamorphosis (Matsuura *et al.*,1968).Not surprisingly, once the insect reaches a maximum weight in the pre-pupal stage the body mass decreases with the age during a brief adult hood (Chamberlin *et al*., 1997). At the end of pp stage, the larva searches for an appropriate site to spine a cocoon of silk to surround its body. When the silkworms secrete the liquid silk during the spinning it passes through the anterior gland and expelled out through the spinneret opening (Shimizu, 2000). Larva undergoes completed metamorphosis and becomes a pupa or chrysalis. It is none feeding stage. Once the cocoon is formed, the larva secrets a hard outer cuticle, and metamorphosis commences. After about 10 days the adult emerges out of the cocoon, in a process termed" eclosion" (plate 2).Imago secrets cocoonase to digest the silk fibers which help in the coming out of adult from cocoon.

Plate 2. Emergence of adult moth

The adult (silk moth) has two pairs of wings and three pairs of legs. It has siphoning mouth parts without feeding function. Adults immediately copulates, and the female lay eggs (plate3&4) dying within 6-10 days of hatching and mating. *B.mori* showed dramatic body mass gain through early larval stages, reaching a zenith in pre pupal and then decreasing in pupae and adults. In some holometabolus insects, for example silkworms, beetles and flies, the pre-pupal stage is the final stage for food consumption because the adults, lucking functional mouth parts, exist only to reproduce (Ganga, 2003;Rockstein, 1973).

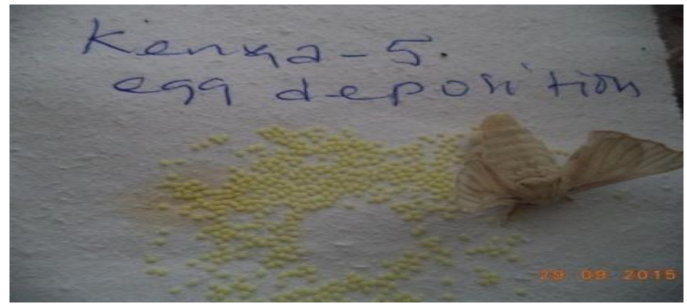

Plate 3.Silk moth copulation

plate 4. Oviposition in silk moth

2.2.4. Importance of mulberry silk worm

Silk obtained from silkworms is used in manufacturing of cloth. It is also used in making of surgical sutures, artificial blood vessels, tire lining, parachute, electric insulating materials, oil, protein, an artificial vitamins; even its waste material (excreta) is used as artificial diet for animals and as green manure for crops (Ishfaq and Akram, 1999). In addition to the uses of its larvae for silk production, its pupae are being employed to extract vitamins A, B12, E and K, whereas the male moths utilized for making medicinal vines and the excreta forms an important part of the fish and poultry feed (Fenemore and Prakash, 1992).

2.2.5. Factors determining growth and production of Mulberry silkworm

2.2.5.1. Nutritional quality and quantity of host plant leaf

Growth and development of silkworm *B. mori* L. is known to vary depending on the quality and quantity of mulberry leaf used as food source, which in turn indicated by commercial characteristics of cocoon crop (Nagaraju, 2002; Bari *et al.*, 1989; Opender , *et al.*, 1979). Superiority of different mulberry varieties used as food for silkworm larvae greatly affects the economy of sericulture industry (Das and Sikdar, 1970). Leaves of superior quality enhance the chances of good cocoon crop (Ravikumar, 1988). Nutritive value of mulberry leaf is a key factor besides environment and technology adoption for better growth and development of the silkworms and cocoon production (Purohit and Pavankumar, 1996). It is quite evident that tender, succulent and nutritious leaves are known to favor the good growth and development of young age silkworms whereas progressively mature leaves with less moisture content are required for late age silkworms (Krishnaswami *et al.*,1971).

The growth and development of silkworms and the economic characters of cocoon are influenced to a great extent by the nutritional content of mulberry leaf (Krishnaswami, 1978). Because of this, in recent years maximum attention has been given for the improvement of mulberry in both quality and quantity. Leaf quality is an important parameter used for evaluation of varieties aimed at selection of superior varieties for rearing performance (Yokoyama, 1963; Bongale *et al*., 1997).

2.2.5.2. Geographical and Ecological Conditions

Silkworms have also been found to perform differently when subjected to varying geographical and ecological conditions (Shekharappa *et al*., 1993).

Geographical conditions

Environmental conditions in tropical zone relatively favors polyvoltine mulberry silkworm breeds (strains) than bivoltine breeds. Howrelia *et al*., (2011) were reported that extremes of temperature of tropics and sub tropics, forcing farmers to rear tolerant tropical strains that are low productive and provide inferior quality silks.

Ecological Conditions

Light and temperature are ecological factors that are known to influence leaf quality on herbivory. The dim light during day time and darkness during night is more congenital for healthy growth of the larvae (Dandin *et al*., 2000).Similarly, Reddy *et al.*,(2002) found that temperature and RH exert synergistic impact regarding silkworm instar larval periods. Mishra and Upadhyay., (2002) have been reported that change in temperature along with RH has pronounced effect on molting period. Similarly, the reports of different researchers (Morohoshi , 1969; Kamili and Masoodi , 2004) recorded that decrease in temperature enhances the molting duration in silkworm. Several studies (Tazima and Ohuma, 1995) demonstrated that silkworms were more sensitive to high temperature during the fourth and fifth stages. In a serious of experiments, researchers (Kato *et al*., 1989) observed that resistance to high temperature is a heritable character and it may be possible to breed silkworm races tolerant to high temperature. Polyvoltine breeds reared in tropical countries are known to tolerate slightly higher temperature and adjust with tropical climatic conditions (Hsieh, 1995).

2.2.5.3. Pesticides

Pesticides: pesticides once having entry to an environment either gets into the complex web of life through food chain or different components of environment through physical passages like drifting by air or aquatic runways. Such facts were meticulously described by (Carson, 1962) in her book 'Silent Spring' where she advocated for choosing either the chemical control or biological control to avoid creation of endless problems to mankind owing to pesticides use. One of the major constraints in silk production is the susceptibility of the silkworms to attack of different pests; parasitoids, predators, and pathogens .Even mulberry silk worms which can be cultured in indoor condition are not free from such constraints. In addition their host plants are also susceptible to the attack by herbivorous pests (insects, mites) and various pathogens (nematodes, bacteria, fungus and virus) (Datta and Datta,2007; and Teotia and Sen, 1994).Growth and development of silkworm to a great extent depend on quality and quantity of food consumed and utilized (Bora, 1998).Application of insecticide in sericulture field is not at all advisable as the leaves of host plants are directly consumed by the silkworms and silkworms become affected either through consumption of contaminated food or contact toxicity of the insecticides. *B.mori* is highly susceptible to insecticides and in China its production is reported to be decreasing by almost 30% per annum because of insecticide poisoning (Li *et al*.,2010).One of the commonly used pyrethroid, reduced the rate of feeding, assimilation and efficiencies of conversion of ingested and digested food into body substance in late instars larvae of *B.mori* (Wiayanthi and Subramanyam,2002).

