# PERFORMANCE OF *Bombyx mori* (L) AND *Samia cynthia ricini* SILKWORMS UNDER CONTROLLED ENVIRONMENTAL CONDITIONS IN UASIN GISHU COUNTY

**BY**

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## DECLARATION

Declaration by the Candidate

This thesis is my original work and has never been submitted to any University or any other Institution of higher learning for the award of any degree. No part or whole of this work may be reproduced without the prior written permission of the author and/or University of Eldoret.

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## DEDICATION

To Ronny Kiprono and Robby Kiprop, the best gifts life ever gave me.

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## ABSTRACT

The domesticated silkworm, *Bombyx mori* and Eri worm, *Samia cynthia ricini* are bivoltine and multivoltine, feeding exclusively on mulberry and castor leaves, respectively. The mature larvae of these silkworms forms a runny fluid before spinning a cocoon, the raw material for the production of silk used in textile industry. Domesticated silkworms are highly sensitive to environmental fluctuations, hindering their adaptability as compared to the wild silkworm. In Uasin Gishu County, temperatures range between $8.4^0$C and $27^0$C which are not suitable for the hatching and rearing of silkworm. The research determined the rearing structures and conditions suitable for silkworm production in Uasin Gishu by constructing Structures with equal dimensions (4mx4mx3m height) with iron roofs as follows; timber walled (L1) and mud walled (L2). Greenhouses with four flaps open (L3), three sides open (L4), two sides open (L5), one side open (L6) and completely enclosed (L7), further concrete walled (L0) structures was also used. A thermo-incubator was used as a control to test hatchability while survival percentage, larval duration to cocooning and cocoon quality and quantity were tested from all the structures. To test for hatchability, 300 eggs replicated three times were hatched in each experimental structure. The temperature and relative humidity were recorded using hygrometer/thermometer, while the duration to an end to every instar and survival was recorded. Similarly, the quality and quantity of cocoons from each structure was determined and compared using convectional parameters. The mean temperature of tested structures during hatching ranged between $23.9^0$C±1.9 in L0 and $30.3^0$C±1.7 in L7, the mean relative humidity of 29.9%±3.9 (L4) and 41.6%±11.6 (L2) was statistically significant in all of them. The time to complete hatching ranged from 3 days in L0 and L4 to 6 days in L1 and L2. The highest percent hatching was 88.8% and 89.5% for *B. mori* and Eri respectively in L1 but, was lowest in L4. The mean temperature of tested structures during rearing ranged between $22.7^0$C±1.9 in L0 and $31.6^0$C±0.8 in L7 during the wet season while in dry season, the mean relative humidity of 33.3%±7.3 (L1) and 43.2%±9.5 (L0) during wet season and 33.1%±7.3 (L1) and 42.2%±7.4 (L7) was statistically significant (p=0.0001). Larval duration (45.67 days) was longest in L2 for *B. mori* and 39.67 days for Eri in L2 during the wet season,in dry season the longest duration (38.5 days) in L0 and shortest in L5 (27.5 days) for *B. mori* whereas, Eri had shortest duration in L5 (21.33 days) and longest in L2 (30.3 days*)*. Larval survival (%) was highest in L2 (76.7±4.2) and L0 (78.7%) during the wet and dry season respectively. For Eri, a similar trend obtained in L2 (77.0%) and L0 (80.1%) in wet and dry seasons respectively. The cocoon weight was highest in worms reared in structure L2 (0.86±0.0) and L5 (0.86±0.1) during the dry season while, L5 (2.78±4.3) was the highest during the wet season. Further, L0 (0.82±0.0) and L4 (1.44±0.4) recorded the lowest cocoon weights during the dry and wet season respectively. Eri cocoon weight was highest in L0 (2.35±0.5) and lowest in L3 (1.82±0.4) during the wet season and highest in L3 (2.44±0.3) and lowest in L4 (1.79±0.5) in the dry season. For *B. mori* during the wet season the longest Filament length was in L2 (1377.8±150.2) m while, the shortest was from L4 (1292.10±84.1) m which was significantly different. In season two, L3 (1382.8±117.2) m was the longest, while the shortest was from L5 (1137.8±105.4) m and was significantly different. From the Eri cocoon during the wet season the longest filament length was from L2 (437.6±32.3) with shortest in structure L5 (397.6±46.9), with similar trend in the dry season. The seasons did not influence average filament length and weights from the tested structures. These results indicate that hatching of silkworm eggs and rearing can be done in a mud walled structures or in a semi enclosed greenhouse or in a concrete walled structure which can produce high quantity of good quality cocoons in Uasin Gishu County.

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## LIST OF ABBREVIATIONS

$^{0}$C - Degrees centigrade

ANOVA - Analysis of variance

ASAL- Arid and semi-arid lands

ASK-Agricultural Society of Kenya

g-grams

ICIPE-International Centre of Insect Physiology and Ecology

KALRO - Kenya Agricultural Livestock Research Organization

LSD - Least significant Difference

Mg - milligrams

Mm - Millimetre

RH - Relative humidity,

Temp - Temperature,

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background of information

Sericulture is the cultivation of silkworms to produce silk. Mature larval forms a runny fluid in the two silk glands located in their head used for spinning a cocoon, the raw material for the production of silk (Zhou et al., 2022). In Kenya both mulberry silkworm (*Bombyx mori L.*) and Castor plant Eri worm, (*Samia cynthia ricini)* have been introduced. Eri worms (*Samia cynthia ricini*) is a fully domesticated non-mulberry silkworm (Sharma and Kalita, 2017), it is a polyphagous and multivoltine silkworm feeding mainly on castor plants. Mulberry silkworm (*Bombyx mori*) is a domesticated species of silkworm bred for silk production feeding on mulberry leaves. The silk worms are the larval stages of *B. mori* and *S. Cynthia ricini* moths respectively. The adult female moths lay eggs which hatch into larvae after being fertilized by the male moth (Sharma and Kalita, 2017).

The National Sericulture Centre report, (2021) shows that Kenya is collaborating with the Japan International Cooperation Agency to promote silk production by developing technologies and providing farmers with training, eggs and access to markets. Five Japanese companies that have shown interest in Kenyan silk, in addition the world's largest silk producer, Guangdong Silk-Tex Group, in the year 2021 announced plans to create a silk processing factory and silk farm in Kenya. If successful, the venture is expected to create more than 300,000 jobs for Kenyans. The challenges and prospects of sericulture industry is availability of cocoon market

and technical support from KALRO which has made the future of sericulture highly prospective (Mburu et al., 2013).

Understanding hatching behaviour is an important aspect in silkworm rearing for silk production (Xiang, et al., 2017). The worms can be reared throughout the year depending on the presence of host plants and the prevailing conducive environmental conditions. Silkworms are highly sensitive to environmental fluctuations due to long periods of domestication. This makes the adaptability to environmental conditions of which silkworm to be quite different from those of wild silkworm (Rahmatulla, 2012). According to Gong et al., (2020a), adverse environmental conditions occur regularly and the way in which it can affect the development of the organism varies. Further, the regulation of these factors can improve silkworm crop (Rahmatulla, 2012). The optimum temperature for normal growth of silkworms is between $24^0$C and 28 $^0$C which is the desirable temperature for maximum productivity (Nguku, 2012). Controlled conditions is a way of optimizing temperature and humidity in regions like Uasin Gishu where temperatures range between 8.4$^o$C and 27 $^o$C, which are not suitable for rearing silkworms. The research seeks to address the challenges in sericulture production in Uasin Gishu County by managing temperature and humidity through rearing silkworms in controlled conditions to compare with natural conditions for sustainable cocoon production in Uasin Gishu County.

### 1.2 Statement of the problem

Global market of silk yarn has risen hence creating shortage in the industry. Rivatex Kenya located in Eldoret is a ready market for silk yarn, yet in the whole of Uasin

Gishu no single farmer practices sericulture which can offer a means of diversification to perpetual maize farming whose market prices has been fluctuating.

The rise in temperature increases various physiological functions in silkworms due to increased enzymatic activities and with a fall in temperature, the physiological activities reduce. Increased temperature during silkworm rearing particularly in late instars accelerates larval growth and shortens the larval duration. But at low temperature, the growth is slow thus prolonging larval period .

Temperature above 30$^{o}$C directly affects the health of the worm. If the temperature is below 20$^{o}$C all the physiological activities are retarded, more so in early instars; this makes the worms to become too weak and susceptible to various diseases. During the first, second and third instars silkworms require high temperature and the worms feed actively, grow rapidly, leading to high growth rate. Such vigorous worms can withstand adverse conditions in later instars and therefore yield good quantity and high-quality cocoons. Similarly, the relative humidity equally affects the vigour and survival of silkworms. An optimum relative humidity of 75% have been reported to optimize the production of silkworms, however the fluctuations reduces the growth rate, survival and ultimately the yield. A balance of recommended relative humidity and pressure is required for silkworm rearing. Further, an imbalance conditions can also expose the worms to diseases, Rahmatullah, (2012) reported that extremely low temperatures causes *Beauveria bassiana*, a fungus that destroys the entire silkworm body. The high fluctuations of temperature and humidity in Uasin Gishu affects negatively the survival, cocoon quality and quantity of silkworms.

**1.3 Justification**

Environmental fluctuations affect the growth and development of silkworms hence the output of silkworm crop such as cocoon weight and cocoon shell ratio (Sangeeta et al., 2017). Day to day temperatures in Uasin Gishu County which range between 8.4$^{o}$Cand 27$^{o}$C (https://www.crakenya.org); Tuigong, (2015) and average humidity of 68% range is not suitable for the development, growth and ultimately the quality and quantity of silk produced but favours the growth of mulberry trees and castor plants which ensure the food for *B. mori* and castor silkworms are available throughout the year. Emphasis on the need of management of temperature and relative humidity for sustainable cocoon production is important. The research sought to address the issue of management of temperature and relative humidity by rearing silkworms in enclosed controlled environmental conditions to manipulate the temperature and humidity for sustainable cocoon production in Uasin Gishu County, a region which normally experiences frequent diurnal fluctuations of temperature and humidity for successful cocoon yield through a pilot research programme of rearing of silkworms in different types of improvised green houses, mud walled house, concrete walled house and timber walled house.

## 1.4 Objectives

### 1.4.1 General objective

The overall objective is to manage temperature and relative humidity fluctuations by rearing silkworms in enclosed structures to provide controlled conditions for sustainable cocoon production in Uasin Gishu County.

### 1.4.2 Specific objectives

1.To establish the hatchability of silkworm eggs under different conditions in Uasin Gishu County.

i. To determine the larval duration and survival of silkworms reared under different environmental conditions and seasons

ii. To compare mature cocoon weight and quality of silkworms reared under different structures and seasons

**1.5 Hypotheses**

i. $H_{01}$ There is no significant difference in hatchability of silkworm eggs under the different conditions in Uasin Gishu County.

ii. $H_{02}$ There is no variation in larval duration and survival of silkworms reared under different environmental conditions in different seasons.

iii. $H_{03}$ The cocoon weight and quality of silk reared under different environmental conditions and seasons do not vary.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Domestication of silkworm

Silk is called the queen of textiles due to its glittering lustre, softness, elegance, durability, and tensile properties Mahale and Naikwadi, (2019). Silk originates from the spittle of an insect and is a natural fibrous substance that is obtained from pupal nests or cocoons spun by larvae. The silk is preferred over all other types of fibres due to its remarkable properties like water absorbency, heat resistance, dyeing efficiency and lustre (Tuigong, 2015).

Sericulture was first discovered in China between 2600 and 2700 BC and it was the first country to domesticate silkworm and make silk from the larvae of this insect. Rahmathulla, (2012) further noted that the technology of raising silkworms was invented and introduced by Leizu, the wife of Huangedi, which indicates the long history of Chinese sericulture. Silkworm is a moth that undergoes complete metamorphosis of egg, larva, pupa, adult. The common species of silkworms are mulberry silkworms (Shah et al., 2007). However, the castor silkworm is also gaining popularity of late (Oduor et al., 2016). The difference between domesticated silkworms and wild silkworms is that wild silkworms have not been selectively bred thus not commercially viable for silk production. Further, the domesticated silkworms are not able to survive extreme environmental fluctuation of temperature and humidity due to long years of domestication. This makes the adaptability to environmental conditions of domesticated silkworm to be quite different from those of wild silkworm (Nguku et al ., 2009)

The environmental factors that mainly influence the growth, development and physiology of insects are temperature and humidity. Despite wide fluctuations in

their surroundings, insects show a remarkable range of adaptations to fluctuating environmental conditions and maintain their internal temperature and water content within tolerable limits. Adaptation is a complex and dynamic state that widely differs from species to species. Surviving under changing environment in insects greatly depends on dispersal, habitat selection, habitat modification, relationship with water, resistance to cold, diapause and developmental rate, sensitivity to environmental signals, and synthesis of variety of cry protectant molecules.

Silkworm rearing is a month-long process that begins with the egg stage and ends with adults laying eggs and dying naturally. During their growth and development, they go through five larval instars, four moults, a cocoon, and a pupal stage (Astudillo et al., 2014). Silkworm rearing entails the cultivation of five larval instars because other stages such as egg, pupa, and adults are non-feeding. The entire life cycle lasts about 45-55 days, with the egg stage lasting 10-12 days, the larval stage lasting 25-30 days, the cocoon spinning stage lasting 2-3 days, the pupal stage lasting 5-7 days while the adult stage lasts 4-5 days (Oduor et al., 2016).

### 2.1.1 Sericulture in Kenya

Sericulture was first introduced in Kenya in 1972 by Japan International Cooperation Agency with the first species introduced as mulberry silk (Mburu et al., 2013). Kenya has the potential to produce different species and strains of silk, although the main variety that is being reared in Kenya is the mulberry silkworm. Silkworm rearing in Kenya was introduced to aid in the economic empowerment and poverty eradication of the youth and women. It was also expected to boost the Kenyan textile industry and supplement cotton that was the dominant textile fibre in the country (Oduor et al., 2016).

Eri worm was introduced in 2015 by an American investor with the aim of boosting rural income in arid and semi-arid regions (ASAL) areas like Makueni and others. Further, Physical characterization of Eri silk fibres in Kenya was assessed by Oduor et al., (2021) and reported the possibility of good quality cocoons of Eri silk in different parts of Kenya. Odour et al., (2016) reported high reception of Ericulture because it's simple to rear. The quality characteristics of cocoons produced depend on silkworm strain, rearing conditions and quality of the feed. Evaluation of raw silk produced by Bivoltine silkworm, *B. mori* found out that ICIPE strain performance was superior to other strains (Nguku et al., 2007). This species feeds on mulberry plant that grow well in Kenya due to good and favourable climatic conditions (Tuigong et al., 2015). Silkworm production can offer supplementary source of income on top of traditional cash crops such as coffee, maize, sugarcane and cotton (https://abcnews.go.com/International/wireStory/kenyan-farmers-turn-silk-production). However, the report stated that Production of silk is lowering in China where silk originated, in Japan which is another major consumer it is more or less completely reduced. Because of this Kenya can contribute to global silk demand, which has been embraced in Thika, Siaya, Makueni and Kakamega in Western parts of Kenya, reason being the rearing of silkworms can adapt to a changing climate in this area that has affected some traditional crops, since the mulberry trees and castor plants are relatively drought-resistant. Tuigong et al., (2015), further classified the *B. mori* in their research as multivoltine as it produces more than two generations within a year and as Penta moulters as they undergo five larval moults in a life cycle**.** The other silkworm species that produce silk in Kenya are Gonometa and Aphe this is according to Central silk Board (2003) Seri Business Manual users guide.

## 2.2 *Bombyx mori* Silkworms

*B. mori* is a domesticated insect considered as a reference in several domains (Mauchamp et al., 2008). The insect belongs to the order Lepidoptera. It is the most widely and intensively studied silkworm. Silk from this worm was first produced in China as early as Neolithic period (Sharma et al., 2018). *B. mori* silkworm feeds exclusively on mulberry leaves. The nutritional elements of mulberry leaves determine the growth and development of the larvae and cocoon production (Seidavi et al., 2005). The major characteristic features of caterpillars of *B. mori* are about four centimetres in length, with a pale brown colouration and brown marks on the thorax (Mauchamp et al., 2008). The first and second instar worms have tiny hairs but later instars are white with a horn on the tail. In the process of producing a cocoon, the caterpillars manufacture an insoluble protein (fibroin) in their silk glands, mix it with a smaller amount of soluble gum, and secrete this mixture to yield a single, continuous silk fibre of some 300 to 900 meters (1000 to 3000 feet) long (Seidavi et al., 2005). The cocoon may be white to yellow in colour. The adult moth that emerges is heavy bodied, furry, rounded, whitish with pale brown lines, and with a wingspan of three to six centimetres (1.5 to 2.5 inches). Females have about twice to three times the weight of males (for they are carrying many eggs), but are similarly coloured.

The caterpillars feed on leaves of mulberry trees, with the preferred food being the white mulberry. The Adults in the Bombycidae family have reduced mouth parts and do not feed. The Silkworms are native to northern India and are totally dependent on humans; there are no wild populations. The nearest wild relative of *B. mori* is *Bombyx mandarina,* the wild silk moth,(Xiang et al., 2018) which is able to

hybridize with the domestic taxon (Goldsmith et al., 2005). Its existence ranges from northern India to northern China, Korea, and Japan. It is not known when the domestic silk moth diverged from its wild relatives, only that the domestic population originated from inland Chinese rather than Japanese or Korean stock (Itoh et al.,2008).

*B. mori* is probably the most heavily domesticated animal known, apart from domestic hybrids such as mules. Regardless whether the domestic silkworm is derived from a wild species that has since gone extinct, or from a stock of *B. mandarina* that was taken into human care some 4,600 years ago, breeding of silkworms have originated after the neolithic age (Itoh et al., 2008). The tools necessary to make use of the silk thread on a large scale only have become available since then. According to Tuigong et al., (2015), mulberry silkworm has been fully domesticated due to its weak grasping power that makes is hard to climb a twig, weak sense of smell to sense mulberry leaves a metre away and also low crawling power to reach food which could be a few centimetres away from it, all this necessitates the bringing of food close to them.

### 2.1.2 Eri Silkworms.(*Samia Cynthia ricini*)

Eri silkworm, is one of the most domesticated and commercialized non-viable mulberry silkworms. It belongs to Order Lepidoptera and family Saturniidae **(**Singh et al., 2015**).** The worm can also be used as an alternative host for multiplication of *Trichogramma chilonis*, an egg parasitoid used in biological control.

The word “Eri” is derived from the term “Erranda”, which refers to the Castor plant. *Ricinis communis*, which is the primary host plant (Chutia et al., 2014).

Ericulture is mainly confined to North-Eastern region of India. Eri Silkworm has several isolated populations, geographically separated (Eco races) in estates of Assam and Meghalaya (Swathiga et al., 2019). In order to develop new silkworm hybrids, classification and characterization is important, for selecting promising strain for hybridization programs (Sharma and Kalita, 2017), which requires an extensive study to improve the existing strains of *Samia ricini* for commercial production of silk and to produce new improved strain through different breeding programs to improve silk productivity and also increase the strains adaptability to different environmental conditions and also to produce disease resistant strain. Brahma et al., (2015) described the morphological features of Eri worm which corresponded with the developmental features of Eri worm. The newly hatched larvae of Eri worms on the first day are dark yellow in colour with black linings and black hairs, in the second day they change colour to creamy yellow with dorsal black spots on the body, the third instar worm is morphologically similar to second instar except variation in size, the fourth instar the Eri larva has a yellow coloured head, creamy white body which is covered with powder like substance, in the early days of the fifth instar, the worm's abdomen is white as its full of silk and as it gets to moulting stage it appears shrunken leading to a slight decrease in size and it remains still until it empties all its excreta then they move in such of a place to spin.