Hexachlorocyclohexane , an organochloride insecticide was reported to cause decrease in fibroin content, pupal and shell weight, adult emergence percentage, fecundity as well as deterioration in quality and quantity of silk thread in *B.mori* (Bhagyalakshmi *et al*.,1995). Troitskaya and Chichigina, (1980) showed that combined use of bacterial and chemical insecticides in silk producing areas possess a real danger to *B.mori.*

2.2.5.4. Parasitoids

Uzi fly, *Exorista sorbillans* (Dipetra:Tachinidae) is a parasitoid of silkworm and a serious threat to sericulture industry. The mated adult female fly lays eggs on the integument of third to fifth instar larva of *Antheraea assama*. The maggots after hatching pierce through the integument and grow inside the body of the silkworm by feeding on the fat body. The matured maggot pierce through the shell of the silk cocoon and crawl away from the site of cocoonage in search of suitable place for pupation. The piercing of the cocoon shell renders the silk cocoon unreelable. In this way the fly is reported to cause 20 to 80% loss of seed crop of *A.assama* .The fly infestation is reported in all the commercial silkworm varieties and form almost all silk producing countries of the world (O'Hara 1992; Sahu *et al*., 2008).

2.2.5.5. Diseases

Grasserie (viral), Flacherie (bacterial), Muscardine (fungal) and Pebrine (protozoan) are four common diseases of silkworm and they have been causing heavy loss to silkworm crops in silk producing countries. Isaiarasu *et al*.,(1969) reported efficacy of aqueous and alcoholic crude extracts of *Acalypta indica,Ocimum sanctum* and *Tridaxro cumbens* against flacherie and muscardine diseases in silkworm. Thus, the natural products based on the indigenous use of the botanicals could be one way of mitigating the problems associated with inappropriate use of synthetic chemicals (Amaugo and Emosairue , 2003)

2.2.6. Mulberry

The mulberry plant belongs to the family Moraceae is an economical important tree being cultivated for its leaves, to rear silkworm *B.mori* (Kunjupillai *et al*., 2012).Mulberry leaf is known to be rich in protein, starch and vitamins, helping the silkworm to meet its dietary requirements. It is conventionally propagated through stem cutting clones and rarely grafting. Propagation via cutting is highly restricted to certain months of the year and is lobour intensive (Ravindran *et al*.,1988).It was a confirmed fact that low organic matter content, high pH etc. are the major limiting factors in mulberry cultivation (Muya *et al*.,2011).

In recent year, the role of mulberry tree in the prevention and control of desertification, water and soil conservation, saline land management and forage for livestock (Quin *et al*., 2012).It was estimated that one hectare of mulberry provides about 15 work years of employment in sericultural activities (Ravikumar, 1988). In addition to its use in sericulture, the expansion of mulberry like other trees is ecologically important. Particularly for the countries like Ethiopia where there is a great potential of dam building the role of tree growing including mulberry can significantly prevent the soil carried by tributary water sources into the dams and this is in turn vitally important in supporting the efforts under taken to ensure the sustainable use of the dams for the benefits of the country and the regions as well.

3. Materials and Methods

3.1. Study area and periods

The study was carried out at Bonga, Bishaw W/Yohannes Secondary and Preparatory School compound South west Ethiopia. It is located at 7.28˚66`N and 36.23˚48`E and an altitude of 1529 m a.s.l. (Fig.1). Bonga town is located 460 km Southwest of Addis Ababa and 105 km of Jimma town.

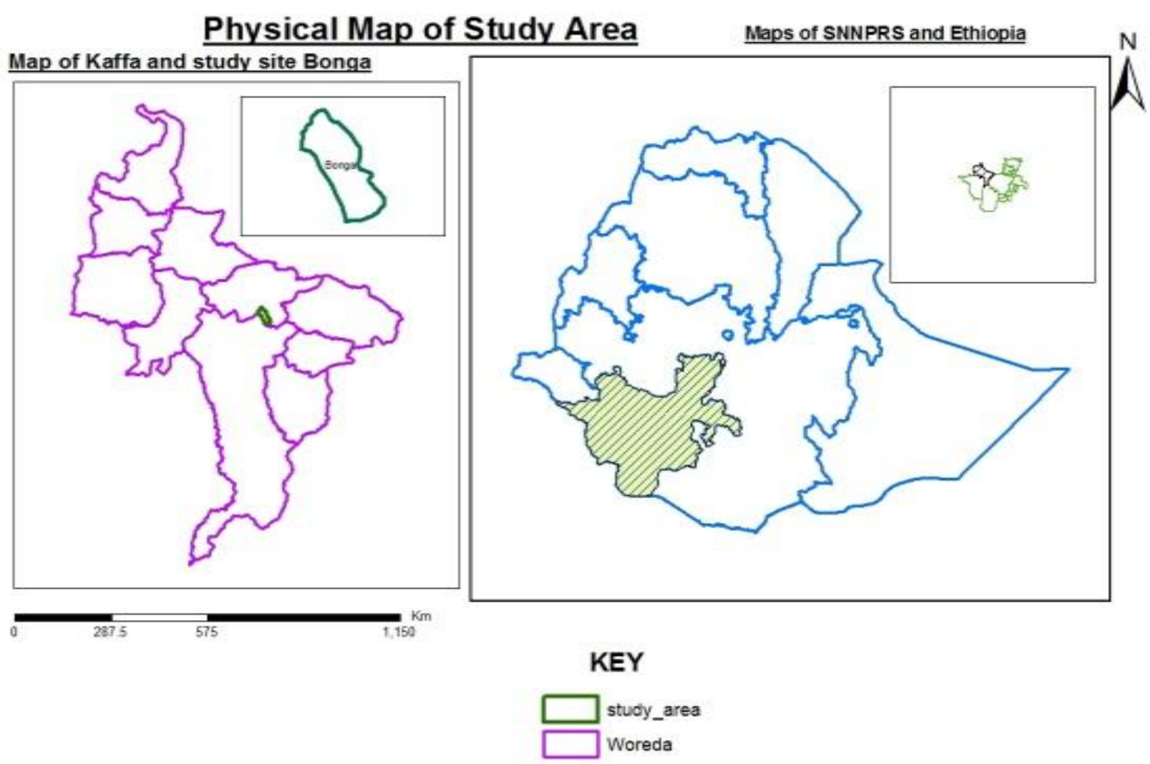

Figure 1. Map of the study area.

3.1.1. Topography and soil

According to TAM Agribusiness (2004) the natural topography of Bonga region is highly slopping ranging from 10 % to over 60 %. The high rainfall (over 1,500 mm/yr) had the soils highly leached and much of the soil fertility is tied up in the top 20 cm and maintained through nutrient recycling between the soil and the living forest vegetation.

Bonga region is humid and has warm tropical rainy climate. The rainfall is uni-modal with low rainfall from November to February and the wettest months between May and September. The coolest months are July and August in the middle of the main rainy season, while the hottest months are from February to May. Bonga experiences one long rainy season, lasting from March /April to October. The mean temperature is 19.4°C at Bonga (Bekele, 2003).

3.2. Experimental setup

3.2.1. Silkworm rearing

Disease free laying (DFLs) of yellow(multivoltine race),kenya-3, Kenya-5,China-2 and Korea-1 (Bivoltine races) were drawn from Jimma Agricultural Research Center(JARC), which is one of the research centers under the Ethiopian Institute of Agricultural Research (EIAR) and raised on fresh mulberry leaves as per the new technology for silkworm rearing (Dandin *et al*.,2000).All the silkworm strains were maintained at the rearing room BW/YSP School, Bonga. The whole process, from silkworm egg incubation to completion of rearing activities, was carried out under hygienic conditions in a silkworm rearing room .Silkworm rearing was conducted for each strain (race) in rearing trays by feeding them the leaves of S13 mulberry from the well maintained mulberry garden on compound. A standard rearing procedure was adopted as recommended by (Datta, 1992). Completely Randomized experimental Design (CRD) were used in the sudy of larval weight and cocoon traits among the five silkworm strains, and growth parameters of S13 mulberry variety as well.

The young larvae (1^{st}-3^{rd}instars) were reared at 26-28° C with 80-90% RH and late age larvae ($4^{th}$and 5^{th}instars) were maintained at 24-26° C with 70-80% RH until maturation of the fifth instar. The leaves were harvested daily from the mulberry garden during the early hours of the day and stored cool to maintain its freshness until feed using wet gunny cloth in wooden chamber.

Fresh and healthy mulberry leaves were used in the present study. Tender leaves of mulberry were fed until the larvae ends second instar stage, and semi-tender leaves to third instar while more matured leaves were fed to fourth and fifth instar larvae four times a day.

Sufficient ventilation was ensured to the larvae by placing the rearing trays one above the other crosswise. A thermometer was used to record the temperature near the larval bed. Alcohol was used to wash the hands before and after handling the worms during the time of rearing. Bed cleaning was thoroughly carried out. Dead larvae if any, during the course of rearing were immediately removed and discarded properly. Thus, the larvae of each strains were reared with equal quantities of leaves. Then parameters like larval weight and the cocoon characteristics were studied of the five mulberry silkworm strains studied. The mature larvae of the experimental sets were randomly selected and measured right before mounting (plate.5).

Plate 5. Measuring matured 5th instar larvae using digital balance

The cocoons were left undisturbed for four days to spin the cocoon and on the seventh day after mounting cocoons were harvested and cleaned. Then cocoon, shell and pupal weight were measured and shell ratio, were also determined for each silkworm strains (plate.6).Experiment was conducted to five mulberry silkworm strains from July last to September 2015.

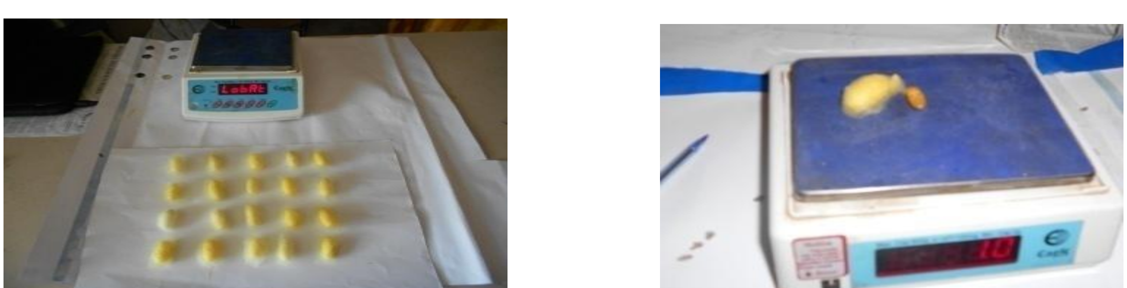

Plate 6.Measuring cocoon, shell and pupal weight

3.2.2. Land preparation for mulberry cultivation

In the first step, prior to 4 months to commence the study, the land was ploughed repeatedly (3 to 4 times) to loosen and to get the fine soil as well. Then 23 plots were prepared in ploughed field and around 2000 S13 mulberry stem cuttings with three and four active vegetative buds (eyes) were procured from Melkasa Agricultural Research Center (MARC) and planted in the holes (trench) at distance of 70 cm between the rows and plants (Plate 7) .The mulberry plants on 23rd plot were only used to evaluate different growth parameters of mulberry variety used in the current study. However, the total number of mulberry plants in the garden were taken in to account while assessing the viability (propagation potential) after planting, the impact of disease and insect pest incidence.

Plate 7.Land preparation and mulberry propagation

Watering the field when there was no rain thoroughly carried out. Compost and farmyard manure were also used to enhance fertility of the soil (plate 8) and these were in turn favors the fertility of the mulberry garden causing the mulberry cuttings to propagate and grow vigorously.

Plate 8: Compost and farmyard manure preparation

Moreover, larvae leftover and silkworm excreta were thoroughly collected and returned to the mulberry field (plate.9).

Plate 9.Larvae leftover and excreta collection

It has been widely accepted that organic farming alone could serve as a holistic approach towards achieving sustainable agriculture as it is nature based, environment friendly and ensures the conservation of resources for the future (Sangeetha and Thevanathan, 2010).

3.2.3. Weed control

Weeds impose direct and indirect impact on mulberry plants. In the first place weeds highly utilized nutrients in the soil to their rapid growth. On the other hand they provided shelter for the insect pests harming the mulberry plants. Thus, the removal of weed from the mulberry garden was found important to avoid its direct and indirect impacts on mulberry plantation. Hence that it was controlled by applying uprooting method (one of traditional weed controlling practice (Plate 10&11.).Application of this practice also favors biological controls to the insect pests as insect pests exposed to a particular species of birds as a result of loss of the weeds in which they were hide themselves.

Plate.10. Weed control by uprooting method

Plate.11.Weeded mulberry plots

Therefore, this way Mori-culture, the first step of sericulture, was successfully accomplished over the field prepared purposely for mulberry garden establishment. The moriculture aspect was studied on the garden whereas the rearing of mulberry silkworm was undertaken in silkworm rearing room.

The whole process from land preparation to mulberry cultivation and silkworm rearing were last from February first to September, 2015. However, the experiment on mulberry silkworm races were confined to one generation (from July last to September, 2015).

During the process of silkworm rearing larval weight, cocoon weight, shell weight and pupal weight were measured and data recorded, and shell ratio were determined according to the following formula:

Larval weight (g): Mean larval weight (g) was recorded for 50 randomly selected larvae at the peak of growth of fifth instar larvae from each strain. This was an indicator of the general weight of the larvae.

Cocoon weight (g): 10 male and 10 female cocoons were chosen randomly on the 7thday of spinning so as to compute for the mean cocoon weight.

Shell weight (g): The average single cocoon shell weight in grams of 10 male and 10 female cocoons shell were chosen randomly. The shells used were the same cocoons used for the cocoon weight determination.

Pupal weight (g): 10 male and 10 female pupae were chosen randomly and the average single pupal weight in gram was determined. The pupae used were also the same cocoons used for the cocoon weight determination.

Shell ratio (%): The total quantity of silk available from a single cocoon was expressed as a percentage using the following equation.

$$\text{Shell ratio} = \frac{\text{Average single cocoon shell weight (g) x100}}{\text{Average Single cocoon weight (g)}}$$

Collection of data on various parameters of mulberry plants like the number of leaves and shoots per plant, the size of leaf, plant height, viability (no. of stem cuttings sprouting shoots out of the total), resistance to disease and insect pest and palatability of the leaves were assessed for theS13variety of mulberry in the present study.