The cocoons spun are white in colour, hard, compact and with elongated spindle shape (Gathalkar, 2017) while inside the cocoon larva transforms to pupa which is dark brown to reddish in colour.

## 2.2. Life cycle of silkworms

### 2.2.1 Life cycle of *B. mori*

Termed holometabolous, the silkworm has a complete life cycle of four distinct stages of metamorphosis: Egg, larvae, pupa and adult (Figure 2.1). The larvae ecdysis four times as they grow through five instar stages and the total larval duration is normally 25-30 days (Raina, 2000).

The larvae of the first and second instar are called young age larvae, while those of the third, fourth and fifth instars are referred to as advance stage or late age larvae (Gurjar et al., 2018). Upon hatching, the larvae are transferred onto the rearing bed using a small brush, a process called brushing. They are then gently provided with tender finely chopped mulberry leaves. (Nguku et al,.2010)

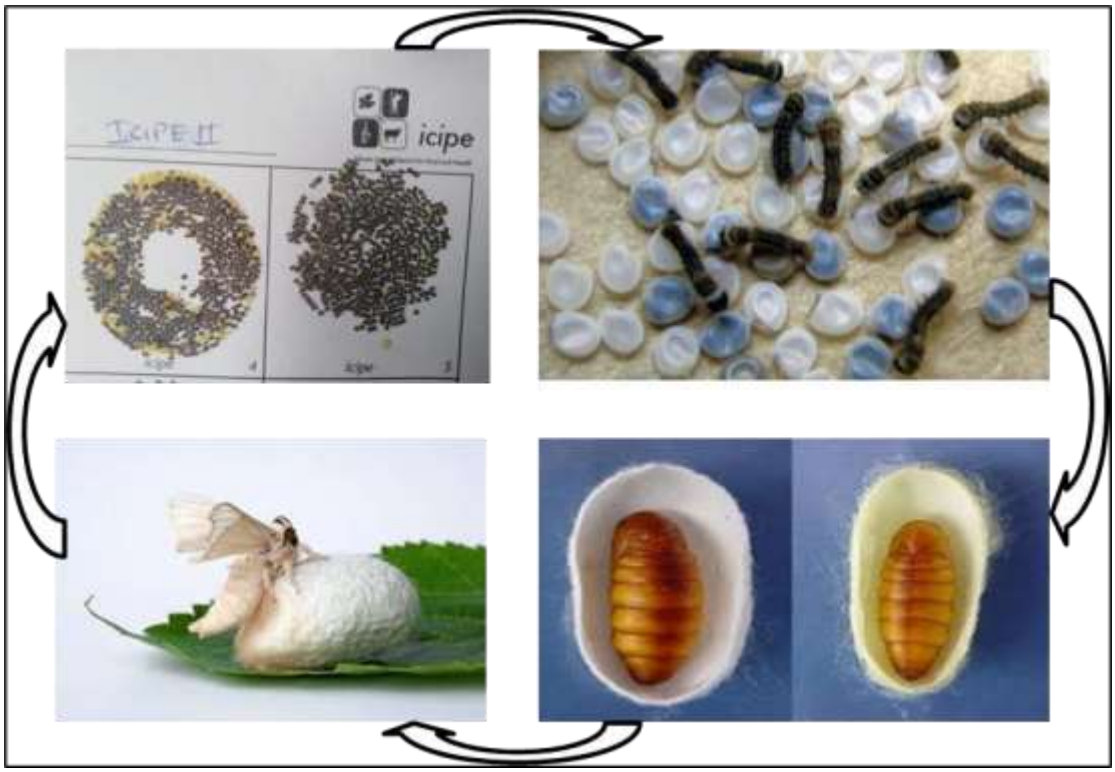


Figure 2.1: *B. mori* silkworm larvae (Source: http://www.mulberryfarms.com/)

### 2.2.2 Life cycle of Eri worm

The life cycle of Eri worm is completed through eggs, larva, pupa and adult moth. In summer, the life cycle normally takes 44-48 days and takes about 85-87 days in winter Fig. 2.2 (Nurkomar et al., 2022)

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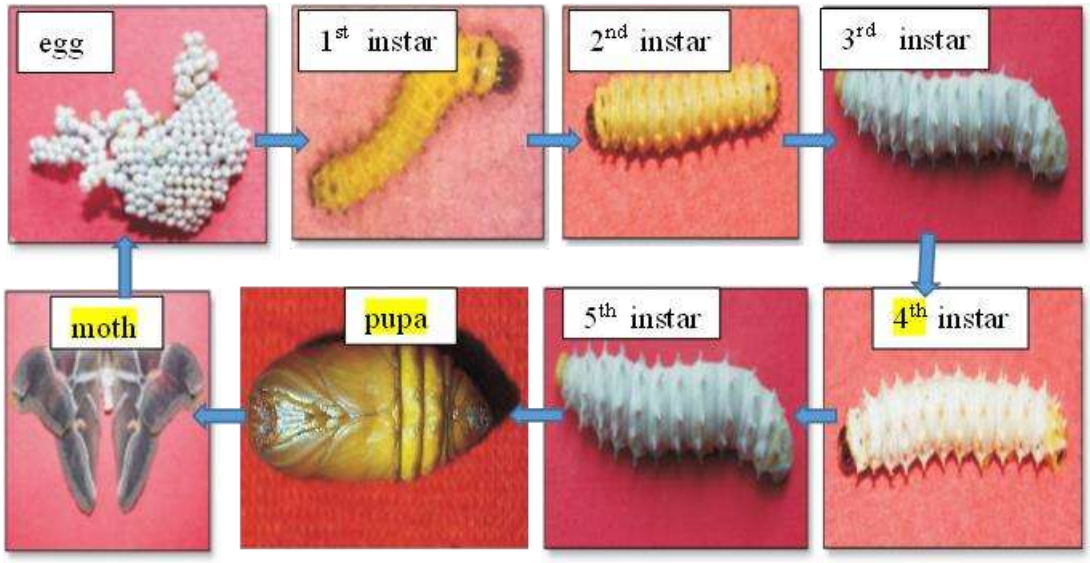


Figure 2.2 Typical life cycle of Eri silkworm. Source (Birari et al., 2019)

### 2.3 Hatching of silkworms' eggs

Egg hatching is the first complex behaviour manifested in the life of an insect (Saunders, 2002). The productivity and quality in sericulture depends mostly on the healthy of the larvae, growth of the larvae and the environmental conditions (Kumar et al., 2001). Hatching of silkworm eggs is greatly influenced by environmental conditions such as temperature and humidity as it affects its physiological activities (Rahmathulla, 2012). The optimal environment conditions include temperatures, 26-28$^0$C and 80-85% relative humidity, should be maintained to ensure proper embryo growth and quality production of cocoons (Raina, 2000).

At high temperature the embryo grows faster up to the setae formation stage and succumbs to death as the yolk cannot be utilized in pace with the high rate of

development and comes in way of normal development (Rahmathulla, 2012). Temperature during incubation also affects voltinism character, as the embryonic stage is the most sensitive to temperature (Gurjar et al., 2018). A study done by (Parrey, 2018) on influence of temperature and humidity on biological traits of silkworm indicated that *B. mori* showed that the maximum mean values of hatchability (93.15%) was observed at 25°C and 70-80% RH but Lower RH of (55 and 65%), even at 25% lowered the hatchability. The lowest mean value of hatchability (68.96) was recorded at 35°C and 55% relative humidity. For better embryonic development and uniform hatching, eggs were spread as a single layer on the sheet and black boxed (Rahmathulla, 2012). The single layered eggs were found to efficiently hatch compared to stacked out eggs even if it is only a single stack (Gong et al., 2020b).

**2.4 Duration taken by silkworm eggs to hatch**

Continuous constant temperature of 26-28$^0$C and 80-85% relative humidity, has been reported to have effect on the voltinism for certain economic aspects of *B. mori* hatching parameters such as hatching duration and also influences the time span in hours from the time a first hatching is observed to its completion, hatching magnitude (Shanthan, 2014; Srinath, 2014).

Studies on Eri worm under laboratory conditions showed that the female lay eggs in clusters of 360 per female with an incubation period of 8.83+-2.09 days, and hatchability of 97% (Vaishali et al., 2019, Patil, 2004). However, the incubation period of Eri silkworm eggs was observed as 6-7 days by Manisha and Visalaksh (2019**).**

The previous studies done by Rahmatulla, (2012) clearly underline the importance of optimization of environmental conditions during larval rearing in relation to silk cocoon production show that temperature and relative humidity in the range of 25-26°C and 70-80% respectively are mandatory for excellent results.

### 2.5 Larval duration and survival

Significant variations in hatchability, pupation and mortality are noticed on the $4^{th}$ and $5^{th}$ instar larvae of inbred silkworm lines. The maximum mean values of hatchability, pupation and the lowest mean larval mortality are observed at 25°C and 70-80% relative humidity. Lower relative humidity of (55 and 65%) even at the temperature of 25°C lowered the hatchability and pupation of the silkworm lines and contributed significantly to higher larval mortality. Further, the previous studies indicated that the mean performance of inbred silkworm lines under various conditions of temperature and humidity was significantly different from each other at various temperature and humidity exposures during $4^{th}$ and $5^{th}$ instars (Srinath, 2014). At 25°C with 75% relative humidity, the performance of silkworm lines remained consistent but variations in temperature or humidity for three hours significantly affected all the three parameters; hatchability, pupation and larval mortality of the growth of the silkworm (Rahmatulla., 2012)

#### 2.5.1 Larval duration of Eri worm

Under the ideal conditions, the total larval duration was found to be 22.97±0.85 days with the duration of first, second, third, fourth and fifth instar larva being 3.77±0.43, 3.23±0.43,3.70±0.47, 4.60±0.50 and 7.67±0.55 days, respectively (Birari,2019). However, the larval duration of Eri worm was observed as 25 days, total life cycle

period of Eri silkworm was observed to be 46 -51 days by Manisha and Visalaksh (2019**).**

### 2.5.2 Larval duration of *B. mori*

The *B. mori* larvae are sensitive to high temperature (above 25 ± 1°C) during late instars ($4^{th}$ and $5^{th}$) (Hussain et al., 2011). Larval duration generally ranges from 24 days to 21 days in bivoltine varieties (21 - 23 days) while the multivoltine (yellow) range from 23-24 days according to Abera, (2016), similarly Pakhale, (2014) in India recorded the larval duration of mulberry silk worms to range between 22.13 days to 23.27 days. All larval duration was recorded (from 1st instar to montage stage) under the rearing conditions of daily mean temperature and relative humidity of $20.77^{0}$C and 72.18% respectively. The larva of *B. mori* undergo four moults thus they have five instar stages. The average larval duration according to Gurjar, (2018) is 3.50±051, 3.530±.51, 4.470±.51, 5.60±0.45, 6.60±0.50 for $1^{st}$, $2^{nd}$, $3^{rd}$, $4^{th}$ and $5^{th}$ instars respectively. There is progressive change in length and breadth of larvae after each moult.

## 2.6 Factors affecting silkworm production

### 2.6.1 Silkworm diseases

Several diseases and pests' constraint silkworm production affecting the insect mostly at the larval stage. Some of the common biotic disease-causing organism include bacteria and viruses.

*Beauveria bassiana* destroys the entire silkworm body. This fungus usually appears when silkworms are raised under cold conditions with high humidity. This disease is not passed on to the eggs from moths, as the infected silkworms cannot survive to the

moth stage, but can spread to the other insects (Gani, 2019). This fungus, however, can spread to other insects.

Pébrine is a disease caused by a parasitic microsporidian, (*Nosema bombycis)*. Diseased larvae show slow growth, undersized, pale and flaccid bodies, and poor appetite. Tiny black spots appear on larval integument. Additionally, dead larvae remain rubbery and do not undergo putrefaction after death. *N. bombycis* kills 100% of silkworms hatched from infected eggs. This disease can be carried over from worms to moths, then to eggs and worms again. The source of microsporidium, inoculum can be from the food that the silkworms eat. (Ghosh, 2014).

### 2.6.2 Environmental conditions for rearing of silkworms.

As a cold-blooded creature, environmental variables, particularly temperature and relative humidity, are critical in controlling silkworm physiology. As a result, maintaining optimal temperature, relative humidity, light, and ventilation conditions for each stage of rearing is critical for effective silkworm rearing (Ramahtullah, 2012). Silkworm eggs must be incubated in the dark, at normal temperature, and with a relative humidity of at least 65% to 75%. First and second instar larvae (Chawki silkworm rearing) require 27-28 °C and 80-85 percent relative humidity, whereas third, fourth, and fifth instar larvae require 24-25 °C and 60-65% relative humidity (late-age silkworm rearing). For a smooth integument change over during the intervening moulting stage of 24 hours between two instars, a temperature of 25-26 °C and relative humidity of 60% is advised.

During spinning, cocoon preservation, moth emergence, coupling, and decoupling processes, room temperature 25$^{o}$C and 65% relative humidity are necessary. The oviposition process requires dark environment and a relative humidity of 75-80%.

**2.7. Routine operations in silkworm cultivation.**

A typical day in silkworm culture includes operations such as mulberry leaf collecting, meal preparation, feeding and bed cleaning. Silkworms can be fed up to four times a day: in the morning (9-10 a.m.) depending on the production system, quality and availability of the feed, in the afternoon (1-2 p.m.), in the evening (4-5 p.m.), and at night (9-10 p.m.). After harvesting the leaves from the plantations, they are rinsed with simple running water and then treated with mild potassium manganate VII for general disinfection. They are fed to silkworms when they have dried sufficiently. During the first and second instars, silkworms are fed chopped soft and succulent mulberry leaves with high moisture content from the plant's apical regions (Aberu, 2016).

During the third instar, the silkworms are given 3-4 pieces of medium-sized leaves. Following the needed treatment, the entire leaf and complete shoot is administered during the fourth and fifth instars (Abera, 2016). Bed cleaning is essential for maintaining hygiene in the immediate proximity of silkworms in order to prevent infection by diseases. The raising beds are cleaned with four different mesh-sized bed cleaning nets. Beds are cleaned once in the first instar, twice in the second instar, and preferably daily in the third, fourth, and fifth instars. Just before the morning meal, bed cleaning nets are distributed. Before the afternoon feed, the silkworm nets are moved to fresh beds, and feeding is restarted. If there is debris, leftover food, or a dead silkworm, are removed.

During the larval phase, four moults occur. The moulting worms require extra attention during this time. To aid the moulting process, lime powder is dusted in the rearing bed to lower humidity to 60-65 percent relative humidity. Moulting lasts about 24 hours, and silkworms should not be disturbed during this time. After

finishing the feeding stage, silkworms reach the matured state (ready-to-spin silk) during the late fifth instar. The mature silkworms can be distinguished by their relocation to the corners of the rearing treys, one-third reduction in size, and translucent yellow colour. These matured silkworms are put to mountages (equipment that provides support for cocoon development) for spinning cocoons (Koju., 2015).

Mountage can be built of locally accessible materials, bamboo-brush mountage, and plastic collapsible mountage (dried leaves and branches of different plants arranged in a zigzag manner in card-board boxes). Cocoons are retrieved from the mountage after two to three days of spinning. Cocoons can be utilized to propagate the generation or to obtain silk fibre. When used to propagate the next generation the cocoons are placed at room temperature and 65-70 percent relative humidity for moths to emerge from cocoons after passing through the intermediate pupal stage which could be 6-7 days for propagating generation. Males and females are paired for four to five hours after emergence, then dissociated, and females are held for the oviposition process.

Males can be utilized for second coupling after being refrigerated for 1-2 days at 5 °C. Following this life cycle, the adults die naturally in 1-2 days.

After finishing embryonic growth, silk worm larvae emerges from oviposited eggs in 10-12 days. To extract silk, cocoons are exposed to the stifling process, in which the pupa inside the cocoons are killed by subjecting them to high temperature treatment via sun drying, steam, or hot air in order to retain the continuity of the silk strand that make up the cocoon (Nguku et al., 2009). The cocoon is then heated or simmered for 3-4 minutes at 95-96 °C to soften the sericin and allow it to dissolve up to 25-26 percent. The silk filament may then be readily retrieved on proper

reeling machinery by locating the real end in the brushing operation, which removes the coarser floss layer.

### 2.8 Quality of the silk fibre

There is need to use silkworm eggs with higher viability and ability to produce excellent cocoon crop irrespective of the environmental conditions. Fluctuations in environmental conditions with nutrient deficient mulberry and poor management practices during larval rearing affects cocoon production (Mubashar et al., 2011). Cocoon production is determined by various factors such as environment and genotype of the silkworm (Rahmatulla et al., 2012). The environmental factors mostly are temperature and relative humidity. High temperature affects biological processes which include the rates of biochemical and physiological reactions (Sarkar, 2018) thus affecting the quality and quantity of cocoon crops such as weight, length, colour, grading etc.

### 2.9 Uses of silk

Mulberry silk is produced by larvae of the Bombycidae family, which is commercially significant as a silk producer. The usage of the silkworm species *B. mori* to create cloth was originally developed in China, possibly around the Longshan era (Seidavi et al., 2005).

Mulberry silk has a few distinct qualities as a textile material. It is the finest animal fibre (diam.10-12 m), has no cellular structure because it is not part of the body, and is a continuous filament. It is a robust filament with tenacity (grams per denier) ranging from 2.8 to 4.9 and elastic recovery ranging from 18.7 to 20.87 percent (Sonwalkar, 1993). Silk yarn can be coloured before or after it is woven into fabric (Aruga, 1994; Marsh, 1979). This silkworm generates fine and precious silk strand, making it a valuable insect to humans, and its substance has been very important for

both textile and non-textile purposes (Mondal et al., 2007; Tsukada et al., 2005). Mulberry silk is a biomaterial used in textile and biomedical field.

Eri silk has a wool-like finish, the appearance of cotton, and the softness of silk, making it an ideal substitute fibre for wool. As a result of its open-mouthed fibre, it has good mixing capabilities with both synthetics and cotton, resulting in textiles that are often more durable and resistant to dust and sweat. Eri silk has also been tested in wound dressing, Silva et al., (2016) because to its biochemical makeup and decreased sericin level, which improves cell adhesion. (Zhou et al., 2020)

Eri silk is mainly used in India to manufacture winter shawls for men and women because of its thermal qualities, which make it a great fabric for shawls, coats, blankets, and bed spreads. (Mahajan and Tamta, 2021). Eri silk is robust and resilient, with great antiperspirant properties (Zhou et al., 2020). Its characteristic texture allows it to be used in home furnishings like as curtains, bed coverings, pillow covers, and wall hangings; the fuzzy feel contributes to the comfort of these furnishing goods. Senthil, (2018) added that Eri silk is also used to make numerous modern things such as wallets, purses, and belts.

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 Study area

The investigation to establish the suitability of sericulture (silkworm rearing) in Uasin Gishu was done in hatching and rearing structures in the University of Eldoret Zoology research site located in Kenya. The structures of equal dimensions of 4m x 4m and 3m high each were constructed and coded L0-L7 (Plate 3.1). L1 was a timber walled structure, while L2 mud walled, both structures were roofed with iron sheets of gauge 28. Four greenhouses with four removable flaps were also set-up, greenhouse with all four flaps open (L3), 3 Flaps open (L4), 2 flaps open (L5), 1 flap open (L6) and all flaps closed (L7). Laboratory conditions (L0) and also Incubator (L8) was used as control for hatchability.

Greenhouses were made of polythene gauge 0.08mm/8mil/200 micron on all sides, the flaps were all covered with plastic nets (aperture 20Mtr weave type hexagonal, made in India) to prevent entry of predators. In each of the rearing structures, the rearing table made of timber was erected to hold the trays. The rearing tables were dipped in ant-wells to prevent insects from climbing the tables and attacking the silkworms. The timber house (L1) was a control representing conditions in Uasin Gishu.