To examine mulberry growth parameters like number of shoots per plant, plant height, number of leaves per plant, the size of matured leaves, 10mulberry plants were randomly selected from a total of 40 plants over a single plot deliberately assigned for the study of S13 mulberry variety, one of the food plant of silkworm, *B.mori*. The above mentioned mulberry growth parameters were computed at 45, 60, 90 and 120 days after planting.

Mulberry Propagation Rate

Sprouting percentage out of the total planted mulberry cuttings were recorded through censes counting in different interval of periods.

Plant height

Plant height was computed by measuring all the shoots of 10 selected and tagged plants from the base to tip at 45, 60, 90 and 120 days after planting. The mean plant height was calculated as:

$$\text{Mean plant height} = \frac{\text{total shoot height}}{\text{Number of plants}}$$

Leaf size

Leaf sizes (Petiole base to apex, from mid-rib base of a leaf to apex and leaf diameter) periodically measured at 45, 60, 90 and 120 days after planting and the measuring activity was undertaken on spot without plucking the leaf and fully opened and healthy leaves were used for this purpose. A tape meter was used for measuring the height and leaf size Viz., Petiole Base to Apex (PBA), Midrib Base to Apex (MBA) and Leaf Diameter (LD) and the unit used while writing the result was centimeter (cm.).

Leaf and shoot (branch) number

$$\text{Number of leaves per plant} = \frac{\text{Total number of leaves from 10 plants}}{\text{Number of plants (10)}}$$

$$\text{Number of shoots (branches) per plant} = \frac{\text{Total number of shoots}}{\text{Number of plants}}$$

3.3. Data analysis

The data collected from larval weight and cocoon traits of each mulberry silkworm strain were tabulated and subjected to critical analysis by adopting method of analysis of variance (ANOVA) using SPSS version 19.0 soft ware. Furthermore, post-hoc test was applied to examine the pair wise comparison among silkworm races. Using LSD (Least significant difference).The mean value were used to compare different growth parameters of S13 mulberry variety in different time intervals.

4. Results

4.1. Larval weight and cocoon traits

4.1.1. Larval weight

The yellow silkworm race mean larval weight was found as 1.99(95% CI 1.93- 2.03), mean Kenya-3 larva weight is 3.37 (95% CI 3.22-3.52), Keneya-5 mean larva weight 3.75 (95% CI 3.59-3.90), korea-1 mean larva weight 4.26 (95% CI 4.19-4.33), China-2 mean larva weight 3.63 (95% 3.51- 3.76) (Table 1).

Table 1: Mean larval weight among mulberry silkworm races in Bonga, southwestern Ethiopia (2015)

Silkworm races	Minimum larval weight	Maximum larval weight	Mean larval weight with 95% C.I.	F-value	p-value
Yellow	1.7	2.4	1.99 (1.93,2.03)	217.33	0.000
Kenya 3	2.3	4.5	3.37 (3.22, 3.52)		
Keneya-5	2.8	4.7	3.75 (3.59,3.90)		
Korea-1	3.8	4.9	4.26 (4.19, 4.33)		
China-2	3.0	4.6	3.63 (3.51, 3.76)		
Total	1.7	4.9	3.41 (3.29, 3.51)		

There is a significant mean larva weight difference among silkworm races. The maximum mean larva weight was obtained from Korea-1 silkworm race while the minimum mean larva weight accounted by Yellow silkworm race. All pair wise comparisons had a significant mean difference except Keneya-5 and China-2 mean larva difference(Table 2).

Table 2: Post hoc test using LSD (least Significant Difference) for pair wise mean larva weight comparison among the silkworm races

	Yellow	Kenya 3	Keneya-5	Korea-1	China-2
Yellow	-	-1.38 *	-1.76*	-2.28*	-1.64*
Kenya 3		-	-0.38*	-0.89*	-0.26*
Keneya-5			-	-0.51*	0.12
Korea-1				-	0.63*
China-2					-

* Significant at 5% significance level

4.1.2. Cocoon weight

The yellow race mean cocoon weight in this study was 0.94(95% CI 0.87 -1.02). InKenya-3, the mean cocoon weight was1.67 (95% CI 1.55-1.78).In Kenya-5 the mean cocoon weight was 1.92 (95% CI 1.79- 2.05), in Korea-1 the mean cocoon weight was 2.23 (95% CI 2.13-2.33) and in China-2 the mean cocoon weight was 1.87 (95% CI1.77-1.96). The mean comparison of the five silkworm race showed that there is a significant mean difference among the races ($p<0.05$) (Table 3)

Table 3: Mean cocoon weight among mulberry silkworm races in Bonga South western Ethiopia, 2015

Silkworm races	Minimum cocoon weight	Maximum cocoon weight	Mean cocoon weight with 95% C.I.	F-value	p-value
Yellow	0.7	1.3	0.94 (0.87, 1.02)		
Kenya 3	1.3	2.1	1.67 (1.55, 1.78)		
Keneya-5	1.5	2.4	1.92 (1.79, 2.05)	95.60	0.000
Korea-1	1.9	2.7	2.23 (2.13, 2.33)		
China-2	1.6	2.2	1.87 (1.77, 1.96)		
Total	0.7	2.7	1.72 (1.63, 1.82)		

The first column shows the minimum cocoon weight while the second column shows the maximum cocoon weight of five silkworm races. The mean cocoon weight of the five silkworm race with 95% confidence interval reported in the third column. The maximum mean cocoon weight was reported from Korea-1 which is 2.23 (2.13, 2.33). The mean comparison of the five silkworm race showed that there is a significant mean difference($P < 0.05$). All pair wise comparison had a significant mean difference except Keneya-5 and China-2 mean cocoon weight difference (Table 4).

Table 4: Post hoc test using LSD (least Significant Difference) for pair wise mean cocoon weight comparison among the silkworm races

	Yellow	Kenya 3	Keneya-5	Korea-1	China-2
Yellow	-	-0.73*	-0.98*	-1.29*	-0.93*
Kenya 3		-	-0.25*	-0.57*	-0.20*
Keneya-5			-	-0.31*	0.05
Korea-1				-	0.37*
China-2					-

* Significant at 5% significance level

4.1.3 Shell weight

The mean shell weight in the yellow race was 0.13 (95% CI 0.10-0.15),in Kenya-3 the mean shell weight was 0.30 (95% CI 0.30-0.30) .In Kenya-5 the mean shell weight was 0.34 (95% CI 0.31-0.36).The Korea-1 mean shell weight was found 0.38 (95% CI 0.35-0.96) and in China-2 the mean shell weight was 0.25(95% CI 0.26-0.29)(Table 5).

Table 5: Mean shell weight among mulberry silkworm races in Bonga south western Ethiopia, 2015

Silkworm races	Minimum shell weight	Maximum shell weight	Mean shell weight with 95% C.I.	F-value	p-value
Yellow	0.1	0.3	0.13 (0.10,0.15)		
Kenya 3	0.3	0.3	0.30 (0.30,0.30)		
Keneya-5	0.3	0.4	0.34 (0.31,0.36)	87.27	0.000
Korea-1	0.3	0.4	0.38 (0.35,0.96)		
China-2	0.2	0.3	0.25 (0.26,0.29)		
Total	0.1	0.4	0.27 (0.25,0.30)		

The minimum shell weight was reported from the Yellow silkworm race while the maximum shell weight was found from the Korea-1 silkworm race. The mean shell weight comparison among the five silk worm race was found statistically significant at 5% significance level.