Plate 3.1 a and b Source: author

(a) Timber walled, mud walled and green house with all flaps open (b) Greenhouse structurers L4, L5, L6, L7.

### 3.2 Source of Silkworm eggs

The hatchability investigation was done using disease free laying of the bivoltine silkworm hybrid ICIPE 11 strains of *B. mori* (Plate 3.2(a) and multivoltine hybrid eggs of Eri worm plate 3.2(b) obtained from the International Centre of Insect Physiology and Ecology (ICIPE). Two laying cards were obtained of each type and were transported to the laboratory during the morning cool hours to avoid drying out. In the laboratory the laying cards were cut into sections of the card containing 300 eggs and each placed on a petri dish, which had been sterilized by wiping with cotton wool containing 2% formalin to eliminate contamination as described by Tuigong et al., 2015)

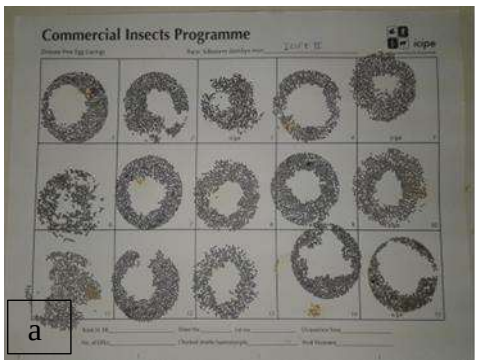



Plate 3.2(a) The eggs *B. mori* of ICIPE II silkworm in the layings; 3.2(b) The eggs of Eri silkworm

### 3.3 Hatchability tests of silkworms under different structures

Experimental hatching of silkworm *(B. mori* and Eri silkworms) were conducted by picking each petri plate having 200 eggs replicated three times and placed under different structures with varying conditions. The experimental treatments were done in pre-constructed structures as described in section 3.1.

The control condition was in a thermo scientific incubator (L8) model 240V AC/12V DC at the biotechnology laboratory, with 3 replicates under constant temperature of 25 $^0$C and humidity of 75%. Daily observations were made and the temperature and humidity for each structure condition was recorded until hatching. Hatching parameters like number of eggs hatched and hatching duration were recorded under the above different structures for the silkworm hybrids.

The day to first hatching was recorded until last hatch, similarly the number of silkworm larvae obtained was counted at 6 hours interval and recorded. Counted larvae were gently brushed off with feathers into the rearing trays for further studies. From the recorded data, other parameters like days to hatching were extracted and hatching percentage were calculated using the formula

$$\text{Percentage hatchability} = \frac{\text{Total number of larvae hatched}}{\text{Total number of eggs incubated}} \times 100$$

### 3.4 Survival and duration of silkworm larva under different conditions

To determine the suitable structure for the rearing of silkworm in Uasin Gishu, the pre-constructed structures Plate 3.1(a) and (b) which were used to investigate hatchability above (section 3.3) were further used. The larvae used to test duration and survival were obtained after uniform hatching of eggs in thermo incubator. In each condition 200 hatched larvae in their 2$^{nd}$ instar were counted by tallying and

reared in wooden trays (1m x 0.5m), each treatment was replicated three times. The worms were fed thrice per day at 9.00 am and at 1.00 pm and 5.00 pm with equal amount of succulent freshly plucked leaves of mulberry for *B. mori* and castor leaves for Eri worms (Sharma et al., 2018) The temperature and relative humidity were recorded in the morning, afternoon and evening, just before feeding the worms while at night the hygrometer/thermometer recorded the minimum and maximum conditions. The duration to every instar and survival to the next instar of the population under each condition was recorded daily until pupation and cocooning.

During rearing to obtain clean beds a net was spread over the clean fresh leaves on a single layer spread, worms scrawled to fresh leaves and the ones left were handpicked, the worms were then transferred using the net to another clean tray and spread well then, they were fed. The waste was put into a compost bucket and disposed. The larvae were allowed to complete its instar stage in the structures. Similarly, the time to the next moult was recorded as the duration of the larval instar in days. The number of surviving larvae in each instar was recorded and the percentage survival calculated using the formula;

$$\text{Percentage survival} = \frac{\text{Total number of larvae moulted to the next instar}}{\text{Total number of larvae at the start of instar}} \times 100$$

The experiment was conducted in both wet season (July - September, 2020) and dry season (December, 2020 - February, 2021) to generate data for seasonal comparisons.

### 3.5 Cocooning

#### 3.5.1 Mounting

Mature silkworm cocoons at $5^{th}$ instar showing maturity characteristics such as stopped feeding and crawl restlessly in search of a corner to attach itself, their abdomen appearing full of silk and shrunk in size were transferred from rearing beds

into the area below the plastic mountages to start spinning (Plate 3.4). Observations were done continuously to ensure timely transfer. As the worm begin to spin they were not be disturbed since disturbance causes it to lay a spinning foundation afresh which means loss of some silk.


Plate 3.4: Spinning of Eri worm on mountages. Source; Author

### 3.5.2 Harvesting of cocoons

Cocoons were harvested on the 7$^{th}$ day from inception of spinning by carefully handpicking. At the end of spinning the larvae transformation into pupae was confirmed by cutting a randomly selected cocoon to observe if the pupa is brown in colour and hard. The harvested cocoons from every treatment were counted separately and recorded.

## 3.6 Cocoon quality and quantity

### 3.6.1. Assessment of single cocoon parameters

From each treatment ten cocoons from each tray (replicates) were sampled for analysis of cocoon quantity and quality based on the following parameters cocoon weight, cocoon quality, shell weight and shell ratio.

All measurements were done using high precision weighing balance of pinnacle brand model with accuracy of 0.01mg/0.1mg from products Engineering corporation company.

Cocoon quality was determined by picking 10 cocoons from each replication and sorted out by removing the defective cocoons classified as (a) Double cocoons (b) Pierced cocoons (c) inside stained cocoons (d) Flimsy cocoons (e) Pointed or constricted cocoons (f) Outside stained cocoons.This is according to the reeling and testing manual Lee, (1999)

$$\text{Percentage of defective cocoons} = \frac{\text{Total number of defective cocoons}}{\text{Total number of cocoons per treatment}} \times 100$$

For the Cocoon weight, ten cocoons were picked randomly from pupated cocoons as described by Hussain et al., (2011), in each of the three replications and each cocoon was weighed in grams using high precision weighing balance described above. The weighed cocoons were then cut longitudinally on the side so that the pupa could be removed and its weight taken, with a lot of care not to harm the pupa. Further, the weight of the shell was determined by subtracting the individual weight of the pupa from the cocoon weight it was obtained from, to provide the ratio of the shell which carries the quantity of silk.

Shell weight = Whole cocoon weight-pupa weight.

$$\text{Shell ratio} = \frac{\text{weight of cocoon shell in grams}}{\text{Weight of the whole cocoon}} \times 100$$

**3.6.2 Determination of filament length.**

Degumming was done to break the peptide bonds of sericin (Chattopadhya, 2017). The standard procedure of degumming of cocoons was followed. The *B .mori* cocoons were degummed using a two pan cooking process (Debasis et al., 2017) which involved putting the cocoons in a perforated cage which was then immersed in

the first cooking pan with water having temperature between 60-70$^{o}$c for about one minute, the cage was then transferred to the second cooking pan at 90$^{o}$c for about 2 minutes after which it was allowed to stand for a minute, cold water was sprinkled on the second pan to reduce temperature from 95$^{o}$C to 75$^{o}$C for 4 minutes. The cage was then opened in the water and cocoons brushed using a straw brush to produce a single filament.

The Eri cocoons were degummed by dipping the cocoons in degumming solution containing 10% sodium carbonate and 10% neutral soap and boiled for one hour (Debasis et al., 2017). Sodium carbonate was further used to produce a fibre breaking elongation and allow uniform degumming without significant deterioration of single fibre tenacity. The degummed cocoons were then put in a spinning wheel to separate filaments thereafter the filament length was taken using a tape measure.

**3.7 Data Analysis**

All data generated from the experiment was entered into the excel spreadsheet for the purpose of management. Analysis was done using Stratigraphic Centurion XVI and all values below 5% ($P \leq 0.05$) were designated as significant.

Pearson Correlation was done to find out how temperature and humidity interacted in various structures and how the number of eggs hatched related with the experimental structures.

The data that showed skewedness was first log transformed then Analysis of variance (ANOVA) was done to compare differences in means of temperature, humidity, hatchability and hatching duration per structure per species, and also larval duration, larval survival and cocoon parameters both in quantity and quality per structure per species per season. A chi-square test was done on cocoon quality, a post hoc test was used to separate the means using Fisher's least significant different.

# CHAPTER FOUR

# RESULTS

## 4.1 Environmental conditions of experimental structures during hatching

The temperatures conditions of the tested eight structures which were assessed during hatching of *B. mori* and Eri silkworms' eggs and compared with control (L8) established that the highest room mean temperature in $^0$C was recorded in L6 (30.31±1.70), while the lowest mean temperatures) was recorded in L0 (23.85±1.86 $^0$C) (Fig. 4.1). The temperatures in the eight structures tested for hatching of eggs of *B. mori* and Eri silkworms showed variation ($F_{0.05\ (7,\ 144)}$ =20.94, p< 0.0001). Significant difference was noted between L0 and L3, L4, L5, L6 and L7 (Appendix I). When the mean temperature of the tested structures was compared with the ideal (L8) conditions, a significant difference was noted between L5, L6 and L7, which was not significant with the temperature of the other structures tested.

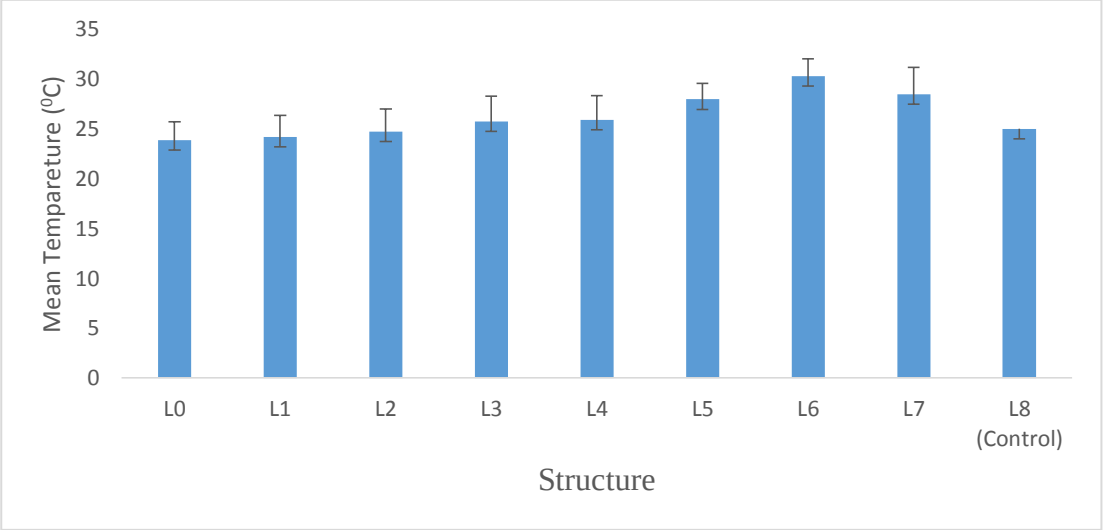


**Figure 4.1: The temperature conditions inside the experimental structure during the incubation of *B. mori* and Eri worm eggs.**

The highest mean % humidity was recorded in the L8 (75.00±0.00) which was also the control. Among the tested structures, L2 (41.56±11.59) followed by L0 (40.50±10.82) recorded the highest % humidity while L4 recorded the lowest

(29.93±3.85) with a statistically significant difference ($F_{0.05\ (7,\ 144)} = 11.35$, $p < 0.0001$) (Fig. 4.2). Relative humidity was significantly different between L0 and L1, L3, L4, L5, L6 and L7 structures (Appendix II).

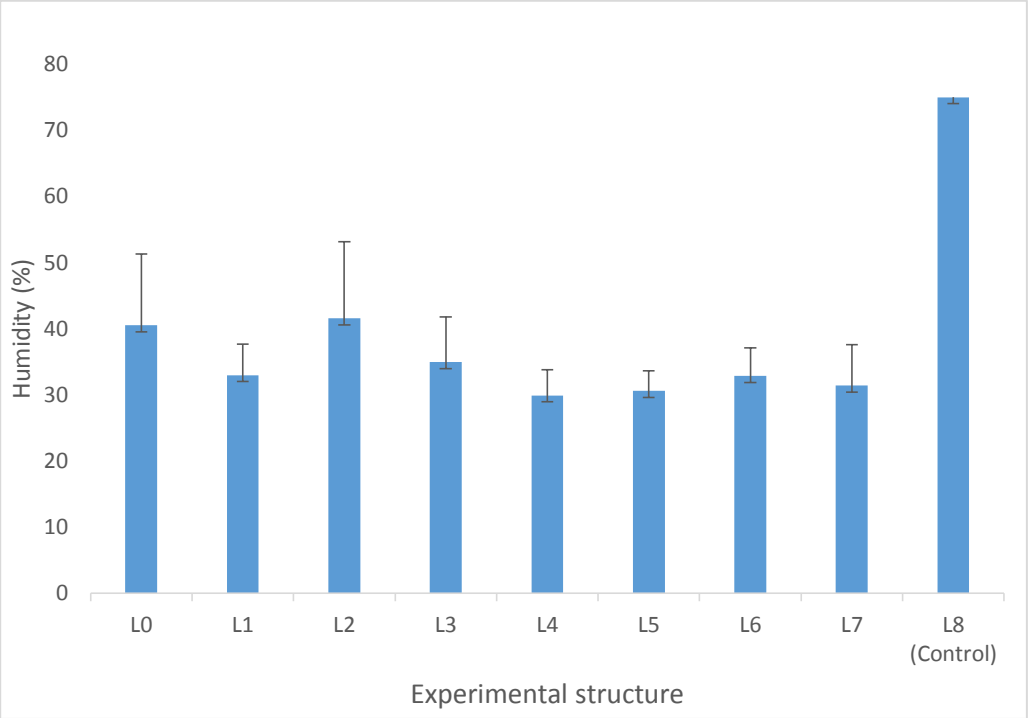


**Figure 4.2: Mean percent humidity conditions inside the structures during incubation of *B. mori* and Eri worm egg**

### 4.1.1 Correlation of temperature and relative humidity during hatching

Temperatures were negatively and significantly correlated with humidity in the L2 structure (r=-0.5524, p=0.0142) but not significantly correlated in L0, L1, L3, L4, L5, L6 and L7 as illustrated in Table 4.1. However, it was generally noted that there was a negative correlation between the temperature and humidity in all the tested structures (Appendix III).

**Table 4.1: Correlation between temperature and humidity inside the structures**

| Structure | Correlation (r) | p- value |
|---|---|---|
| L0 | -0.23 | 0.34 |
| L1 | -0.42 | 0.071 |
| L2 | -0.55 | 0.014* |
| L3 | -0.33 | 0.18 |

| | | |
|---|---|---|
| L4 | -0.29 | 0.23 |
| L5 | -0.13 | 0.60 |
| L6 | -0.29 | 0.22 |
| L7 | -0.36 | 0.13 |
| L8 (Control) | - | - |

**Significant at 0.05*

## 4.2 Hatching of silkworm eggs

### 4.2.1 Hatching duration of *B. mori and* Eri eggs in different structures

The time taken by *B. mori eggs* to complete hatching was between 3 days to 6 days. The longest duration was in L2 and L1 structures at six (6) days to hatch all eggs, four (4) days in L5 and L7, while in structures L0 and L4 they took only three (3) days for all eggs to complete hatching (Figure 4.3). The same trend was observed for Eri eggs. In the control (L8) hatching of *B. mori* and Eri eggs took an average of three (3) days to complete hatching. Further no eggs hatched under L6 and L7 structures for both silkworm species.

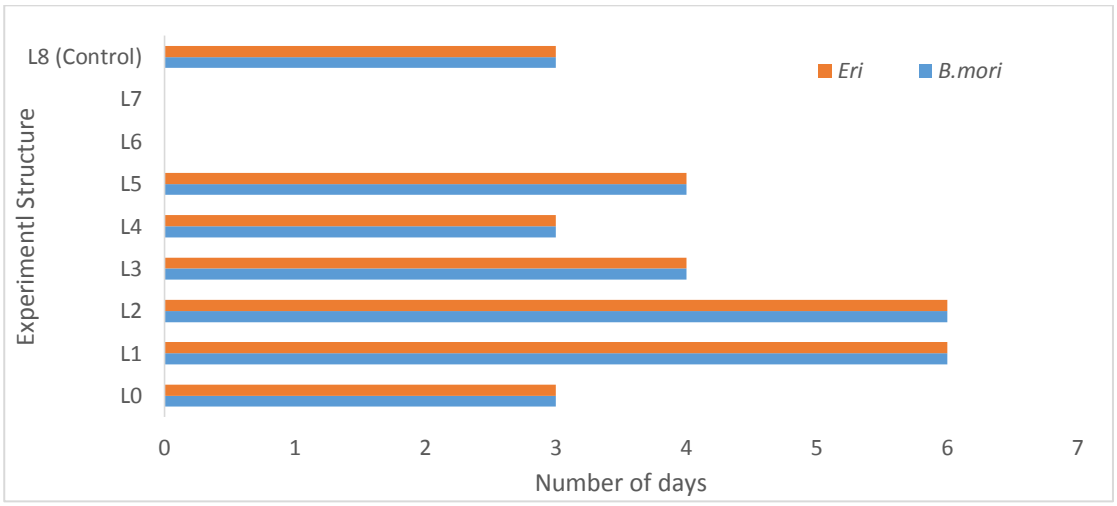


**Figure 4.3: Hatching duration of *B. mori* and Eri eggs.**

### 4.2.2 The percentage of eggs hatched in the tested structures

Total number of *B. mori* and Eri eggs that hatched in the different structures was compared. In the control structure (L8), total number of eggs that hatched was 188 (94.0%) for *B. mori* and 193 (96.5%) for Eri. The highest mean number of *B. mori* eggs that hatched in the tested structures was L0 (177.67±39.11) representing 88.8%, while L5 structure recorded the lowest number of eggs hatched (39.67±3.51) (18.67%) with a significant difference ($F_{0.05\,(5,\,12)} = 499.48$, $p < 0.0001$) (Appendix IV). No hatching was recorded in structures L6 and L7.

For the Eri worm, highest total number of hatched eggs was recorded in structure L0 at 91.83% (183.67±5.13), followed by eggs incubated in L1 (179.00±6.42) (89.50%), but the least was recorded in L4 (32.22±4.51) (16.2%) followed by L5 (37.33±6.11) (18.70%) structures with a significant difference ($F_{0.05\,(5,\,12)} = 522.81$, $p < 0.0001$) (Appendix IV). Mean significant difference in the total number of eggs hatched was between structures L0 and L1, L3, L4 and L5. There was also a significant difference in total number of eggs hatched between structures L1 and L2, L3, L4 and L5 (Figure 4.4).

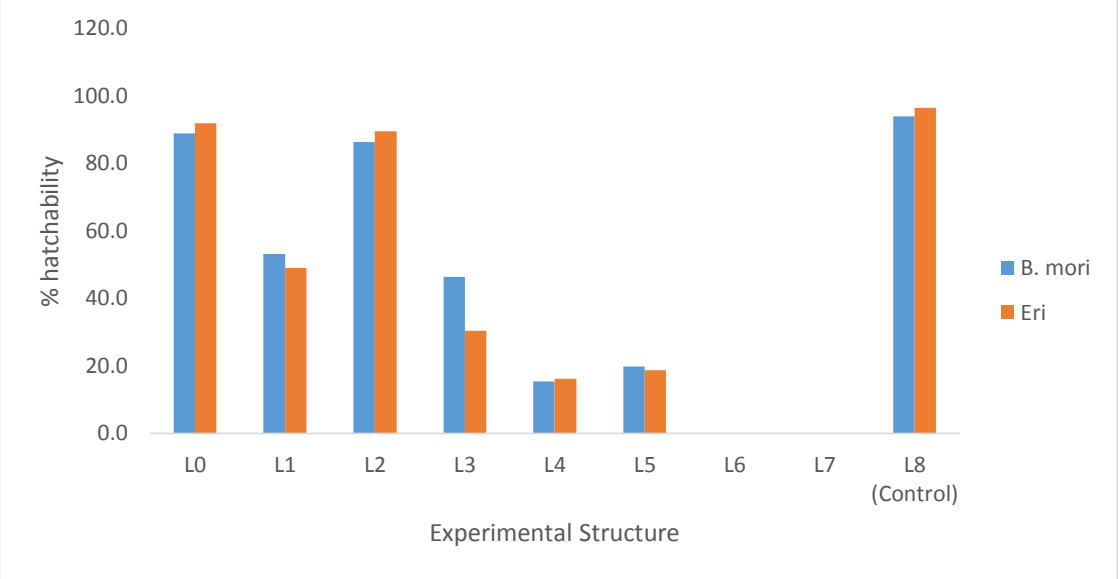


**Figure 4.4: The percentage of eggs hatched in the experimetal structures**

### 4.2.3 Correlation between the experimental structure in relation to number of eggs hatched

The number of eggs hatched in structures L0 positively and significantly correlated with L8 (Control) as illustrated in Table 4.2. There was a positive correlation between number of eggs hatched in structures L0 and L2 (r=0.8581, p=0.3433), L0 and L3 (r=0.9143, p=0.2655) which was not significant, a higher correlation was also noted for L3 and L5 (r=0.5766, p=0.6088), L3 and L8 (r=0.9286, p=0.2421) and between L5 and L8 (r=0.5000, p=0.6667), but the others showed a week negative correlation.

**Table 4.2: Correlation of structure in relation to number of eggs hatched**

| Structures | L1 | L2 | L3 | L4 | L5 | L8 (control) |
|---|---|---|---|---|---|---|
| L0 | -0.85 | 0.86 | 0.91 | -0.99 | 0.47 | 0.99 |
| | 0.36 | 0.34 | 0.26 | 0.10 | 0.69 | 0.02* |
| L1 | | -0.45 | -0.99 | 0.92 | -0.87 | -0.87 |
| | | 0.70 | 0.09 | 0.25 | 0.33 | 0.33 |
| L2 | | | 0.57 | -0.76 | -0.05 | 0.84 |
| | | | 0.61 | 0.45 | 0.97 | 0.37 |
| L3 | | | | -0.97 | 0.79 | 0.93 |
| | | | | 0.16 | 0.42 | 0.24 |
| L4 | | | | | -0.61 | -0.99 |
| | | | | | 0.59 | 0.08 |
| L5 | | | | | | 0.50 |

| | |
|---|---|
| | 0.67 |

**Significant at 0.05*

### 4.2.4 Correlation of conditions (Temperatures and humidity) with duration to hatching

There was a positive non-significant correlation between eggs incubation period and the % relative humidity of the structures (r=0.2975, p=0.4369) but a negative correlation with temperature conditions (r=0.3349, 0.3784) (Table 4.3). Mean % humidity was negatively and insignificantly correlated with mean temperatures of the structures (r=0.2771, p=0.4704).

**Table 4.3: Pearson correlation between mean eggs incubation period and the environmental condition of the structures**

| Eggs incubation period (days) | Humidity | Temperatures |
|---|---|---|
| Correlation | 0.2975 | -0.3349 |
| p-Value | 0.4369 | 0.3784 |
| Correlation | | 0.2771 |
| p-Value | | 0.4704 |

*Significant at 0.05

### 4.3 Environmental conditions of experimental structures during rearing in wet and dry

When the temperature conditions of eight structures were assessed during wet season. The highest mean temperature in $^{0}$C was recorded in L7 (31.62±0.81), while the lowest mean temperatures were recorded in L0 (22.73±1.86) (Table 4.4). The temperatures in the eight structures showed significant variations ($F_{0.05\ (7,\ 368)}$ =334.77, p< 0.0001) (Appendix V). Significant difference was noted between L0 and L1, L3, L4, L5, L6 and L7. L1 temperature was significantly different from that of L3, L4, L5, L6 and L7. L2 differed significantly from L3, L4, L5, L6 and L7. L5

temperatures differed from L6 and L7. In the dry season, the highest mean temperature was recorded in structure L7 (31.52±0.74) $^0$C followed by structure L6 (29.34±0.85) $^0$C, while the lowest mean temperatures were recorded in structure L0 (22.86±2.20) $^0$C with a significant difference ($F_{0.05\ (7,\ 368)} = 294.26$, $p < 0.0001$) (Appendix V). Significant difference was noted between L0 and L1, L3, L4, L5, L6 and L7. L1 temperature was significantly different from that of L3, L4, L5, L6 and L7. L3 differed significantly from L4, L5, L6 and L7. L5 temperatures differed from L6 and L7. Significant difference was noted between L0 and L1, L3, L4, L5, L6 and L7. L1 temperature was significantly different from that of L3, L4, L5, L6 and L7. L3 differed significantly from L4, L5, L6 and L7. L5 temperatures differed from L6 and L7. There was no significant difference in temperature variation between seasons in all structures ($p < 0.05$) (Table 4.4).

Similarly, the relative humidity conditions of the eight structures were assessed for season one (wet) and two (dry). The highest average humidity was recorded in L0 (43.18±9.53) (Table 4.4) followed by structure L7 (42.89±7.37) %, while the lowest was recorded in structure L1 (33.26±7.29) % during the wet season. Relative Humidity in the eight structures showed significant variations ($F_{0.05\ (7,\ 368)} = 12.78$, $p < 0.0001$) (Appendix VI). Significant difference was noted between L0 and L3, L4, L5, L6 and L7. L1 humidity was significantly different from that of L3, L4, L5, L6 and L7. L3 differed significantly from L6 and L7. A similar trend was observed in season dry highest mean humidity was recorded in structure L7 (42.16±7.35) followed in structure L0 (29.34±0.85), while the lowest mean humidity was recorded in structure L1 (33.11±7.26) with a significant difference ($F_{0.05\ (7,\ 368)} = 10.77$, $p < 0.0001$) (Appendix VI). Significant difference was noted between L1 and L0, L4, L5, L6 and L7. L3 humidity was significantly different from that of L0, L5,

L6 and L7. Conditions in L3 differed significantly from L4, L5, L6 and L7. L5 temperatures differed with that of structure L7. There was no significant difference in humidity variation between seasons in all structures ($p>0.05$) (Table 4.4).

**Table 4.4: Environmental conditions for rearing on the experimental structures during wet (season 1) and dry (season 2)**

| | Season | L0 | L1 | L2 | L3 | L4 | L5 | L6 | L7 | F-Ratio | P-Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature ($^0$ C) | Wet | 22.73± 1.86$^{a}$ | 23.61± 1.25$^{ab}$ | 23.21± 1.71$^{b}$ | 25.00± 0.98$^{c}$ | 26.47± 0.67$^{d}$ | 27.45± 0.78$^{e}$ | 29.47± 0.86$^{f}$ | 31.63± 0.81$^{g}$ | 334.77 | <0.0001 |
| | Dry | 22.86± 2.20$^{a}$ | 23.58± 1.29$^{ab}$ | 23.29± 1.65$^{b}$ | 25.02± 0.90$^{c}$ | 26.48± 0.61$^{d}$ | 27.36± 0.79$^{e}$ | 29.34± 0.86$^{f}$ | 31.52± 0.74$^{g}$ | 294.26 | <0.0001 |
| Humidity (%) | Wet | 43.18± 9.53$^{a}$ | 33.26± 7.29$^{a}$ | 33.99± 5.05$^{ab}$ | 35.20± 6.48$^{bc}$ | 37.41± 7.81$^{cd}$ | 39.22± 7.87$^{de}$ | 40.80± 7.65$^{e}$ | 42.90± 7.37$^{e}$ | 12.78 | <0.0001 |
| | Dry | 41.94± 10.78$^{de}$ | 33.11± 7.27$^{a}$ | 33.42± 5.40$^{a}$ | 34.51± 6.79$^{ab}$ | 36.87± 7.93$^{bc}$ | 38.82± 7.61$^{cd}$ | 40.24± 7.63$^{de}$ | 42.16± 7.38$^{e}$ | 10.77 | <0.0001 |

*Means denoted by a different letter in the same row are significantly different (0.05)*

## 4.4 Survival and duration of silkworm larvae

### 4.4.1 Survival of silkworm larvae

The larval survival of silkworm followed a similar pattern among the two species tested. There was a high rate of the silkworm surviving to moulting to the third instar in all the structures for *B. mori.* During the wet season the highest survival was in L2 (76.73±4.81%), followed by L0 but was least in L5 with none surviving in L1, L6 and L7 beyond the fourth instar, which indicated a highly significant difference (Table 4.5). When the survival of Eri worms' larvae was considered in the tested structures for both seasons, the highest survival was in L0, followed by L3, but least in L5; however as in *B. mori* all the worms died in structures L1, L6 and L7 before attaining the fifth instar (Appendix VII).

For *B. mori* during the dry season a higher survival was noted as compared with the wet season. Structure L0 (78.70±8.8%) recorded the highest survival rate which was highly significant compared with the other tested structures (Appendix VII). The least survival percentage for the structures where the worms reached the fifth instar was in L5 (48.28±4.2%) which was similar to the wet season. Structurers L1, L6 and L7 recorded no survival worms beyond the third instars as all the worms died at the end of instar three and this was also observed for Eri worms.

The Eri worm survival percentage followed a similar trend with the *B. mori.* L0 (80.10±3.7%) was the highest followed by L2 (80.07±3.7%), but the least was in L4 (56.77±9.9%.). However, in all the instars except in instar 2, survival percentage was found to significantly differ in all the experimental structure for both seasons (Table 4.5, Appendix VIII).

**Table 4.5: Survival percentage of silkworm larvae reared under different experimental structures during wet and dry season**

| | Season | | L0 | L1 | L2 | L3 | L4 | L5 | L6 | L7 | P (<0.05) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *B. mori* | Wet season | 2nd | 83.33±12.5 | 83.33±7.64 | 83.33±30.1 | 83.33±15.3 | 83.33±12.5 | 87.00±11.5 | 83.33±5.77 | 83.33±15.2 | 0.01 |
| | | 3rd | 82.37±8.61 | 63.33±4.51 | 77.03±3.96 | 78.03±2.51 | 74.30±12.6 | 66.87±11.7 | 73.70±9.86 | 62.90±4.19 | 0.04 |
| | | 4th | 79.23±13.6 | 0.00±0.00 | 77.03±12.9 | 78.0±7.35 | 70.30±6.04 | 66.10±8.11 | 0.00±0.00 | 0.00±0.00 | 0.00 |
| | | **5th** | **76.70±8.78** | **0.00±0.00** | **76.73±4.81** | **76.00±8.54** | **60.00±6.25** | **56.67±4.16** | **0.00±0.00** | **0.00±0.00** | **0.00** |
| | Dry season | 2nd | 83.33±12.6 | 82.80±2.6 | 83.33±15.3 | 82.37±8.61 | 82.33±12.6 | 87.00±11.5 | 83.33±11.6 | 83.33±12.6 | 0.01 |
| | | 3rd | 80.37±7.61 | 76.67±5.77 | 71.67±16.5 | 76.00±8.89 | 71.30±12.6 | 62.00±2.00 | 70.77±9.05 | 76.67±5.77 | 0.03 |
| | | 4th | 80.21±13.6 | 0.00±0.00 | 70.77±9.1 | 78.0±7.4 | 71.67±16.5 | 55.67±2.08 | 0.00±0.00 | 0.00±0.00 | 0.00 |
| | | **5th** | **78.70±8.8** | **0.00±0.00** | **77.80±16.5** | **70.77±8.54** | **56.30±6.25** | **48.20±4.2** | **0.00±0.00** | **0.00±0.00** | **0.00** |
| Eri worm | Wet season | 2nd | 82.73±6.1 | 83.33±12.6 | 82.67±16.3 | 88.03±9.1 | 82.80±2.6 | 81.07±7.7 | 83.33±11.6 | 83.33±15.3 | 0.99 |
| | | 3rd | 77.77±4.1 | 76.93±4.1 | 77.03±5.6 | 76.00±8.9 | 76.67±5.8 | 74.00±6.0 | 70.77±9.1 | 71.67±16.5 | 0.94 |
| | | 4th | 77.70±7.6 | 0.00±0.00 | 76.90±9.6 | 71.40±3.9 | 68.77±9.9 | 62.00±2.0 | 0.00±0.00 | 0.00±0.00 | 0.00 |
| | | **5th** | **77.40±3.7** | **0.00±0.00** | **76.90±4.2** | **71.40±3.5** | **68.77±9.9** | **55.67±2.1** | **0.00±0.00** | **0.00±0.00** | **0.00** |
| | Dry season | 2nd | 81.63±6.1 | 83.33±12.6 | 82.37±8.6 | 88.03±9.1 | 82.80±2.6 | 81.07±7.7 | 84.23±10.6 | 82.32±14.3 | 0.98 |
| | | 3rd | 78.75±4.1 | 76.93±4.1 | 76.00±8.9 | 76.00±8.9 | 76.67±5.8 | 75.00±6.0 | 70.76±8.1 | 71.57±15.4 | 0.93 |
| | | 4th | 76.40±7.6 | 0.00±0.00 | 77.70±7.6 | 76.67±5.8 | 67.77±9.9 | 62.00±2.0 | 0.00±0.00 | 0.00±0.00 | 0.00 |
| | | **5th** | **80.10±3.7** | **0.00±0.00** | **80.07±3.7** | **78.00±9.9** | **56.77±9.9** | **59.70±1.1** | **00.00±0.0** | **0.00±0.0** | **0.00** |

**Significant at 0.05*

### 4.4.2 The larval period of silkworm reared in different structures

In L0, L2, L3, L4 and L5 structures, *B. mori* and Eri survived up to 5$^{th}$ instar taking different days (larval duration) to cocoon. *B. mori* larvae took 45.67 and 38.30 days during the wet season in structures L2 and L0 respectively, while Eri took 39.33 in structure L0 and L2 during the wet season and 30.33 days during the dry season for all the instars to cocoon in structure L0. The shortest duration was in the structures L5 (40.00±1.00 and 27.67±0.58) for *B. mori* in the wet and dry season respectively, which was found to be significantly different. (Appendix IX). Similarly, the Eri worm took the least number of days in L5 at 34.33±0.58 days and 21.33±0.58 days during the wet season and dry season respectively and was significantly different among the structures (Appendix X). The larval duration was not significantly shorter in the dry season for *B. mori* ($\chi^2$ = 4.1988, d.f.=4, p = 0.3798) (Appendix XI) and Eri, ($\chi^2$ = 5.6277, d.f.=4, p= 0.2287) as compared to the wet season for the two silkworm species (Appendix XI).

In terms of individual instars, *B. mori,* in the 5$^{th}$ instar took the longest period (9 days) followed by 4$^{th}$ instar while 1$^{st}$ and the 2$^{nd}$ instar took the shortest duration (Figure 4.5). Similarly, for Eri, the longest larva duration was recorded at 5$^{th}$ instar with an average of 8.6±1.51 days while the least was recorded in 1$^{st}$ instar with an average of 2.50±0.92 days. The comparison of the larval duration of two species regardless of the structures showed that a longer duration was taken in the 5$^{th}$ instar for the worms of the two species.

**Table 4.6: Duration in days taken by larvae of silkworm to cocoon in the experimental structures**

| | | L0 | L1 | L2 | L3 | L4 | L5 | L6 | L7 | F-Ratio | P-Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *B. mori* | wet | 45.33±0.58 | 0.00±0.00 | 45.67±0.58 | 44.33±0.58 | 42.67±1.53 | 40.00±1.00 | 0.00±0.00 | 0.00±0.00 | 2108.70 | 0.00 |
| | dry | 38.33±0.58 | 0.00±0.00 | 37.33±0.58 | 36.00±0.00 | 32.33±0.58 | 27.67±0.58 | 0.00±0.00 | 0.00±0.00 | 5879.39 | 0.00 |
| Eri | wet | 39.33±0.58 | 0.00±0.00 | 39.33±0.58 | 36.33±0.58 | 35.33±0.58 | 34.33±0.58 | 0.00±0.00 | 0.00±0.00 | 5305.03 | 0.00 |
| | dry | 29.67±1.15 | 0.00±0.00 | 30.33±0.58 | 23.33±0.58 | 23.33±0.58 | 21.33±0.58 | 0.00±0.00 | 0.00±0.00 | 1666.57 | 0.00 |

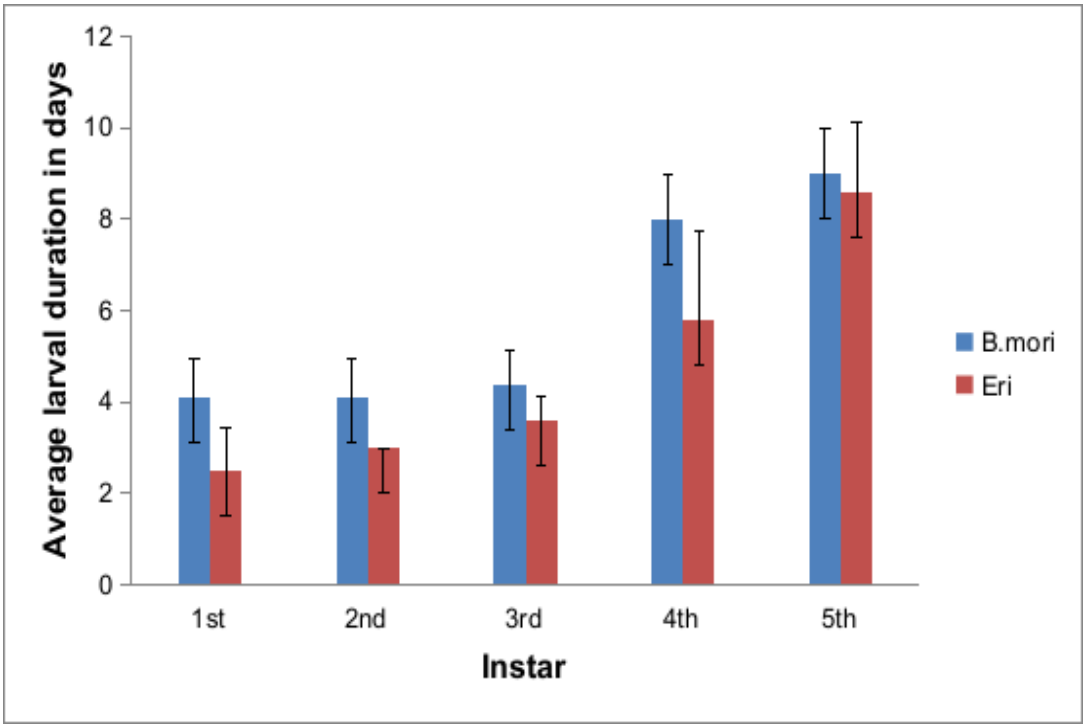


**Figure 4.5: The larval duration of *B. mori* and Eri in the instars reared in the different structure condition**

### 4.5 Quality of cocoons from the tested structures

#### 4.5.1 Defective cocoons for *B. mori* in tested structures during season 1 and season 2

The number of defective cocoons for *B. mori* was established for the different structures per season. In wet season, majority of double defective cocoons in *B. mori* was recorded in structure L5 (37.5%) and Lowest in L4 (12.49%) in the structures where the defect was observed (Table 4.7) with a significant difference ($\chi^2$ = 12.52, d.f.=3, p = 0.0058) (Appendix XII). The inside stained cocoon, highest percentage was in L2 (66.70%) and lowest in L4 (33.33%) with a significant difference ($\chi^2$ = 178.9, d.f.=4, p = 0.0000) (Appendix XII). Outside stained percentage was high in L4 and L5 (29.00%) ($\chi^2$ = 13.48,

d.f.=4, p = 0.0000). Highest malformed cocoons were observed in L2 and L5, while flimsy cocoons were recorded in structures L0, L2 (19.98%) each and L5 (60.02%) recorded the most. There was a significant difference in percentage flimsy cocoons in the structures ($\chi^2$ = 119.97, d.f.=4, p < 0.0001). Pierced cocoons were found in structure L2, L3 and L4 which was significantly different ($\chi^2$ = 65.41, d.f.=4, p = 0.0000) as shown in Table 4.7

In the dry season the structures L2, L4 and L5 recorded the highest percentage of double defective cocoons (28.58%) ($\chi^2$ = 212.5, d.f.=4, p < 0.0000) (Appendix XII). Inside stained cocoons were more in L5 (75.02%) and lowest in L4 (28.98%) but none in L0, L2 and L3. Highest number of outside stained cocoons was recorded in L2. All structures in dry season recorded malformed, but flimsy cocoons were recorded from all the structures except L3 (Table 4.7) while pierced cocoons were recorded only in structures L0 and L2.