All pair wise comparison had a significant mean difference except Keneya-5 and China-2 mean shell weight difference(Table 6).

Table 6: Post hoc test using LSD (least Significant Difference) for pair wise mean shell weight comparison among the silkworm races

	Yellow	Kenya 3	Keneya-5	Korea-1	China-2
Yellow	-	-0.17*	-0.21*	-0.25*	-0.12*
Kenya 3		-	-0.04*	-0.075*	0.05*
Keneya-5			-	-0.04*	0.08
Korea-1				-	0.13*
China-2					-

* Significant at 5% significance level

4.1.4 .Pupae Weight

The yellow race mean pupa weight was 0.81(95% CI 0.74 - 0.88), in Kenya-3 the mean pupa weight was 1.36(95% CI 1.25-1.48), in Kenya-5 the mean pupa weight was 1.59(95% CI 1.47-1.69) ,in Korea-1 the mean pupa weight was 1.86 (95% CI 1.76-1.94) and in China-2 silkworm race the mean pupa weight was 1.61(95% CI 1.37-1.53) ,(Table 7)

Table 7: Mean pupa weight among mulberry silkworm races in Bonga South western Ethiopia, 2015

Silkworm races	Minimum pupa weight	Maximum pupa weight	Mean pupa weight with 95% C.I.	F-value	P-value
Yellow	0.6	1.1	0.81 (0.74,0.88)		
Kenya 3	1.0	1.8	1.36 (1.25, 1.48)		
Keneya-5	1.2	2.0	1.59 (1.47, 1.69)	75.04	0.000
Korea-1	1.5	2.3	1.86 (1.76,1.94)		
China-2	1.3	1.9	1.61 (1.53,1.69)		
Total	0.6	2.3	1.45 (1.37, 1.53)		

The minimum pupa weight was found from the Yellow silkworm while the maximum pupa weight was found from the Korea-1 silkworm. The mean comparison was conducted for all silkworm races using the method of ANOVA. The ANOVA result showed that there is a significant mean pupa difference among the silkworm races. The F-test statistic value is very high which indicates the significant mean difference among the silkworm races. However, the decision in this study was done based on the P-value. The P-value which is less than the 0.05 value revealed the significance of the mean difference. All pair wise comparison had a significant mean difference except Keneya-5 and China-2 mean pupa weight difference (Table 8).

Table 8: Post hoc test using LSD (least Significant Difference) for pair wise mean pupa weight comparison among the silkworm races

	Yellow	Kenya 3	Keneya-5	Korea-1	China-2
Yellow	-	-0.56*	-0.78*	-1.05*	-0.81*
Kenya 3		-	-0.22*	-0.49*	-0.25*
Keneya-5			-	-0.27*	-0.03
Korea-1				-	0.24*
China-2					-

* Significant at 5% significance level

Over all the mean weight of larva, cocoon, shell and pupa of the five mulberry silkworm races was indicated in figure 2.

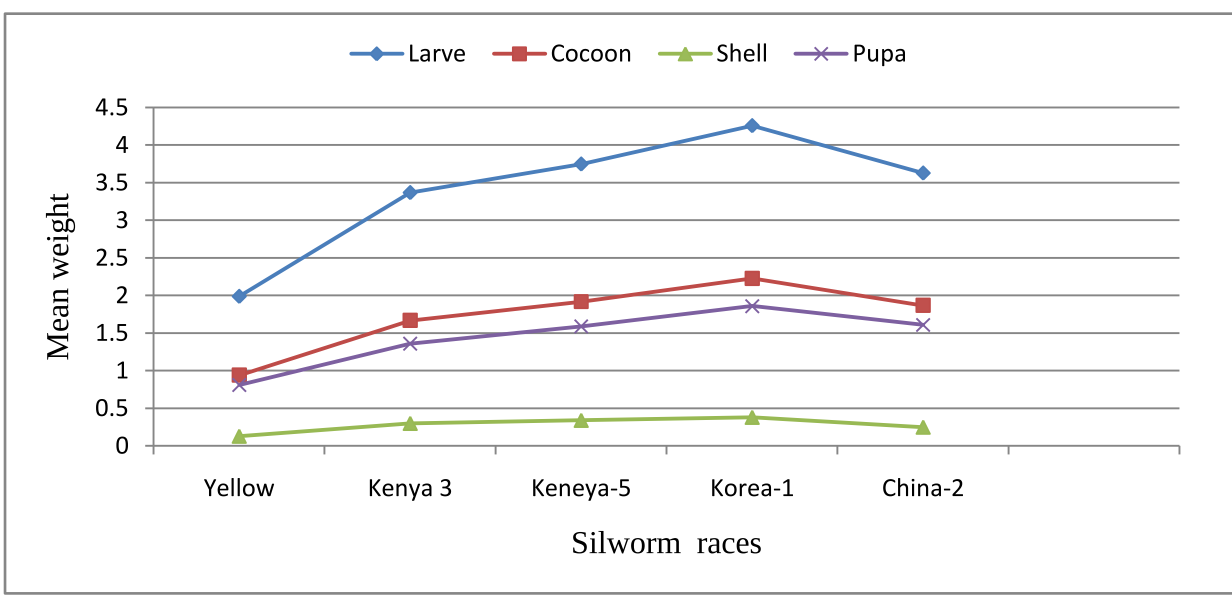

Figure 2: Mean weight of larvae, cocoon, shell and pupa for silkworm races

4.1.5. Shell ratio (%)

The yellow silkworm race mean shell ratio was 0.14 (95% CI 0.11 - 0.16) while in Kenya-3 the mean shell ratio was found 0.18(95%CI 0.17-0.19) and in Kenya-5 the mean shell ratio was found 0.18(95%CI0.17-0.18) whereas in Korea-1 the mean shell ratio was found 0.17 (95%CI0.15-0.17) and in China-2 the mean shell ratio was found 0.13 (95%CI 0.12-0.15) (figure 3) and (Table 9).