**Table 4.7: *B. mori* defective cocoons during wet and dry season**

| | | structures | | | | |
|---|---|---|---|---|---|---|
| Defects (%) | Season | L0 | L2 | L3 | L4 | L5 |
| Double | wet | 25.00 | 25.00 | 0.00 | 12.50 | 37.50 |
| | dry | 14.30 | 28.60 | 0.00 | 28.60 | 28.60 |
| Inside stained | wet | 0.00 | 66.70 | 0.00 | 33.30 | 0.00 |
| | dry | 0.00 | 0.00 | 0.00 | 25.00 | 75.00 |
| Outside stained | wet | 14.30 | 14.30 | 14.30 | 28.60 | 28.60 |
| | dry | 0.00 | 40.00 | 20.00 | 20.00 | 20.00 |
| Malformed | wet | 0.00 | 40.00 | 0.00 | 20.00 | 40.0 |
| | dry | 16.70 | 16.70 | 16.70 | 16.70 | 33.40 |
| Flimsy | wet | 20.00 | 20.00 | 0.00 | 60..02 | 0.00 |
| | dry | 25.00 | 25.00 | 0.00 | 25.00 | 25.00 |
| Pierced | wet | 0.00 | 33.30 | 33.30 | 33.30 | 0.00 |
| | dry | 50.00 | 50.00 | 0.00 | 0.00 | 0.00 |

### 4.5.2 Defective cocoons in Eri worm reared in different structures during wet and dry season

In wet season, majority of double defective cocoons in Eri was recorded in structure L0 (75.0%) while during the dry season it was 66.7% (Table 4.8). Inside stained cocoon highest percentage was (33.33%) in L4 with a significant difference ($\chi^2$ = 130.81, d.f.=4, p = 0.0000) in wet season as well as in dry season (Appendix XIII). Highest outside stained cocoons were recorded in season two in L5 (50.0%) and in season one it was in L2 and L3 (33.3%) ($\chi^2$ = 62.60, d.f.=4, p = 0.0000). No malformed cocoons were observed in L0, L2, L3 and L5 for wet season while in the dry season L2 and L4 had 33.30% and 60% respectively. Flimsy cocoons were recorded in structures L3 (3.00% and 2.00%) in wet and dry season respectively. Pierced cocoons were found in structure L2 only and during the wet season, with no significant difference ($p \leq 0.05$).

**Table 4.8: Eri defective cocoons for two seasons**

| Defects (%) | Season | L0 | L2 | L3 | L4 | L5 |
|---|---|---|---|---|---|---|
| Double% | wet | 75.00 | 33.30 | 0.00 | 0.00 | 0.00 |
| | dry | 66.70 | 33.30 | 0.00 | 0.00 | 0.00 |
| Inside stained% | wet | 0.00 | 0.00 | 0.00 | 33.30 | 100.00 |
| | dry | 0.00 | 0.00 | 0.00 | 20.00 | 0.00 |
| Outside stained% | wet | 25.00 | 33.30 | 33.30 | 0.00 | 0.00 |
| | dry | 33.30 | 33.30 | 50.00 | 0.00 | 0.00 |
| Malformed% | wet | 0.00 | 0.00 | 0.00 | 50.00 | 0.00 |
| | dry | 0.00 | 33.30 | 0.00 | 60.00 | 0.00 |
| Flimsy% | wet | 0.00 | 0.00 | 3.00 | 0.00 | 0.00 |
| | dry | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 |
| Pierced% | wet | 0.00 | 33.30 | 0.00 | 0.00 | 0.00 |
| | dry | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

### 4.5.3 Filament length for *B. mori* and Eri cocoon

For *B. mori* during the wet season, the longest Filament length was recorded from structure L2 (1377.80±150.17) m followed by structure L3 (1363.33±165.13) m while the shortest Filament length was recorded from structure L5 (1163.10±891.95) m. There was a significant difference in filament lengths for *B. mori* recorded from the various structures in wet season (p = 0.0032) (Appendix XIV). Significant difference was noted between structure L5 and all the other structures. During the dry season, the longest filament length for *B. mori* was recorded from structure L3 (1382.80±117.23) m followed by structure L2 (1377.80±150.17) m while the shortest filament length was recorded from structure L5 (1137,70±105.40) m. There was a significant difference in filament lengths for *B. mori* recorded from structures during dry season ($F_{0.05\ (4,\ 45)} = 6.028$, p= 0.0004).

The cocoon filament lengths for Eri silkworm in wet season, was longest in structure L2 (437.6±32.26) with shortest non-significant filament length recorded in structure L5 (397.61±46.82) m ($F_{0.05\ (4,\ 45)} = 1.53$, p= 0.2104) (Appendix XV). In dry season, the longest filament length was recorded from structure L2 (448.70±31.87) with shortest significant filament length recorded in L5 (376.70±40.42) m ($F_{0.05\ (4,\ 45)} = 4.92$, p= 0.0022). Significant difference was recorded between structures L0 and L4, L0 and L5, L2 and L4, L2 and L5 and also between L3 and L5 as shown in Table 4.9. Seasons did not influence average filaments lengths resulting from the tested structures.

**Table 4.9: Mean Filament length (m) for *B. mori* and Eri cocoon in reared different structures and seasons**

| Species | Season | L0 | L2 | L3 | L4 | L5 | F-ratio | p-value |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *B. mori* | Wet | 1363.30± 165.13[a] | 1377.80± 150.17[a] | 1326.30± 117.20[a] | 1292.10± 84.12[a] | 1163.40± 91.95[b] | 4.64 | 0.003 |
| | Dry | 1361.50± 166.58[a] | 1377.80± 150.17[a] | 1382.80± 117.23[a] | 1288.50± 99.22[a] | 1137.70± 105.40[b] | 6.28 | 0.000 |
| Eri | Wet | 433.90 ± 55.65[a] | 437.60 ± 32.26a | 427.50 ± 45.00[a] | 402.00 ± 54.56[a] | 397.60 ± 46.82[a] | 1.53 | 0.210 |
| | Dry | 445.70 ± 53.44[a] | 448.70 ± 31.87[a] | 436.30 ± 37.43[a] | 403.20 ± 54.52[b] | 376.70 ± 40.42[b] | 4.92 | 0.002 |

*Means denoted by a different letter in the same row are significantly different (0.05)*

### 4.6 Cocoon, pupa and Shell weight for *B. mori* and Eri during wet and dry season

#### 4.6.1 Cocoon weight

During wet season, *B. mori*, cocoon weight was high in L2 (1.36±0.03) and L5 (1.36±0.05) (Table 4.10) and low in structure L0 (1.32±0.04) but did not differ among the structures (F= 1.08, p=0.3780). In dry season, *B. mori*, cocoon weight was high in structure L5 (1.78±4.30) and low in structure L4 (1.44±0.40) but did not differ among the structures (F= 0.77, p=0.5474). *B. mori* Cocoon weight was significantly high in dry season compared to wet season for all the structures (Appendix XVI).

During the wet season, Eri cocoon weight was high in structure L0 (2.35±0.49) and low in structure L3 (1.82±0.35) (Table 4.10), with a significant difference in structures (F= 2.87, p=0.0333) (Appendix XVII). In dry season, cocoon weight was significantly high (F= 4.91, p=0.0024) in structure L3 (2.44±0.34) g and low in structure L4 (1.79±0.47) g. It was only in structure L0 where Eri cocoon weight was high in wet season in comparison to dry season.

**Table 4.10: Mean Cocoon weight (g) for *B. mori and* Eri cocoon in different structures and seasons**

| Species | Season | L0 | L2 | L3 | L4 | L5 | F-ratio | p-value |
|---|---|---|---|---|---|---|---|---|
| *B. mori* | Wet | 1.32± 0.04[a] | 1.36± 0.03[a] | 1.35± 0.06[a] | 1.33± 0.07[a] | 1.36± 0.05[a] | 1.08 | 0.378 |
| | Dry | 1.74± 0.16[b] | 1.65± 0.17[b] | 1.57± 0.13[b] | 1.44± 0.40[b] | 1.78± 4.30[b] | 0.77 | 0.5474 |
| Eri | Wet | 2.35± 0.50[a] | 1.90± 0.41[a] | 1.82± 0.35[a*] | 1.87± 0.39[a] | 2.03± 0.32[a] | 2.87 | 0.0333 |
| | Dry | 2.23± 0.26[a] | 2.23± 0.35[a] | 2.44± 0.34[b*] | 1.79± 0.47[a] | 2.06 0.27[a] | 4.91 | 0.0024 |

*Means denoted by a different letter in the same row are significantly different (0.05)*

### 4.6.2 Pupa weight for *B. mori* and Eri during wet and dry season

During wet season, *B. mori,* pupa weight was high in structure L5 (1.15±0.10) followed by L3 (1.11±0.27) and low in structure L0 (1.07±0.15) (Table 4.11) but did not differ significantly among the structures (F= 2.38, p=0.0653) (Appendix XVIII). In dry season, the *B. mori,* pupa weight was higher in structure L0 (1.44±0.14) and low in structure L4 (1.21±0.40) but did not differ significantly among the structures (F= 1.81, p=0.1429). *B. mori* cocoon weight was significantly high in dry season for L0 in comparison to wet season ($p<0.05$).

During wet season for Eri pupa weight, there was a higher weight in structure L0 (2.01±0.37) and low in structure L3 (1.55±0.37) with no significant difference in structures (F= 2.50, p=0.0554) (Appendix XIX). During dry season, the weight of pupae reared in structure L3 (2.13±0.31) was high and low in structure L4 (1.59±0.42) with a significant difference (F= 3.95, p=0.0081). (Table 4.11, Appendix XIX) Significant difference was recorded between structures L0 and L4, L2 and L4, L3 and between L4 and L3 and L5. Structure L2 and L3 had high pupa weights in season two which was significantly different from that of season one ($p<0.05$).

**Table 4.11: Pupa weight for *B. mori and* Eri worm in the experimental structures**

| Species | Season | L0 | L2 | L3 | L4 | L5 | F-ratio | p-value |
|---|---|---|---|---|---|---|---|---|
| *B. mori* | Wet | 1.07± 0.15[a]* | 1.09± 0.13[a] | 1.11± 0.10[a] | 1.10± 0.37[a] | 1.15± 0.27[a] | 2.38 | 0.0653 |
| | Dry | 1.44± 0.14[a]* | 1.39± 0.12[a] | 1.33± 0.09[a] | 1.21± 0.40[a] | 1.24± 0.26[a] | 1.81 | 0.1429 |
| Eri | Wet | 2.01± 0.38[a] | 1.65± 0.34[a]* | 1.55± 0.37[a]* | 1.66± 0.37[a] | 1.78± 0.30[a] | 2.5 | 0.0554 |
| | Dry | 1.95± 0.26[bc] | 2.00± 0.34[bc]* | 2.13± 0.31[c]* | 1.59± 0.43[a] | 1.60± 0.27[ab] | 3.95 | 0.0081 |

*Means denoted by a different letter in the same row are significantly different (0.05)*

### 4.6.3 Shell weight for *B. mori* and Eri during dry and wet season

During season one (wet), *B. mori,* shell weight was high in structure L0 (0.23±0.07) and L3 (0.23±0.07) and lowest in L4 (0.20±0.07) (Table 4.12) but did not differ among the structures (F= 0.32, p=0.8645) (Appendix XX). In dry season, *B. mori,* shell weight was high in structure L3 (0.32±0.32) g and low in structure L5 (0.17±0.07) g but did not differ among the structures (F= 1.62, p=0.1862). *B. mori* shell weight was significantly higher in dry season for L0 structure in comparison to wet season (p=0.0012) (Appendix XX).

During wet season, Eri shell weight was high in structure L0 (0.30±0.13) and low in structure L4 (0.21±0.06) with no significant difference in structures (F= 1.20, p=0.3231) (Appendix XXI). In dry season, shell weight was high in structure L5 (0.44±0.62) and low in structure L4 (0.19±0.06) with no significant difference (F= 1.15, p=0.3450) as indicated in Table 4.12 but it was established that shell weight did not differ among seasons ($p \leq 0.05$).

**Table 4.12: Shell weight for *B. mori* and Eri in wet and dry season in the experimental structures**

| Species | Season | L0 | L2 | L3 | L4 | L5 | F-ratio | p-value |
|---|---|---|---|---|---|---|---|---|
| *B. mori* | Wet | 0.23± 0.07$^{a}$ | 0.22± 0.06$^{a}$ | 0.23± 0.08$^{a}$ | 0.20± 0.07$^{a}$ | 0.21± 0.07$^{ab}$ | 0.32 | 0.8645 |
| | Dry | 0.29± 0.06$^{a}$ | 0.23± 0.07$^{ab}$ | 0.32± 0.32$^{a}$ | 0.20± 0.08$^{ab}$ | 0.17± 0.08$^{abc}$ | 1.62 | 0.1862 |
| Eri | Wet | 0.30± 0.13$^{a}$ | 0.24± 0.12$^{ab}$ | 0.26± 0.10$^{ab}$ | 0.21± 0.06$^{ab}$ | 0.23± 0.07$^{ab}$ | 1.2 | 0.3231 |
| | Dry | 0.25± 0.05$^{ab}$ | 0.21± 0.04$^{abc}$ | 0.29± 0.06$^{ab}$ | 0.19± 0.06$^{abc}$ | 0.44± 0.62$^{a}$ | 1.15 | 0.3450 |

*Means denoted by a different letter in the same row are significantly different (0.05)*

### 4.6.4 Shell/pupa weight for *B. mori* and Eri

During wet season, *B. mori*, shell/ pupa weight was higher in structure L2 (0.22±0.06) and low in structure L4 (0.16±0.07) (Table 4.13) but did not differ among the structures (F= 1.78, p=0.1494) (Appendix XXII). In dry season, *B. mori*, shell/pupa weight was high in L3 (0.24±0.22) and low in L5 (0.15±0.07) but did not differ significantly among the structures (F= 0.62, p=0.6518) (Appendix XXII).

Eri shell / pupa weight during the wet season was higher in L3 (0.19±0.16) and low in L4 (0.30±0.13) with no significant difference (F= 1.01, p=0.4142) (Appendix XXIII). In dry season, shell/pupa weight was more in L5 (0.23±0.29) and low in L4 (0.11±0.03) with no significant difference (F= 1.47, p=0.2267). Shell/pupa weights did not differ significantly among seasons ($p \leq 0.05$) for the two species.

**Table 4.13: Shell/pupa weight for *B. mori* and Eri**

| | Season | L0 | L2 | L3 | L4 | L5 | F-Ratio | P-Value |
|---|---|---|---|---|---|---|---|---|
| *B. mori* | Wet | 0.22± 0.06[a] | 0.17± 0.04[ab] | 0.16± 0.07[ab] | 0.16± 0.07[ab] | 0.16± 0.06[ab] | 1.78 | 0.15 |
| | Dry | 0.20± 0.04[a] | 0.16± 0.04[ab] | 0.24± 0.23[a] | 0.20± 0.20[a] | 0.15± 0.07[ab] | 0.62 | 0.65 |
| Eri | wet | 0.14± 0.02[ab] | 0.14± 0.06[ab] | 0.19± 0.16[a] | 0.13± 0.04[ab] | 0.13± 0.04[ab] | 1.01 | 0.41 |
| | dry | 0.13± 0.03[ab] | 0.11± 0.02[ab] | 0.14± 0.02[ab] | 0.11± 0.03[ab] | 0.23± 0.29[a] | 1.47 | 0.23 |

*Means denoted by a different letter in the same row are significantly different (0.05)*

### 4.6.5 Shell/cocoon weight for *B. mori and* Eri worm

The shell/ cocoon weight for *B. mori*, during wet season was high in L0 (0.18±0.05) and low in structure L4 (0.13±0.04) (Table 4.14) but did not differ significantly among the structures (F= 2.30, p=0.0737) (Appendix XXIV). In dry season, *B. mori*, shell/cocoon

weight was high in structure L3 (0.20±0.19) and low in structure L5 (0.11±0.06) but did not differ among the structures (F= 1.06, p=0.3869).

For the case of wet season, Eri shell /cocoon ratio was found to be higher in structure L3 (0.15±0.08) and low in L4 (0.12±0.03) with no significant difference (F= 0.87, p=0.4869) (Appendix XXV), whereas in dry season, shell/cocoon weight was more in structure L5 (0.21±0.27) and low in L4 (0.11±0.03) with no significant difference (F= 1.27, p=0.2970) (Table 4.14). The overall shell/pupa weight did not differ significantly ($p \leq 0.05$) for the two species of silkworms within the seasons.

**Table 4.14: Shell/cocoon weight for *B. mori* and Eri worm**

| Species | Season | L0 | L2 | L3 | L4 | L5 | F-ratio | p-value |
|---|---|---|---|---|---|---|---|---|
| *B. mori* | 1 | 0.18± 0.05$^{a}$ | 0.14± 0.03$^{ab}$ | 0.14± 0.04$^{ab}$ | 0.13± 0.04$^{ab}$ | 0.14± 0.04$^{ab}$ | 2.3 | 0.0737 |
| | 2 | 0.17± 0.03$^{a}$ | 0.14± 0.03$^{ab}$ | 0.20± 0.20$^{a}$ | 0.15± 0.10$^{ab}$ | 0.11± 0.06$^{abc}$ | 1.06 | 0.3869 |
| Eri | 1 | 0.12± 0.03$^{ab}$ | 0.12± 0.04$^{ab}$ | 0.15± 0.08$^{a}$ | 0.12± 0.03$^{ab}$ | 0.12± 0.03$^{ab}$ | 0.87 | 0.4869 |
| | 2 | 0.11± 0.02$^{ab}$ | 0.10± 0.02$^{ab}$ | 0.12± 0.02$^{ab}$ | 0.11± 0.03$^{ab}$ | 0.21± 0.27$^{a}$ | 1.27 | 0.297 |

*Means denoted by a different letter in the same row are significantly different (0.05)*

### 4.6.6 Pupa/cocoon weight for *B. mori* and Eri

The Pupa/cocoon weight for, *B. mori,* during wet season was high in structure L4 (0.07±0.83) and low in structure L2 (0.03±0.84) (Table 4.15) but did not differ significantly among the structures (F= 0.88, p=0.4855) (Appendix XXVI). In dry season, *B. mori,* pupa/cocoon weight was high in structure L5 (0.25±0.25) and low in structure L0 (0.03±0.03) but did not differ significantly among the structures (F= 0.31, p=0.8715).

In wet season, Eri pupa / cocoon weight was more in structure L4 (0.89±0.03) and low in L3 (0.85±0.08) with no significant difference (F= 0.96, p=0.4365) (Appendix XXVII). For the data recorded in dry season, pupa/cocoon weight was more in L2 and L4 (0.89±0.03) and low in structure L3 (0.87±0.02) with no significant difference (F= 1.04, p=0.3991) (Table 4.15). The pupa/cocoon weight did not differ significantly among seasons ($p \leq 0.05$) for the two species.

**Table 4.15: Pupa/cocoon weight for *B. mori* and Eri**

| Species | Season | L0 | L2 | L3 | L4 | L5 | F-Ratio | p-Value |
|---|---|---|---|---|---|---|---|---|
| *B. mori* | Wet | 0.04± 0.83$^{ab}$ | 0.03± 0.84$^{ab}$ | 0.06± 0.85$^{a}$ | 0.07± 0.83$^{a}$ | 0.04± 0.80$^{ab}$ | 0.88 | 0.4855 |
| | Dry | 0.03± 0.03$^{abc}$ | 0.04± 0.04$^{abc}$ | 0.06± 0.06$^{ab}$ | 0.10± 0.10$^{ab}$ | 0.25± 0.25$^{a}$ | 0.31 | 0.8715 |
| Eri | Wet | 0.86± 0.04$^{a}$ | 0.87± 0.04$^{a}$ | 0.85± 0.08$^{a}$ | 0.89± 0.03$^{a}$ | 0.87± 0.04$^{a}$ | 0.96 | 0.4365 |
| | Dry | 0.87± 0.02$^{a}$ | 0.89± 0.04$^{a}$ | 0.87± 0.02$^{a}$ | 0.89± 0.03$^{a}$ | 0.87± 0.04$^{a}$ | 1.04 | 0.3991 |

*Means denoted by a different letter in the same row are significantly different (0.05)*

# CHAPTER FIVE

# DISCUSSION

## 5.1 Hatchability

The abiotic factors such as temperature and humidity determine to a large extend the success of sericulture. These factors affect silkworm in all stages of development starting from hatching of silkworm eggs, which is the first and the most important foremost developmental event (Shanthan, 2014; Srinath, 2014). The current research indicated varying duration of incubation to hatching in the bivoltine *B. mori* and multivoltine Eri silkworm. These differences were reported in the tested structures which experienced varied temperature and humidity levels. Various authors reported an average of 10-12 days to hatching (Pakhale et al., 2014; Wankhede et al., 2014) under ideal conditions of temperature between 24$^{o}$C to 28$^{o}$C and humidity of 70-85%, these conditions prevailed in the experimental structures coded L0, L2 and L8 (incubator control), but in structures L4 and L5 there was imbalance of humidity and temperature conditions during the hatching period.

Another observation in the present research was the duration to complete hatching of eggs. A duration of up to six days was noted in structures L2 and L3, but lower in some structures where the temperature recorded was high and low humidity. Datta (1992); Lertsatitthanakorn et al., 2006; Sharma and Kalita (2017) explained that the development of embryos in silkworm eggs tend to attain uniformity and eliminates mixed age characteristics in balanced environmental conditions of temperature and humidity this could explain the current results observed in some of the experimental structures. It was observed that most of the hatching occurred on the first day of

hatching and was at the peak in the early hours of the day. Singh et al., (2002) reported that the hatching peak in *B. mori* was very close to dawn under alternating cycles of light and dark, which agrees with the results recorded in the current research. Temperatures above 30$^{o}$C affect the metabolic functions resulting to low hatching percentage (Rahmathulla, 2012). Similarly, temperature below 20$^{o}$C causes inactivity in metabolic functions resulting to low hatching percentage and long duration taken to hatch. This could explain the low hatchability of eggs at the timber made structure which recorded a high diurnal range of temperatures whereas the temperature of Uasin Gishu could be as low 15$^{o}$C during the night, a condition which was obtaining during the duration of this research.

No hatching was recorded in structures coded L6 and L7 where high temperature was recorded. At high temperature the embryo grows faster up to the setae formation stage and succumbs to death as the yolk cannot be utilized in pace with the high rate of development (Rahmathulla, 2012), which can be the reason for the observation made in L6 and L7. This report is the first to indicate that hatching of silkworm can be done in University of Eldoret under greenhouse and mud house structure and by extension the greater Uasin Gishu County. This was because the structures were able to moderate the diurnal and seasonal fluctuations in the outside environmental conditions.

The L0 structure showed high positive correlation with the control (L8) this is attributed to low fluctuations in environmental conditions in the structure, also the mud house is completely dark at night providing black-boxing conditions recommended by Prakash et al., (2012) for the hatching of eggs of silk producing worm. All the other structures showed a weak negative correlation, there was low hatching in the structures because of

the poor balance of temperature and humidity as explained by Pakhale et al., (2014) Wankhade et al., (2014).

**5.2 Larval Duration and Survival**

Temperature and humidity combined optimally largely determines the optimal growth of the silkworms and subsequent high yields and good-quality cocoons. This is because they directly affect the physiological functions of the worm (Thapa and Ghimire 2005; and Rahmathulla et al., 2012). The environmental conditions in the tested structures showed variation and was found to impact the survival percentage and larval duration in a similar pattern on the bivoltine and multivoltine silkworm in Uasin Gishu. An optimal range of temperature of 21–27 °C with relative humidity (RH) of 70–85% are ideal for silkworm (Tazima,1978; Oduor et al., 2016).

These conditions obtained in the structures which showed high survival rates, on L0, L2, and L3, which showed a positive correlation with temperature and humidity, but poor in L4 and L5. The larval duration was found shorter in all the younger silkworms with a similar trend among the tested hybrids, but longer in the older ($5^{th}$ instar), in all the structures, where survival was recorded. This phenomenon could be due to the levels of tolerance to humidity conditions and also due to their vigorous growth at this age than at near cocooning phase, agreeing with the results of Lertsatitthanakorn et al., (2006) and Rahmatulla et al., (2012).

Similarly, there was longer larval duration in structures exhibiting high temperatures and low humidity and this could be due to low rate of feeding and/or low food conversion efficiency as explained by Sharma & Kalita (2017). According to Abera, (2016) the multivoltine Eri worm larval duration is longer compared to the shorter duration of

mulberry silkworm in structures with elevated temperature, a reported larval duration of between 21 days to 23 days for mulberry feeders and 23 to 24 days for multivoltine (23-24 days) indicating a slightly longer larval duration for Eri silkworm which is contrary to the current report, but was similar to Pakhale et al., (2014) study in India. Singh et al., (2002) reported longer larval duration of 29+3 days, which they attributed to differences in temperature and humidity, therefore this could explain the results reported in the current study. The ideal temperature range for Eri worm rearing is between 20$^{o}$C and 35 $^{o}$C and an increase in temperature beyond that causes less spinning and mortality in larvae (Doloi et al., 2019) the reason why Eri worms did not survive to 5$^{th}$ instar, in L6 and L7 could be due to these conditions.

### 5.3 Cocoon quality

#### 5.3.1 Defective cocoons

The number of defective cocoons for *B. mori* was established from the different structures per season. Double cocoons occur when two silkworms spin the silk together, it occurs when temperature is high, in this research majority of double cocoons were observed in L5, this is due to high temperatures recorded in L5 which causes the mature worms to crowd thereby resulting to the spinning of cocoons together, this agrees with previous research done by Taha et al., (2014). Inside stained cocoon occurs when the pupa dies inside the cocoon causing stain, it occurs when the temperatures become low causing longer larval duration making the worm to be susceptible to diseases thus death, this could explain the phenomenon of highest percentage recorded in L2, where the temperatures were the lowest compared to other structures. Flimsy cocoons are cocoons with loose shell, of which majority was recorded in structures L4 and mostly this could

be due to deformities of silkworm species. Pierced cocoons occur when the moth emerges from the cocoon and were found in structure L2, L3 and L4 because the structures were having relatively cooler conditions thereby the interval of the cocoon formation to the end of spinning. This resulted to some cocoons maturing earlier than others so that by the time of harvesting the other cocoons, they were already getting to moth stage as explained by Lee, (1999).

Outside stained cocoons are cocoons with a spot on the shell caused by the absorption of intestinal fluid or urine of mature worms, this occurs when a mature worm crawls over already formed cocoon. In the present research it was found in all structures in wet season for *B. mori* whereas in Eri it was found in all structures apart from L4 and L5 which could be due to high temperatures in the structures and low humidity. High humidity at the time of spinning result to diuresis and cocoon staining (Yazawa et al., 2020). This explains why stained cocoons were found in structures with high humidity which are similar to what Ramachandra et al., (2001) reported. The least defects in both seasons were in L3. This structure had a netting on the four flaps which allowed continuously opening of the polythene during the day and therefore provided aeration, which has been reported as one of the key requirements during spinning (Ramachandra et al., 2001). Defective cocoons are poor quality cocoons since they are less reelable and the quality of silk filament produced is low.

### 5.3.2 Filament length for *B. mori* and Eri cocoon

Filament size deviation is an important commercial undesired characteristic of raw silk as a uniform filament size results to reduced breakages hence better weaving (Zulfigar et al., 2022). The research established that at high temperatures the filament length was

low for each species in the respective structures. Which agrees with the research done by Lalitha et al., (2020), who found out that when temperature is high it results to inferior quality cocoons and silk filament. The high temperature tends to shorten the larval duration resulting to less accumulation of silk thus shorter cocoon filament.

When the environmental temperature is low, the larval duration is prolonged giving more time for silk accumulation thereby resulting to high filament length, this explains the fact that Eri cocoon length was highest in L2 for both seasons and *B. mori* longest length in season one. The present research established that Eri cocoons produce short filaments of silk while *B. mori* produce long silk filaments which agrees with previous research which showed that *B. mori* had an average filament length of 1028.26m though the present research recorded higher filament of more than 1100m in all the structures because the silkworm species used in the study were hybrid. Eri highest filament length is 403.04m (Melissa et al.,2020) which related closely to the 402m and 403 average length in L4 for dry season and wet season respectively recorded in this study.

### 5.3.3 Cocoon, pupa and Shell weight for *B. mori* and Eri

The worms in the fifth instar ingest more than 88 % of leaves and reaches its maximum weight within one or two days before they start spinning cocoons. In addition, they rapidly develop the silk gland which occupies 40% of their weight (Angel et al., 2021). Another research stated that adequate feeding of silkworm is important in cocoon production and further revealed that increasing frequency of feeding causes enhancement of cocoon shell weight, cocoon weight and shell ratio (Hosseini et al., 2008), this strongly agrees with present research which found out that the above cocoon parameters were low in L5 the structure that had high mean temperature which affected

growth performances of the larvae at later instars by affecting their physiological activities (Thapa and Ghimire, 2005). When worms physiological activities are affected, feeding also reduces, and this was high in L0 and L2 whose temperature fluctuations were not extreme and rarely got to beyond 28$^{o}$C thus recording high cocoon weight. The average mean temperature in wet season was significantly lower compared to dry season which could be increasing physiological activities of the worms thus resulting to an increase in cocoon weight of *B. mori* which was significantly high during dry season in comparison to wet season for all the structures.

Pupa\shell, Pupa\cocoon, Shell\cocoon were done to determine which part of the cocoon had the highest weight. But on comparing the weight of the shell and pupa, the weight of pupa was significantly high to shell weight since shell weight is secreted by the silk glands of the mature silkworms before pupation. Shell percentage calculated from the weight of cocoon gives the quantity of raw silk that can be reeled from a given quantity of fresh cocoon. Raw silk percentage is important in determining costs of raw silk as the 65-84% is the best according to ICIPE.

# CHAPTER SIX

# CONCLUSION AND RECOMMENDATION

## 6.1 Conclusion

- Hatchability of silkworm eggs for the two species; *B. mori* and Eri worm can successfully be done in mud walled house where there is no thermo regulating incubator in Uasin Gishu county.
- The hatched worms can be reared within the mud-walled structure, a concrete walled house or green house with all flaps open during the day and closed at night, further the duration of larvae in these structures was found to be equivalent to the ideal silkworm durations from other areas. Overall Eri worm larval duration was shorter than for mulberry silkworm in Uasin Gishu.
- The silk cocoon quantity and quality were found to be best in green house with four flaps open (L3) and mud house (L0) for all the tested parameters, length, weight and lower pupa/shell ratio. Silkworm cultivation is possible in Uasin Gishu in both wet and dry season inside greenhouse with four flaps open during the day with no significant difference in production with good quality silk and quantity.
- The test of rearing and hatching is within the rearing of resources of poor farmers.

## 6.2 Recommendations.

- The research recommends the rearing of silkworms for cocoon production to be used in textile industries in Uasin Gishu due to good quality and quantity of cocoons observed in Green house with four flaps, mud walled and concrete walled structures.

- Considering the short life cycle of *B. mori* and Eri silkworms and favourable environmental conditions for cultivation of mulberry and castor plants, farmers to be encouraged to venture into sericulture to create employment to thousands of unemployed youth both in the farm and textile industries while improving the country's gross domestic product.
- Further research in Uasin Gishu for silkworm production can be done on the performances of the different genotypes of castor and mulberry plants on silkworm growth and also for use in the production of silkworm chow. The research tested the quality of silk cocoons produced from the two genotypes and were found to be of high quality. However, there is need for further tests on the tensile strength of the fibers and usability in the biomedical field to make sponges and sutures.
- Moriculture and Ericulture are feasible diversification ventures of farming in Uasin Gishu County and areas with similar agro-ecological conditions.

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# APPENDICES

**Appendix I: Temperatures during hatching**

| Summary Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
| L0 | 19 | 23.86 | 1.87 | 7.83% | 20.55 | 27.65 | 7.1 |
| L1 | 19 | 24.21 | 2.13 | 8.78% | 19.05 | 28.8 | 9.75 |
| L2 | 19 | 24.75 | 2.26 | 9.15% | 19.2 | 27.35 | 8.15 |
| L3 | 19 | 25.74 | 2.57 | 9.99% | 19.65 | 29.3 | 9.65 |
| L4 | 19 | 25.93 | 2.39 | 9.22% | 21.6 | 29 | 7.4 |
| L5 | 19 | 27.97 | 1.58 | 5.64% | 24.75 | 30.25 | 5.5 |
| L6 | 19 | 30.31 | 1.71 | 5.64% | 27.55 | 33.5 | 5.95 |
| L7 | 19 | 28.49 | 2.70 | 9.47% | 24.1 | 32.6 | 8.5 |
| L8 | 19 | 25.00 | 0.00 | 0% | 25 | 25 | 0 |
| Total | 171 | 26.25 | 2.89 | 11.01% | 19.05 | 33.5 | 14.45 |
| ANOVA Table | | | | | | | |
| Source | | Sum of Squares | Df | Mean Square | F-Ratio | p-Value | |
| Between groups | | 732.45 | 7 | 91.5566 | 20.94 | 0.0001 | |
| Within groups | | 686.65 | 144 | 4.23861 | | | |
| Total (Corr.) | | 1419.1 | 151 | | | | |

**Appendix II: % Humidity during hatching**

| Summary Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
| L0 | 19 | 40.50 | 10.82 | 26.71% | 23 | 54 | 31 |
| L1 | 19 | 33.00 | 4.65 | 14.08% | 24.5 | 41.5 | 17 |
| L2 | 19 | 41.56 | 11.59 | 27.89% | 23 | 58 | 35 |
| L3 | 19 | 34.95 | 6.83 | 19.55% | 25 | 47.5 | 22.5 |
| L4 | 19 | 29.93 | 3.85 | 12.86% | 24 | 37 | 13 |
| L5 | 19 | 30.61 | 3.05 | 9.98% | 26 | 38 | 12 |
| L6 | 19 | 32.84 | 4.26 | 12.98% | 25.5 | 40 | 14.5 |
| L7 | 19 | 31.42 | 6.18 | 19.67% | 22 | 45 | 23 |
| L8 | 19 | 75.00 | 0.00 | 0% | 75 | 75 | 0 |
| Total | 171 | 38.87 | 14.89 | 38.31% | 22 | 75 | 53 |
| ANOVA Table | | | | | | | |
| Source | | Sum of Squares | Df | Mean Square | F-Ratio | p-Value | |
| Between groups | | 30496 | 7 | 3812.05 | 11.35 | 0.0001 | |
| Within groups | | 7202.3 | 144 | 44.4583 | | | |
| Total (Corr.) | | 37699 | 151 | | | | |

**Appendix III: Correlation between temperature and % humidity during hatching**

| Structure | R | N | p value |
|---|---|---|---|
| L0 | -0.23 | -19 | 0.342 |
| L1 | -0.42 | -19 | 0.0711 |
| L2 | -0.55 | -19 | 0.0142 |
| L3 | -0.33 | -19 | 0.1746 |
| L4 | -0.29 | -19 | 0.2256 |
| L5 | -0.13 | -19 | 0.6047 |
| L6 | -0.3 | -19 | 0.2196 |
| L7 | -0.36 | -19 | 0.125 |
| L8 | -0.37 | -19 | 0.1137 |

**Appendix IV: ANOVA tables for % Hatchability**

*B. mori*

| ANOVA Table | | | | | |
|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | p-Value |
| Between groups | 9180 | 5 | 4590.11 | 499.48 | 0.0001 |
| Within groups | 87.33 | 12 | 14.5556 | | |
| Total (Corr.) | 9268 | 17 | | | |

Eri

| ANOVA Table | | | | | |
|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | p-Value |
| Between groups | 3708 | 5 | 1236.08 | 522.81 | 0.0001 |
| Within groups | 46.67 | 12 | 5.83333 | | |
| Total (Corr.) | 3755 | 17 | | | |

**Appendix V: ANOVA output for temperatures during rearing in the wet and dry seasons.**

**Temperatures wet season**

| Summary Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
| L0 | 47 | 22.73 | 1.86 | 8.20% | 19 | 31.2 | 12.2 |
| L1 | 47 | 23.61 | 1.25 | 5.28% | 21.1 | 25.8 | 4.7 |
| L2 | 47 | 23.21 | 1.71 | 7.36% | 19 | 26.4 | 7.4 |
| L3 | 47 | 25.00 | 0.98 | 3.94% | 22.4 | 26.9 | 4.5 |
| L4 | 47 | 26.47 | 0.67 | 2.52% | 25.1 | 27.5 | 2.4 |
| L5 | 47 | 27.45 | 0.78 | 2.86% | 26 | 29.7 | 3.7 |
| L6 | 47 | 29.47 | 0.86 | 2.94% | 27.6 | 31.2 | 3.6 |
| L7 | 47 | 31.63 | 0.81 | 2.55% | 30.1 | 33.2 | 3.1 |
| Total | 376 | 26.19 | 3.21 | 12.24% | 19 | 33.2 | 14.2 |
| ANOVA Table | | | | | | | |
| Source | Sum of Squares | Df | Mean Square | F-Ratio | p-Value | | |
| Between groups | 3332.93 | 7 | 476.133 | 334.77 | 0.0001 | | |
| Within groups | 523.397 | 368 | 1.42227 | | | | |
| Total (Corr.) | 3856.33 | 375 | | | | | |