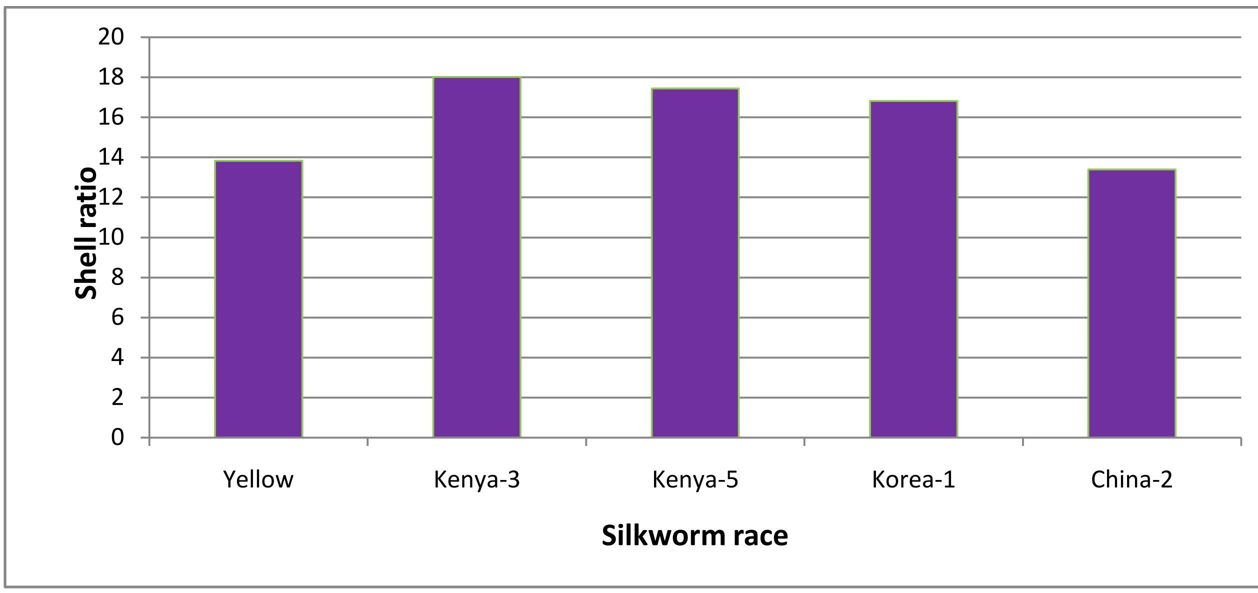

Figure 3: Shell ratio for silkworm races

Table 9: Mean shell ratio among mulberry silkworm races in Bonga Southwestern Ethiopia, 2015.

Silkworm races	Minimum shell ratio	Maximum shell ratio	Mean shell ratio with 95% C.I.	F-value	P-value
Yellow	0.083	0.23	0.14 (0.11, 0.16)	10.77	0.000
Kenya 3	0.14	0.23	0.18 (0.17, 0.19)		
Keneya-5	0.14	0.20	0.18 (0.17, 0.18)		
Korea-1	0.14	0.22	0.17 (0.15, 0.17)		
China-2	0.10	0.19	0.13 (0.12,0.15)		
Total	0.08	0.23	0.16 (0.15,0.17)		

The mean shell ratio of the tested silkworm strains revealed that there is a significant mean shell ratio among the five silkworm strains (Table 9). Similarly all pair wise comparison had a significant mean difference except (yellow and China-2), (Kenya-3 andKeneya-5) (Kenya-3 and Korea-1), (Kenya-5 and Korea-1) ,and (Korea-1 and China-2) mean shell ratio difference(Table 10).

Table 10: Post hoc test using LSD (least Significant Difference) for pair wise mean shell ratio comparison among the silkworm races

	Yellow	Kenya 3	Keneya-5	Korea-1	China-2
Yellow	-	-0.045*	-0.04*	-0.03*	0.01
Kenya 3		-	0.008	0.02	0.05*
Keneya-5			-	0.01	0.04*
Korea-1				-	0.03
China-2					-

* Significant at 5% significance level

4.2. Rate of mulberry propagation

Results from census counting at 45,60,90 and 120 days after planting reveals an increased number to mulberry propagation from 377,720,1030 and 1120 respectively out of the total planted 2000 stem cuttings (Fig.4).Mulberry were found to grow periodically by this conventional method of propagation. Thus, of the 2000 mulberry stem cuttings 56% were found during the fourth round censes counting.

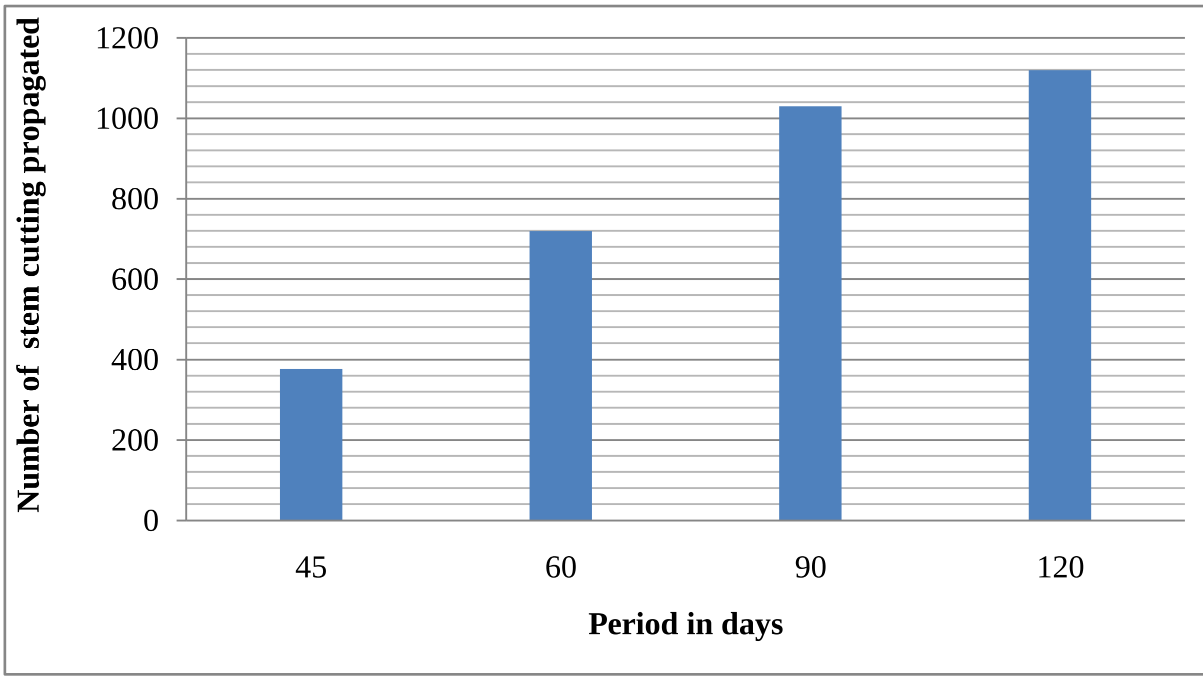

Figure 4 :Mulberry propagation rate

However, more stem cuttings were started to sprout later. Thus, mulberry propagation rate increased than the figure cited during the final censes counting. Several stem cutting from S13 mulberry variety were spent long duration without sprouting but they revive to sprout later like resurrection plants. However, after rooting and sprouting rapid growth were exhibited over the rest mulberry propagation periods.

4.2.1. Plant height

Significant variation in height of mulberry plants was experienced at different interval of periods. Thus, the mean value of mulberry height at 45 day was 62.8 with range of 56 to 71 cm. During the day 60 after planting the mean height of mulberry was 75.35 with range of 67 to 82 cm., While at day 90 after planting the mean height of mulberry was 104 with range of 95 to 111cm and at 120 days after planting the mean mulberry height was 137.4 with range of 126 to 148 cm. (Table 11).

Table 11. Mean height of mulberry plant at different time intervals in Bonga south western Ethiopia, 2015.