**Temperatures Dry season**

| Summary Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
| L0 | 47 | 22.86 | 2.20 | 9.64% | 19.2 | 31.2 | 12 |
| L1 | 47 | 23.58 | 1.29 | 5.47% | 21.1 | 25.8 | 4.7 |
| L2 | 47 | 23.29 | 1.65 | 7.08% | 19 | 26.4 | 7.4 |
| L3 | 47 | 25.02 | 0.90 | 3.59% | 22.4 | 26.9 | 4.5 |
| L4 | 47 | 26.48 | 0.61 | 2.32% | 25.2 | 27.5 | 2.3 |
| L5 | 47 | 27.36 | 0.79 | 2.87% | 26 | 29.7 | 3.7 |
| L6 | 47 | 29.34 | 0.86 | 2.92% | 27.6 | 31.2 | 3.6 |
| L7 | 47 | 31.52 | 0.74 | 2.36% | 30.1 | 33 | 2.9 |
| Total | 376 | 26.18 | 3.16 | 12.06% | 19 | 33 | 14 |
| ANOVA Table | | | | | | | |
| Source | Sum of Squares | Df | Mean Square | F-Ratio | p-Value | | |
| Between groups | 3172.53 | 7 | 453.218 | 294.26 | 0.0001 | | |
| Within groups | 566.797 | 368 | 1.54021 | | | | |
| Total (Corr.) | 3739.32 | 375 | | | | | |

**Appendix VI: ANOVA output for Humidity during rearing in the wet and dry seasons**

**Humidity wet season**

| Summary Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
| L0 | 47 | 43.18 | 9.53 | 22.07% | 20.8 | 55.2 | 34.4 |
| L1 | 47 | 33.26 | 7.29 | 21.92% | 23.5 | 48.6 | 25.1 |
| L2 | 47 | 33.99 | 5.05 | 14.85% | 24.2 | 45 | 20.8 |
| L3 | 47 | 35.20 | 6.48 | 18.42% | 25.1 | 50 | 24.9 |
| L4 | 47 | 37.41 | 7.81 | 20.87% | 26.1 | 48.2 | 22.1 |
| L5 | 47 | 39.22 | 7.87 | 20.07% | 23.8 | 50 | 26.2 |
| L6 | 47 | 40.80 | 7.65 | 18.74% | 25.1 | 50.6 | 25.5 |
| L7 | 47 | 42.90 | 7.37 | 17.17% | 28 | 55.6 | 27.6 |
| Total | 376 | 38.25 | 8.26 | 21.59% | 20.8 | 55.6 | 34.8 |

| ANOVA Table | | | | | | | |
|---|---|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | p-Value | | |
| Between groups | 5001.76 | 7 | 714.536 | 12.78 | 0.0001 | | |
| Within groups | 20570.2 | 368 | 55.8973 | | | | |
| Total (Corr.) | 25572 | 375 | | | | | |

**Humidity dry season**

| Summary Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
| L0 | 47 | 41.94 | 10.78 | 25.71% | 20.8 | 55.2 | 34.4 |
| L1 | 47 | 33.11 | 7.27 | 21.95% | 23.5 | 48.6 | 25.1 |
| L2 | 47 | 33.42 | 5.40 | 16.17% | 23.5 | 45 | 21.5 |
| L3 | 47 | 34.51 | 6.79 | 19.67% | 25.1 | 50 | 24.9 |
| L4 | 47 | 36.87 | 7.93 | 21.50% | 26.1 | 48.2 | 22.1 |
| L5 | 47 | 38.82 | 7.61 | 19.61% | 23.8 | 50 | 26.2 |
| L6 | 47 | 40.24 | 7.63 | 18.96% | 25.1 | 50.6 | 25.5 |
| L7 | 47 | 42.16 | 7.38 | 17.50% | 28 | 55.6 | 27.6 |
| Total | 376 | 37.64 | 8.40 | 22.33% | 20.8 | 55.6 | 34.8 |

| ANOVA Table | | | | | | | |
|---|---|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | p-Value | | |
| Between groups | 4501.71 | 7 | 643.102 | 10.77 | 0.0001 | | |
| Within groups | 21981.3 | 368 | 59.7319 | | | | |
| Total (Corr.) | 26483 | 375 | | | | | |

**Appendix VII: Survival percentage of *B. mori* silkworm larvae under different structures in wet and dry seasons**

**2nd Instar**

| ANOVA Table | Wet Season | | | | | Dry Season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | Sum of Squares | Df | Mean Square | F-Ratio | p-Value |
| Between groups | 170.638 | 7 | 24.3768 | 0.1 | 0.9200 | 170.638 | 7 | 24.3768 | 0.1 | 0.01 |
| Within groups | 3616.67 | 15 | 241.111 | | | 3616.67 | 15 | 241.111 | | |
| Total (Corr.) | 3787.3 | 22 | | | | 3787.3 | 22 | | | |

**3rd Instar**

| ANOVA Table | Wet Season | | | | | Dry Season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | Sum of Squares | Df | Mean Square | F-Ratio | p-Value |
| Between groups | 1262.06 | 7 | 180.294 | 2.73 | 0.4400 | 1262.06 | 7 | 180.294 | 2.73 | 0.03 |
| Within groups | 1058.09 | 16 | 66.1308 | | | 1058.09 | 16 | 66.1308 | | |
| Total (Corr.) | 2320.15 | 23 | | | | 2320.15 | 23 | | | |

**4th Instar**

| ANOVA Table | Wet Season | | | | | Dry Season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | Sum of Squares | Df | Mean Square | F-Ratio | p-Value |
| Between groups | 170.638 | 7 | 24.3768 | 0.9974 | 0.0000 | 170.638 | 7 | 24.3768 | 0.1 | 0.0000 |
| Within groups | 3616.67 | 15 | 241.111 | | | 3616.67 | 15 | 241.111 | | |
| Total (Corr.) | 3787.3 | 22 | | | | 3787.3 | 22 | | | |

**5th Instar**

| ANOVA Table | Wet Season | | | | | Dry Season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | Sum of Squares | Df | Mean Square | F-Ratio | p-Value |
| Between groups | 1262.06 | 7 | 180.294 | 2.73 | 0.0000 | 1262.06 | 7 | 180.294 | 2.73 | 0.0000 |
| Within groups | 1058.09 | 16 | 66.1308 | | | 1058.09 | 16 | 66.1308 | | |
| Total (Corr.) | 2320.15 | 23 | | | | 2320.15 | 23 | | | |

**Appendix VIII: Survival percentage of Eri silkworm larvae under different structures in wet and dry season**

**2nd Instar**

| ANOVA Table | Wet Season | | | | | Dry Season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | Sum of Squares | Df | Mean Square | F-Ratio | p-Value |
| Between groups | 170.638 | 7 | 24.3768 | 0.1 | 0.99 | 170.638 | 7 | 24.3768 | 0.1 | 0.9800 |
| Within groups | 3616.67 | 15 | 241.111 | | | 3616.67 | 15 | 241.111 | | |
| Total (Corr.) | 3787.3 | 22 | | | | 3787.3 | 22 | | | |

**3rd Instar**

| ANOVA Table | Wet Season | | | | | Dry Season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | p-Value | Sum of Squares | Df | Mean Square | F-Ratio | p-Value |
| Between groups | 1262.06 | 7 | 180.294 | 2.73 | 0.94 | 1262.06 | 7 | 180.294 | 2.73 | 0.9300 |
| Within groups | 1058.09 | 16 | 66.1308 | | | 1058.09 | 16 | 66.1308 | | |
| Total (Corr.) | 2320.15 | 23 | | | | 2320.15 | 23 | | | |

**4th Instar**

| ANOVA Table | Wet Season | | | | | Dry Season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | p-Value | Sum of Squares | Df | Mean Square | F-Ratio | p-Value |
| Between groups | 170.638 | 7 | 24.3768 | 0.9974 | 0.0000 | 170.638 | 7 | 24.3768 | 0.1 | 0.0000 |
| Within groups | 3616.67 | 15 | 241.111 | | | 3616.67 | 15 | 241.111 | | |
| Total (Corr.) | 3787.3 | 22 | | | | 3787.3 | 22 | | | |

**5th Instar**

| ANOVA Table | Wet Season | | | | | Dry Season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | p-Value | Sum of Squares | Df | Mean Square | F-Ratio | p-Value |
| Between groups | 1262.06 | 7 | 180.294 | 2.73 | 0.0000 | 1262.06 | 7 | 180.294 | 2.73 | 0.0000 |
| Within groups | 1058.09 | 16 | 66.1308 | | | 1058.09 | 16 | 66.1308 | | |
| Total (Corr.) | 2320.15 | 23 | | | | 2320.15 | 23 | | | |

**Appendix IX: Duration (mean total number of days) taken by *B. mori larvae* in different structures in wet and dry seasons**

**Wet Season**

| Summary Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
| L0 | 3 | 45.33 | 0.58 | 1.27% | 45 | 46 | 1 |
| L1 | 3 | 0.00 | | | 0 | 0 | 0 |
| L2 | 3 | 45.67 | 0.58 | 1.26% | 45 | 46 | 1 |
| L3 | 3 | 44.33 | 0.58 | 1.30% | 44 | 45 | 1 |
| L4 | 3 | 42.67 | 1.53 | 3.58% | 41 | 44 | 3 |
| L5 | 3 | 40.00 | 1.00 | 2.50% | 39 | 41 | 2 |
| L6 | 3 | 0.00 | 0.00 | | 0 | 0 | 0 |
| L7 | 3 | 0.00 | 0.00 | | 0 | 0 | 0 |
| Total | 22 | 29.73 | 20.87 | 70.20% | 0 | 46 | 46 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | p-Value |
|---|---|---|---|---|---|
| Between groups | 9137.7 | 7 | 1305.39 | 2108.7 | 0.0001 |
| Within groups | 8.66667 | 14 | 0.619048 | | |
| Total (Corr.) | 9146.36 | 21 | | | |

**Dry Season**

| Summary Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
| L0 | 3 | 38.33 | 0.58 | 1.51% | 38 | 39 | 1 |
| L1 | 3 | 0.00 | 0.00 | | 0 | 0 | 0 |
| L2 | 3 | 37.33 | 0.58 | 1.55% | 37 | 38 | 1 |
| L3 | 3 | 36.00 | 0.00 | 0% | 36 | 36 | 0 |
| L4 | 3 | 32.33 | 0.58 | 1.79% | 32 | 33 | 1 |
| L5 | 3 | 27.67 | 0.58 | 2.09% | 27 | 28 | 1 |
| L6 | 3 | 0.00 | 0.00 | | 0 | 0 | 0 |
| L7 | 3 | 0.00 | 0.00 | | 0 | 0 | 0 |
| Total | 24 | 21.46 | 17.27 | 80.49% | 0 | 39 | 39 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | p-Value |
|---|---|---|---|---|---|
| Between groups | 6859.29 | 7 | 979.899 | 5879.39 | 0.0001 |
| Within groups | 2.66667 | 16 | 0.166667 | | |
| Total (Corr.) | 6861.96 | 23 | | | |

**Appendix X: Duration (mean total number of days) taken by Eri larvae in different structures in wet and dry seasons**

**Wet Season**

| Summary Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
| L0 | 3 | 39.33 | 0.58 | 1.47% | 39 | 40 | 1 |
| L1 | 3 | 0.00 | 0.00 | | 0 | 0 | 0 |
| L2 | 3 | 39.33 | 0.58 | 1.47% | 39 | 40 | 1 |
| L3 | 3 | 36.33 | 0.58 | 1.59% | 36 | 37 | 1 |
| L4 | 3 | 35.33 | 0.58 | 1.63% | 35 | 36 | 1 |
| L5 | 3 | 34.33 | 0.58 | 1.68% | 34 | 35 | 1 |
| L6 | 3 | 0.00 | 0.00 | | 0 | 0 | 0 |
| L7 | 3 | 0.00 | 0.00 | | 0 | 0 | 0 |
| Total | 24 | 23.08 | 18.34 | 79.47% | 0 | 40 | 40 |

| ANOVA Table | | | | | |
|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | p-Value |
| Between groups | 7736.5 | 7 | 1105.21 | 5305.03 | 0.00001 |
| Within groups | 3.33333 | 16 | 0.208333 | | |
| Total (Corr.) | 7739.83 | 23 | | | |

**Dry Season**

| Summary Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
| L0 | 3 | 29.67 | 1.15 | 3.89% | 29 | 31 | 2 |
| L1 | 3 | 0.00 | 0.00 | | 0 | 0 | 0 |
| L2 | 3 | 30.33 | 0.58 | 1.90% | 30 | 31 | 1 |
| L3 | 3 | 23.33 | 0.58 | 2.47% | 23 | 24 | 1 |
| L4 | 3 | 23.33 | 0.58 | 2.47% | 23 | 24 | 1 |
| L5 | 3 | 21.33 | 0.58 | 2.71% | 21 | 22 | 1 |
| L6 | 3 | 0.00 | 0.00 | | 0 | 0 | 0 |
| L7 | 3 | 0.00 | 0.00 | | 0 | 0 | 0 |
| Total | 24 | 16.00 | 13.01 | 81.32% | 0 | 31 | 31 |

| ANOVA | | | | | |
|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | p-Value |
| Between groups | 3888.67 | 7 | 555.524 | 1666.57 | 0.00 |
| Within groups | 5.33333 | 16 | 0.333333 | | |
| Total (Corr.) | 3894 | 23 | | | |

**Appendix XI: The larval duration of *B. mori* and Eri per instars reared in the different structure condition**

Goodness-of-Fit Test for *B. mori and* Eri worm

| | | Wet Season | | Dry Season | | | Wet Season | | Dry Season | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Class | Structure | Observed Frequency | Expected Frequency | Observed Proportion | Expected Proportion | Contribution to Test Statistic | Observed Frequency | Expected Frequency | Observed Proportion | Expected Proportion | Contribution to Test Statistic |
| 1 | L0 | 4 | 5.93 | 0.14 | 0.20 | 0.63 | 3 | 4.70 | 0.13 | 0.20 | 0.61 |
| 2 | L2 | 4 | 5.93 | 0.14 | 0.20 | 0.63 | 3 | 4.70 | 0.13 | 0.20 | 0.61 |
| 3 | L3 | 4 | 5.93 | 0.14 | 0.20 | 0.63 | 4 | 4.70 | 0.17 | 0.20 | 0.10 |
| 4 | L4 | 8 | 5.93 | 0.27 | 0.20 | 0.73 | 6 | 4.70 | 0.26 | 0.20 | 0.36 |
| 5 | L5 | 9 | 5.93 | 0.30 | 0.20 | 1.60 | 9 | 4.70 | 0.38 | 0.20 | 3.93 |
| | | Chi-Square = 4.19884 with 4 d.f. p-Value = 0.3798 | | | | | Chi-Square = 5.62766 with 4 d.f. P-Value = 0.2287 | | | | |

**Appendix XII: *B. mori* defective cocoons during wet and dry season**

| | | Wet Season | | | | | Dry Season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Class | Structure | Observed Frequency | Expected Frequency | Observed Proportion | Expected Proportion | Contribution to Test Statistic | Observed Frequency | Expected Frequency | Observed Proportion | Expected Proportion | Contribution to Test Statistic |
| **Defective Cocoons (Double)** | | | | | | | | | | | |
| 1 | L0 | 25 | 25 | 0.25 | 0.25 | 0 | 0 | 20 | 0 | 0.2 | 20 |
| 2 | L2 | 25 | 25 | 0.25 | 0.25 | 0 | 0 | 20 | 0 | 0.2 | 20 |
| 3 | L3 | | | | | | 0 | 20 | 0 | 0.2 | 20 |
| 4 | L4 | 13 | 25 | 0.13 | 0.25 | 5.76 | 25 | 20 | 0.25 | 0.2 | 1.25 |
| 5 | L5 | 38 | 25 | 0.38 | 0.25 | 6.76 | 75 | 20 | 0.75 | 0.2 | 151.25 |
| | | Chi-Square = 12.52 with 3 d.f. P-Value = 0.0058 | | | | | Chi-Square = 212.5 with 4 d.f. P-Value = 0.0000 | | | | |
| | | | | | | | | | | | |
| **Defective Cocoons (Inside Stained)** | | | | | | | | | | | |
| 1 | L0 | 0 | 20 | 0 | 0.2 | 20 | 0 | 20 | 0 | 0.2 | 20 |
| 2 | L2 | 67 | 20 | 0.67 | 0.2 | 110.45 | 0 | 20 | 0 | 0.2 | 20 |
| 3 | L3 | 0 | 20 | 0 | 0.2 | 20 | 0 | 20 | 0 | 0.2 | 20 |
| 4 | L4 | 33 | 20 | 0.33 | 0.2 | 8.45 | 25 | 20 | 0.25 | 0.2 | 1.25 |
| 5 | L5 | 0 | 20 | 0 | 0.2 | 20 | 75 | 20 | 0.75 | 0.2 | 151.25 |
| | | Chi-Square = 178.9 with 4 d.f. P-Value = 0.0000 | | | | | | | | | |
| | | | | | | | | | | | |
| **Defective Cocoons (Outside Stained)** | | | | | | | | | | | |
| 1 | L0 | 14 | 20.02 | 0.13986 | 0.2 | 1.81021 | 0 | 20 | 0 | 0.2 | 20 |
| 2 | L2 | 14 | 20.02 | 0.13986 | 0.2 | 1.81021 | 40 | 20 | 0.4 | 0.2 | 20 |
| 3 | L3 | 14 | 20.02 | 0.13986 | 0.2 | 1.81021 | 20 | 20 | 0.2 | 0.2 | 0 |
| 4 | L4 | 29 | 20.02 | 0.28971 | 0.2 | 4.02799 | 20 | 20 | 0.2 | 0.2 | 0 |
| 5 | L5 | 29 | 20.02 | 0.28971 | 0.2 | 4.02799 | 20 | 20 | 0.2 | 0.2 | 0 |
| | | Chi-Square = 13.4866 with 4 d.f. P-Value = 0.0091 | | | | | Chi-Square = 40.0 with 4 d.f. P-Value = 0.0000 | | | | |
| | | | | | | | | | | | |
| **Defective Cocoons (Malformed)** | | | | | | | | | | | |
| 1 | L0 | 0 | 20 | 0 | 0.2 | 20 | 17 | 20.04 | 0.16 | 0.2 | 0.4611 |
| 2 | L2 | 40 | 20 | 0.4 | 0.2 | 20 | 17 | 20.04 | 0.16 | 0.2 | 0.4611 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | L3 | 0 | 20 | 0 | 0.2 | 20 | 17 | 20.04 | 0.16 | 0.2 | 0.4611 |
| 4 | L4 | 20 | 20 | 0.2 | 0.2 | 0 | 17 | 20.04 | 0.16 | 0.2 | 0.4611 |
| 5 | L5 | 40 | 20 | 0.4 | 0.2 | 20 | 33 | 20.04 | 0.32 | 0.2 | 8.3813 |
| | | Chi-Square = 80.0 with 4 d.f. P-Value = 0.0000 | | | | | Chi-Square = 10.2259 with 4 d.f. P-Value = 0.0368 | | | | |
| | | | | | | | | | | | |
| **Defective Cocoons (Flimsy)** | | | | | | | | | | | |
| 1 | L0 | 20 | 20.004 | 0.19996 | 0.2 | 0.00 | 25 | 20 | 0.25 | 0.2 | 1.25 |
| 2 | L2 | 20 | 20.004 | 0.19996 | 0.2 | 0.00 | 25 | 20 | 0.25 | 0.2 | 1.25 |
| 3 | L3 | 0 | 20.004 | 0 | 0.2 | 20.00 | 0 | 20 | 0 | 0.2 | 20 |
| 4 | L4 | 60 | 20.004 | 0.59988 | 0.2 | 79.97 | 25 | 20 | 0.25 | 0.2 | 1.25 |
| 5 | L5 | 0 | 20.004 | 0 | 0.2 | 20.00 | 25 | 20 | 0.25 | 0.2 | 1.25 |
| | | Chi-Square = 119.976 with 4 d.f. P-Value = 0.0000 | | | | | Chi-Square = 25.0 with 4 d.f. P-Value = 0.0001 | | | | |
| | | | | | | | | | | | |
| **Defective Cocoons (Pierced)** | | | | | | | | | | | |
| 1 | L0 | 0 | 19.98 | 0 | 0.2 | 19.98 | 50 | 20 | 0.5 | 0.2 | 45 |
| 2 | L2 | 33 | 19.98 | 0.33033 | 0.2 | 8.4845 | 50 | 20 | 0.5 | 0.2 | 45 |
| 3 | L3 | 33 | 19.98 | 0.33033 | 0.2 | 8.4845 | 0 | 20 | 0 | 0.2 | 20 |
| 4 | L4 | 33 | 19.98 | 0.33033 | 0.2 | 8.4845 | 0 | 20 | 0 | 0.2 | 20 |
| 5 | L5 | 0 | 19.98 | 0 | 0.2 | 19.98 | 0 | 20 | 0 | 0.2 | 20 |
| | | Chi-Square = 65.4135 with 4 d.f. P-Value = 0.0000 | | | | | Chi-Square = 150.0 with 4 d.f. P-Value = 0.0000 | | | | |
| | | | | | | | | | | | |