	Plant height in cm.			
	45 days	60 days	90 days	120 days
Minimum	56	67	95	126
Maximum	71	82	111	148
Mean	62.8	75.35	104	137.4

4.2.2. Leaf size

The result obtained for leaf size indicated that there were significant mean difference in all leaf index viz., PBA, MBA and LD in different time intervals (Table 12).Leaf growth in all parameters showed direct relationship with time intervals. The mean value of leaf size from PBA at day 45 was 13.5 with range of 12.5 to 15cm. , at day 60 the mean was 15.65 with range of 14.5 to16.5cm.at day 90 the mean was 20.95 with range of 21 to 25cm. and at day 120 the mean was 29.75 with range of 27 to 32.

The mean value mulberry leaf size from MBA at 45 day was 11.75 with range of 10 to 13, at 60 day the mean for MBA was 13.5 with range of 13 to 15 cm., and at 90 day the mean for MBA was 19.4 with range of 18 to 21cm where as at day 120 the mean for MBA was 25.5 with range of 23 to 29.5cm.

The mean value of leaf diameter at day 45 was 7.35 with range of 6.5 to 8cm., and at 60 day the mean of mulberry leaf diameter was 8.6 with rage of 7 to 10 cm., at 90 days the mean mulberry leaf diameter was 13.25 with range of 11 to 15 cm., and at day 120 the mean of mulberry leaf diameter was 19.5 with range of 17 to 22 cm.

Table 12: mean value of mulberry leaf size over different time intervals in Bonga south western Ethiopia, 2015.

	Petiole base to apex (PBA) in cm.				Mid-rib base to apex(MBA) in cm.				Leaf Diameter (LD) In cm.			
	45	60	90	120	45	60	90	120	45	60	90	120
Minimum	12.5	14.5	21	27	10	13	18	23	6.5	7	11	17
Maximum	15	16.5	25	32	13	15	21	29.5	8	10	15	22
Mean	13.5	15.65	20.95	29.75	11.75	13.5	19.4	25.5	7.35	8.6	13.25	19.5

4.2.3. Leaf and shoot number

Leaf numbers per plant for ten tagged S13 mulberry plant were recorded at different intervals of periods. The result indicated an increase mean value over the periods and the difference in mean value for leaf number was 8.7 at day 45 with range of 7 to 11.At day 60 the mean value of leaf number was13.5 with range of 12 to 14. At day 90 the mean value of leaf number was 27.9 with range of 27 to 13.At day 120 the mean value of leaf number was 41.6 with range of 38 to 44.

On the other hand the number of shoots (branches) per plant for the same tagged plants were periodically counted over the given period of intervals and the mean value record were 1.3 at day 45 after planting with range of 1 to 2. At day 60 the mean value was 2 with range of 1to 3. At day 90 the mean value shoot number was 4.5 with range of 3 to 6 and at day 120 the figure for leaf number in mean value increased to 10.4 with range of 7 to 13 (Table 13).

Table 13: Mean value of mulberry leaf number over different time intervals in Bonga, south western Ethiopia

	Number of leaves per plant				Number of shoots per plant			
	45	60	90	120	45	60	90	120
Minimum	7	12	27	38	1	1	3	7
Maximum	11	14	30	44	2	3	6	13
Mean	8.7	13.5	27.9	41.6	1.3	2	4.5	10.4

5. Discussion

The larval weight, cocoon weight, shell weight and shell ratio are important quantitative traits used to evaluate variability among the mulberry silkworm strains. It has been reported that about twenty-one characters contribute to silk yield (Thiagarajan *et al*.,1993) some of these characters are heritable, and others are determined by environmental factors (Moorthy *et al*.,2006 Singh *et al*.,1994) . Environment has played great role on many of the economically important characters, which are quantitatively inherited. Many workers analyzed correlation between different traits in silkworm as said earlier based on quantitative traits (Singh *et al.,1994* and Nagaraju,1989). cocoons weight is the most significant feature to evaluate the variability among silkworm strains. Cocoons are sold in the market place based on weight as this index signals the approximate quantity of raw silk that can be reeled. The whole weight of a single cocoon is influenced by silkworm species, rearing season and harvest conditions. In nature the weight of a fresh cocoon does not remain constant but instead continues diminishing until the pupa transforms in to a moth and emerges from the cocoon. The weight of the shell is the most consequential factor as this measure forecasts raw silk yield. As with other characteristics introduced in this study, shell weight differs in correspondence to varieties of silkworms. The pupa makes up the largest portion of cocoon weight. As the entire cocoon including the pupa is sold as part of the raw materials, it is essential to quantify the ratio of the weight of the silk shell versus the weight of the cocoon. Many workers evaluated silkworm genotypes mostly based on quantitative traits and performance in different rearing season (Moorthy *et al*., 2006; Rao *et al*.,2004; Ramesh *et al*.,2001 and Kumaresan *et al*.,2000).

Among the various factors influencing silkworm growth and cocoon production, leaf quality plays a major role (Bose, 1989 and Matsumara, 1951). It is a confirmed fact that, leaf quality differs among mulberry varieties which in turn responsible for the difference in silkworm rearing performances (Arug , 1994). Increased production of superior quality mulberry leaves with high nutritive value enhances the chances of good cocoon crop and successful sericulture (Ravikumar, 1988 and Krishnamurthy,1983).

There has been ample literature stating that the tropical multivoltine races of *B.mori* are more tolerant to high temperature, as against the bivoltine races of temperate origin. In this study all bi-voltine mulberry silkworms exhibited higher performance in larval and cocoon traits than the multivoltine (yellow race) and it was in agreement with the finding of (Rahamatulla 2012) who has been reported the bivoltine silkworm strains have better yield potential and superior quality of silk than polivoltine. However polvoltine breeds reared in tropical countries are known to tolerate slightly higher temperature and adjust with tropical climatic conditions (Hsieh, 1995).

The seasonal performances of bivoltine breeds also depend upon the technology of rearing of silkworm under tropical conditions (Krishnaswami, 1994, 1978 and1971).There has been established fact that, for exploiting maximum benefit from above mentioned rearing technology, use for high yielding varieties of mulberry & superior bivoltine silkworm breeds and favourable conditions plays vital role in success of cocoon crops (Naseema *et al*.,2000;Noamani*et al*.,1990;Rajanna and Sreerama ,1990).

The mean larval weight (4.26) from Korea-1 were found highest and the mean larval weight (1.99) from yellow race were found the least with 95% confidence intervals among the mulberry silkworm races. The mean cocoon weight (2.23) from Korea-1were found highest and the mean cocoon weight (0.94) from yellow race were found the least with 95% confidence intervals among the mulberry silkworm races. This finding confirms the importance of larval weight for getting higher cocoon weight thereby more silk yield and it was in agreement with the finding of the (Pal and Moorthy,2011). Significant variation were obtained at 5% significant level in mean larval weight, cocoon weight, pupal weight and shell weight, of all mulberry silkworm strains except Kenya-5 and China-2.

The post-hoc test using LSD method was also revealed significant variation of mean shell ratio at 5% significant level between the following pairs of mulberry silkworm races. These pair of silkworms whose mean shell ratio were showed significant variation include (yellow and Kenya-3), (Yellow and Kenya-5) , (yellow and Korea-1), (Kenya-3 and China-2), (Kenya-5 and China-2) whereas no significant variation of mean shell ratio were obtained at 5% significant level between (Yellow race and China-2), (Kenya-3 and Kenya-5),(Kenya-3 and Korea-1),(Kenya-5 and Korea-1) and (Korea-1 and China-2). Therefore, based on the result derived from analysis of variance (ANOVA) and Post-hoc test LSD (least significant difference) the Korea-1 Silkworm strain was found to be superior of all silkworm strains in mean larval weight, cocoon weight ,shell weight and pupal weight though the mean shell ratio was insignificant between (Korea-1 and Kenya-3),(Korea-1 and Kenya-5) and (Korea-1 and China-2).

The propagation(sprouting) percentage for large number of mulberry genotypes ranged from 45% to 76.66% (Muniswamy and Munirajappa,2011).The finding in propagation (sprouting) percentage of S13 mllberry genotype was 56% under the ecological condition of Bonga and it was found between the range cited above. Therefore, the present finding was consistent with the former scholars. Moreover, the yield potential of S13 mulberry genotype under the ecological condition of Bonga area were also found promising.

6. Conclusion and Recommendation

Although all the mulberry silkworm races incorporated in the present study have been released for commercial exploitation. However, the Korea-1 silkworm strains were found superior of all mulberry silkworm strains under the experimental group. However, further study for prolonged duration is needed as silk worm performance might vary season wise. Furthermore, introducing many other mulberry silkworm strain (genotype) to the country and emphasizing to evolve new strains with high cocoon economic trait performance through breeding is worthy to widen the chance to get more quality and quantity raw silk and for success of sericulture in our condition. The findings of this study was also proved the mulberry variety used in this study carried desirable traits in terms of its yield potential and growth. It was also experienced good adaptation to new environment. However, the locally available and other varieties of mulberry should be studied so as to enhance the development of sericulture.

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Appendix

Photographic illustrations noticed for some of the activities carried out over the past 8 months

Mulberry garden

Silkworm rearing room

time table for feeding and bed cleaning


When mulberry leaves harvested



Cocoons of yellow race and korea-1 in the mountages



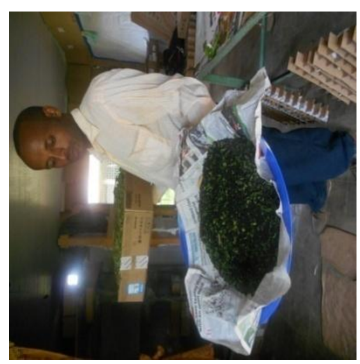
Leaves to silkworm rearing room



Home-made mountages from locally available material.


*Disinfection with alcohol before and after handling *when measuring the larval weight of yellow race



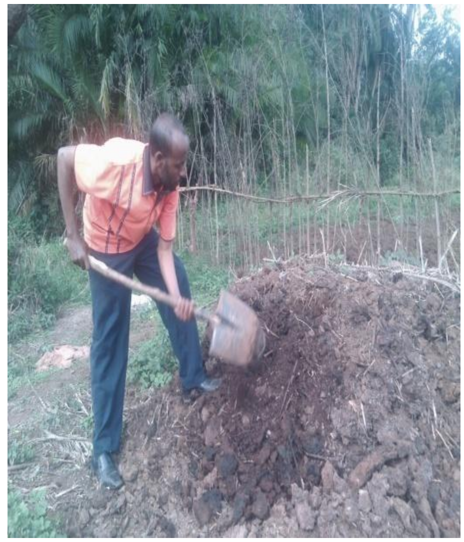


Bed cleaning larvae leftover and their excreta collected to use as manure

Fencing

When mulberry field tilled with oxen

When the field was measured with tape meter to form plots



When preparing compost to mix with soil for establishing mulberry garden

When breaking the soil with pole to get loose and fine soil structure

Plot preparation

When marking with small sticks to dug big holes When stem cutting is planted in the hole

When pressing the soil around mulberry stem cutting

45 days after planting

60 days after planting

90 days after planting

120 days after planting

Disinfection of rearing room with 2% formalin solution using Knapsack sprayer

Rearing stands, trays , ant well

Leaf chopping board, knife and table

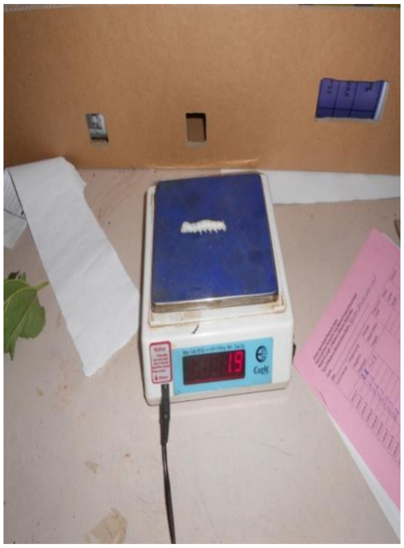
Leaf chamber, wet gunny cloth

Alcohol

Rearing bed

Mountages

thermometer



When matured larva of yellow race measured using Electronic Digital balance

Cocoons of yellow race randomly selected

Copulation in yellow race

Oviposition by female silk moth

Eggs

Eggs under incubation period

Cocoon in mountage

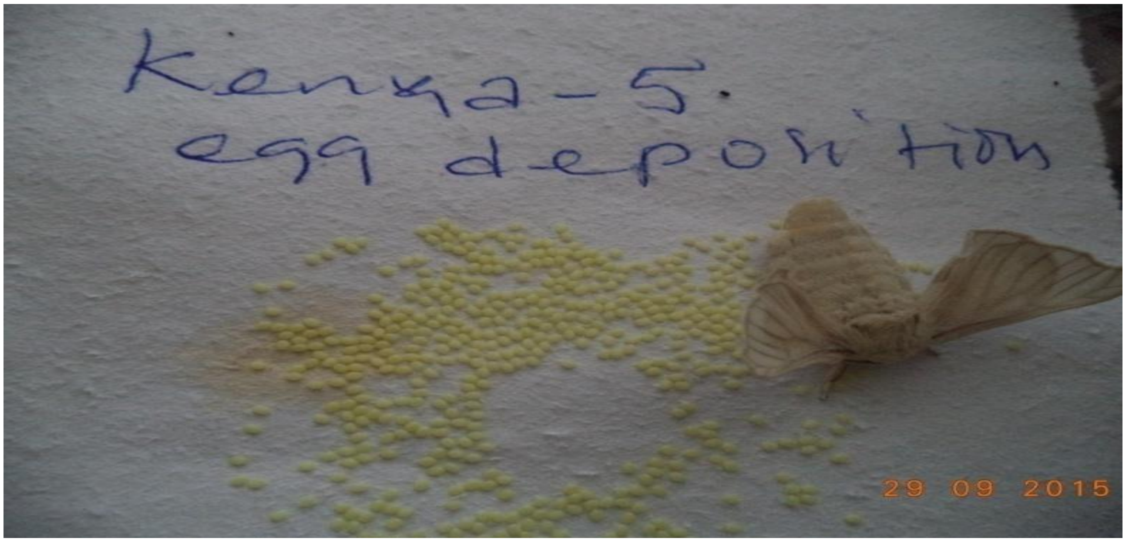
Silk worms in their feeding trays


Keneya -5
29 09 2015


korea - 1
29 09 2015


korea - 1
during egg deposition
29 09 2015


Kenka - 3
egg deposition
29 09 2015


Kenya-5.
egg deposition
29 09 2015