**Appendix XIII: Eri defective cocoons during wet and dry season**

| | | Wet Season | | | | | Dry Season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Class | Structure | Observed Frequency | Expected Frequency | Observed Proportion | Expected Proportion | Contribution to Test Statistic | Observed Frequency | Expected Frequency | Observed Proportion | Expected Proportion | Contribution to Test Statistic |
| **Defective Cocoons (Double)** | | | | | | | | | | | |
| 1 | L0 | 75 | 21.66 | 0.692521 | 0.2 | 131.355 | 67 | 20 | 0.67 | 0.2 | 110.45 |
| 2 | L2 | 33 | 21.66 | 0.304709 | 0.2 | 5.93701 | 33 | 20 | 0.33 | 0.2 | 8.45 |
| 3 | L3 | 0 | 21.66 | 0 | 0.2 | 21.66 | 0 | 20 | 0 | 0.2 | 20 |
| 4 | L4 | 0 | 21.66 | 0 | 0.2 | 21.66 | 0 | 20 | 0 | 0.2 | 20 |
| 5 | L5 | 0 | 21.66 | 0 | 0.2 | 21.66 | 0 | 20 | 0 | 0.2 | 20 |
| | | Chi-Square = 202.272 with 4 d.f. P-Value = 0.0000 | | | | | Chi-Square = 178.9 with 4 d.f. P-Value = 0.0000 | | | | |
| | | | | | | | | | | | |
| **Defective Cocoons (Inside Stained)** | | | | | | | | | | | |
| 1 | L0 | 0 | 6.66 | 0 | 0.2 | 6.66 | 0 | 4 | 0 | 0.2 | 4 |
| 2 | L2 | 0 | 6.66 | 0 | 0.2 | 6.66 | 0 | 4 | 0 | 0.2 | 4 |
| 3 | L3 | 0 | 6.66 | 0 | 0.2 | 6.66 | 0 | 4 | 0 | 0.2 | 4 |
| 4 | L4 | 33 | 6.66 | 0.990991 | 0.2 | 104.174 | 20 | 4 | 1 | 0.2 | 64 |
| 5 | L5 | 0 | 6.66 | 0 | 0.2 | 6.66 | 0 | 4 | 0 | 0.2 | 4 |
| | | Chi-Square = 130.814 with 4 d.f. P-Value = 0.0000 | | | | | Chi-Square = 80.0 with 4 d.f. P-Value = 0.0000 | | | | |
| | | | | | | | | | | | |
| **Defective Cocoons (Outside Stained)** | | | | | | | | | | | |
| 1 | L0 | 25 | 18.32 | 0.272926 | 0.2 | 2.43572 | 33 | 23.32 | 0.283019 | 0.2 | 4.01811 |
| 2 | L2 | 33 | 18.32 | 0.360262 | 0.2 | 11.7632 | 33 | 23.32 | 0.283019 | 0.2 | 4.01811 |
| 3 | L3 | 33 | 18.32 | 0.360262 | 0.2 | 11.7632 | 50 | 23.32 | 0.428816 | 0.2 | 30.5241 |
| 4 | L4 | 0 | 18.32 | 0 | 0.2 | 18.32 | 0 | 23.32 | 0 | 0.2 | 23.32 |
| 5 | L5 | 0 | 18.32 | 0 | 0.2 | 18.32 | 0 | 23.32 | 0 | 0.2 | 23.32 |
| | | Chi-Square = 62.6022 with 4 d.f. P-Value = 0.0000 | | | | | Chi-Square = 85.2003 with 4 d.f. P-Value = 0.0000 | | | | |
| | | | | | | | | | | | |
| **Defective Cocoons (Malformed)** | | | | | | | | | | | |
| 1 | L0 | 0 | 10 | 0 | 0.2 | 10 | 0 | 18.66 | 0 | 0.2 | 18.66 |
| 2 | L2 | 0 | 10 | 0 | 0.2 | 10 | 33 | 18.66 | 0.353698 | 0.2 | 11.0201 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | L3 | 50 | 10 | 1 | 0.2 | 160 | 60 | 18.66 | 0.643087 | 0.2 | 91.586 |
| 4 | L4 | 0 | 10 | 0 | 0.2 | 10 | 0 | 18.66 | 0 | 0.2 | 18.66 |
| 5 | L5 | 0 | 10 | 0 | 0.2 | 10 | 0 | 18.66 | 0 | 0.2 | 18.66 |
| | | Chi-Square = 200.0 with 4 d.f. P-Value = 0.0000 | | | | | Chi-Square = 158.586 with 4 d.f. P-Value = 0.0000 | | | | |
| | | | | | | | | | | | |
| **Defective Cocoons (Flimsy)** | | | | | | | | | | | |
| 1 | L0 | 0 | 0.6 | 0 | 0.2 | 0.6 | 0 | 0.4 | 0 | 0.2 | 0.4 |
| 2 | L2 | 0 | 0.6 | 0 | 0.2 | 0.6 | 0 | 0.4 | 0 | 0.2 | 0.4 |
| 3 | L3 | 3 | 0.6 | 1 | 0.2 | 9.6 | 2 | 0.4 | 1 | 0.2 | 6.4 |
| 4 | L4 | 0 | 0.6 | 0 | 0.2 | 0.6 | 0 | 0.4 | 0 | 0.2 | 0.4 |
| 5 | L5 | 0 | 0.6 | 0 | 0.2 | 0.6 | 0 | 0.4 | 0 | 0.2 | 0.4 |
| | | Chi-Square = 12.0 with 4 d.f. P-Value = 0.0174 | | | | | Chi-Square = 8.0 with 4 d.f. P-Value = 0.0916 | | | | |
| | | | | | | | | | | | |
| **Defective Cocoons (Pierced)** | | | | | | | | | | | |
| 1 | L0 | 0 | 6.66 | 0 | 0.2 | 6.66 | | | | | |
| 2 | L2 | 33 | 6.66 | 0.990991 | 0.2 | 104.174 | | | | | |
| 3 | L3 | 0 | 6.66 | 0 | 0.2 | 6.66 | | | | | |
| 4 | L4 | 0 | 6.66 | 0 | 0.2 | 6.66 | | | | | |
| 5 | L5 | 0 | 6.66 | 0 | 0.2 | 6.66 | | | | | |
| | | Chi-Square = 130.814 with 4 d.f. P-Value = 0.0000 | | | | | | | | | |
| | | | | | | | | | | | |

**Appendix XIV: Filament length for *B. mori* cocoon**

wet season

| Summary Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
| L2 | 10 | 1377.8 | 150.166 | 0.10899 | 1120 | 1580 | 460 |
| L3 | 10 | 1326.3 | 117.195 | 0.088362 | 1150 | 1502 | 352 |
| L4 | 10 | 1292.1 | 84.1156 | 0.0651 | 1168 | 1404 | 236 |
| L5 | 10 | 1163.4 | 91.9459 | 0.079032 | 1048 | 1348 | 300 |
| L0 | 10 | 1363.3 | 165.125 | 0.121121 | 1042 | 1578 | 536 |
| Total | 50 | 1304.58 | 143.243 | 0.1098 | 1042 | 1580 | 538 |

| ANOVA Table | | | | | |
|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value |
| Between groups | 293685 | 4 | 73421.3 | 4.64 | 0.0032 |
| Within groups | 711723 | 45 | 15816.1 | | |
| Total (Corr.) | 1.01E+06 | 49 | | | |

dry season

| Summary Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
| L2 | 10 | 1361.5 | 16657.8 | 12.23 | 1035 | 1580 | 460 |
| L3 | 10 | 13777.8 | 15016.6 | 10.9 | 1120 | 1580 | 352 |
| L4 | 10 | 1382.8 | 11722.8 | 8.48 | 1170 | 1520 | 236 |
| L5 | 10 | 1288.5 | 99217.2 | 7.7 | 1098 | 1425 | 300 |
| L0 | 10 | 1137.7 | 10539.8 | 9.26 | 1009 | 1320 | 536 |
| Total | 50 | 13096.6 | 15596.4 | 11.91 | 1009 | 1580 | 538 |

| ANOVA Table | | | | | |
|---|---|---|---|---|---|
| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value |
| Between groups | 426976 | 4 | 106745 | 6028 | 0.0004 |
| Within groups | 764940 | 45 | 16998.7 | | |
| Total (Corr.) | 1005410.00 | 49 | | | |

**Appendix XV: Filament length for Eri cocoon**

| wet season | | | | | | | |
|---|---|---|---|---|---|---|---|
| Summary Statistics | | | | | | | |
| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
| L2 | 10 | 437.6 | 32.2601 | 7.37% | 399 | 498 | 99 |
| L3 | 10 | 427.5 | 45.0043 | 10.53% | 345 | 498 | 153 |
| L4 | 10 | 402 | 54.5568 | 13.57% | 298 | 490 | 192 |
| L5 | 10 | 397.6 | 46.824 | 11.78% | 315 | 465 | 150 |
| L0 | 10 | 433.9 | 55.6546 | 12.83% | 310 | 496 | 186 |
| Total | 50 | 419.72 | 48.6214 | 11.58% | 298 | 498 | 200 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 13845.9 | 4 | 3461.47 | 1.53 | 0.2104 | | |
| Within groups | 101992 | 45 | 2266.49 | | | | |
| Total (Corr.) | 115838 | 49 | | | | | |

dry season

| Summary Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
| L2 | 10 | 445.7 | 53.4375 | 11.99 | 345 | 519 | 174 |
| L3 | 10 | 448.7 | 31.868 | 71.00 | 402 | 502 | 100 |
| L4 | 10 | 436.3 | 37.426 | 8.58 | 389 | 498 | 109 |
| L5 | 10 | 4032 | 54.5177 | 13.52 | 290 | 485 | 195 |
| L0 | 10 | 3767 | 40.4229 | 10.73 | 312 | 445 | 133 |
| Total | 50 | 42212 | 51.06 | 12.10 | 290 | 519 | 229 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 13845.9 | 4 | 9711.32 | 4.92 | 0.0022 | | |
| Within groups | 101992 | 45 | 1975.64 | | | | |
| Total (Corr.) | 115838 | 49 | | | | | |

**Appendix XVI: Cocoon weight for *B. mori* cocoon**

Wet season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0_1 | 10 | 1.32 | 0.04 | 0.05 | 0.77 | 0.91 | 0.14 |
| L2_1 | 10 | 1.36 | 0.03 | 0.04 | 0.81 | 0.91 | 0.10 |
| L3_1 | 10 | 1.35 | 0.06 | 0.07 | 0.71 | 0.93 | 0.22 |
| L4_1 | 10 | 1.33 | 0.07 | 0.09 | 0.67 | 0.91 | 0.24 |
| L5_1 | 10 | 1.36 | 0.05 | 0.06 | 0.78 | 0.92 | 0.14 |
| Total | 50 | 1.34 | 0.05 | 0.06 | 0.67 | 0.93 | 0.26 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.011928 | 4 | 0.002982 | 1.08 | 0.378 | | |
| Within groups | 0.12433 | 45 | 0.002763 | | | | |
| Total (Corr.) | 0.136258 | 49 | | | | | |

Dry season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0 | 10 | 1.74 | 0.16 | 0.09 | 1.40 | 1.90 | 0.50 |
| L2 | 10 | 1.65 | 0.17 | 0.10 | 1.40 | 1.90 | 0.50 |
| L3 | 10 | 1.57 | 0.13 | 0.09 | 1.40 | 1.80 | 0.40 |
| L4 | 10 | 1.44 | 0.40 | 0.28 | 0.70 | 1.90 | 1.20 |
| L5 | 10 | 2.78 | 4.30 | 1.55 | 0.90 | 15.00 | 14.10 |
| Total | 50 | 1.84 | 1.92 | 1.05 | 0.70 | 15.00 | 14.30 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 11.6252 | 4 | 2.9063 | 0.77 | 0.5474 | | |
| Within groups | 168.81 | 45 | 3.75133 | | | | |
| Total (Corr.) | 180.435 | 49 | | | | | |

**Appendix XVII: Cocoon weight for *Eri* cocoon**

Wet season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0_1 | 10 | 2.35 | 0.50 | 0.21 | 1.70 | 3.10 | 1.40 |
| L2_1 | 10 | 1.90 | 0.41 | 0.22 | 1.40 | 2.60 | 1.20 |
| L3_1 | 10 | 1.82 | 0.35 | 0.19 | 1.30 | 2.30 | 1.00 |
| L4_1 | 10 | 1.87 | 0.39 | 0.21 | 1.20 | 2.30 | 1.10 |
| L5_1 | 10 | 2.03 | 0.32 | 0.16 | 1.50 | 2.50 | 1.00 |
| Total | 50 | 1.99 | 0.43 | 0.21 | 1.20 | 3.10 | 1.90 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 1.8252 | 4 | 0.4563 | 2.87 | 0.0333 | | |
| Within groups | 7.143 | 45 | 0.158733 | | | | |
| Total (Corr.) | 8.9682 | 49 | | | | | |

Dry season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0 | 10 | 2.23 | 0.26 | 0.12 | 1.90 | 2.80 | 0.90 |
| L2 | 8 | 2.23 | 0.35 | 0.16 | 1.70 | 2.60 | 0.90 |
| L3 | 10 | 2.44 | 0.34 | 0.14 | 1.90 | 3.10 | 1.20 |
| L4 | 10 | 1.79 | 0.47 | 0.26 | 1.10 | 2.30 | 1.20 |
| L5 | 10 | 2.06 | 0.27 | 0.13 | 1.70 | 2.50 | 0.80 |
| Total | 48 | 2.15 | 0.40 | 0.19 | 1.10 | 3.10 | 2.00 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 2.32617 | 4 | 0.581542 | 4.91 | 0.0024 | | |
| Within groups | 5.093 | 43 | 0.118442 | | | | |
| Total (Corr.) | 7.41917 | 47 | | | | | |

**Appendix XVIII: Pupa weight for *B. mori***

Wet season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0_1 | 10 | 1.07 | 0.15 | 0.14 | 0.80 | 1.30 | 0.50 |
| L2_1 | 10 | 1.29 | 0.13 | 0.10 | 1.00 | 1.40 | 0.40 |
| L3_1 | 10 | 1.35 | 0.10 | 0.08 | 1.20 | 1.50 | 0.30 |
| L4_1 | 10 | 1.20 | 0.37 | 0.31 | 0.60 | 1.60 | 1.00 |
| L5_1 | 10 | 1.30 | 0.27 | 0.21 | 0.70 | 1.50 | 0.80 |
| Total | 50 | 1.24 | 0.24 | 0.19 | 0.60 | 1.60 | 1.00 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.48 | 4.00 | 0.12 | 2.38 | 0.07 | | |
| Within groups | 2.35 | 46.00 | 0.05 | | | | |
| Total (Corr.) | 2.84 | 50.00 | | | | | |

Dry season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0 | 10 | 1.44 | 0.14 | 0.10 | 1.20 | 1.60 | 0.40 |
| L2 | 10 | 1.39 | 0.12 | 0.09 | 1.20 | 1.60 | 0.40 |
| L3 | 10 | 1.33 | 0.09 | 0.07 | 1.20 | 1.50 | 0.30 |
| L4 | 10 | 1.21 | 0.40 | 0.33 | 0.40 | 1.60 | 1.20 |
| L5 | 10 | 1.24 | 0.26 | 0.21 | 0.70 | 1.50 | 0.80 |
| Total | 50 | 1.32 | 0.24 | 0.18 | 0.40 | 1.60 | 1.20 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.39 | 4 | 0.097984 | 1.81 | 0.1429 | | |
| Within groups | 2.48 | 46 | 0.054097 | | | | |
| Total (Corr.) | 2.88 | 50 | | | | | |

**Appendix XIX: Pupa weight for Eri**

Wet season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0_1 | 10 | 2.01 | 0.38 | 0.19 | 1.50 | 2.60 | 1.10 |
| L2_1 | 10 | 1.65 | 0.34 | 0.21 | 1.20 | 2.30 | 1.10 |
| L3_1 | 10 | 1.55 | 0.37 | 0.24 | 0.80 | 2.00 | 1.20 |
| L4_1 | 10 | 1.66 | 0.37 | 0.22 | 1.00 | 2.00 | 1.00 |
| L5_1 | 10 | 1.78 | 0.30 | 0.17 | 1.30 | 2.20 | 0.90 |
| Total | 50 | 1.73 | 0.37 | 0.22 | 0.80 | 2.60 | 1.80 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 1.246 | 4 | 0.3115 | 2.5 | 0.0554 | | |
| Within groups | 5.59 | 45 | 0.124422 | | | | |
| Total (Corr.) | 6.84 | 49 | | | | | |

Dry season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0 | 10 | 1.95 | 0.26 | 0.13 | 1.60 | 2.50 | 0.90 |
| L2 | 10 | 2.00 | 0.34 | 0.17 | 1.50 | 2.40 | 0.90 |
| L3 | 10 | 2.13 | 0.31 | 0.15 | 1.70 | 2.80 | 1.10 |
| L4 | 10 | 1.59 | 0.43 | 0.27 | 1.00 | 2.00 | 1.00 |
| L5 | 10 | 1.80 | 0.27 | 0.15 | 1.50 | 2.20 | 0.70 |
| Total | 50 | 1.89 | 0.37 | 0.19 | 1.00 | 2.80 | 1.80 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 1.68 | 4 | 0.422448 | 3.95 | 0.0081 | | |
| Within groups | 4.59 | 43 | 0.10686 | | | | |
| Total (Corr.) | 6.28 | 47 | | | | | |

**Appendix XX: Shell weight for *B. mori***

Wet season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0_1 | 10 | 0.23 | 0.067495 | 29.35% | 0.1 | 0.3 | 0.2 |
| L2_1 | 10 | 0.22 | 0.063246 | 28.75% | 0.1 | 0.3 | 0.2 |
| L3_1 | 11 | 0.227273 | 0.078625 | 34.59% | 0.1 | 0.4 | 0.3 |
| L4_1 | 10 | 0.2 | 0.066667 | 33.33% | 0.1 | 0.3 | 0.2 |
| L5_1 | 10 | 0.21 | 0.073787 | 35.14% | 0.1 | 0.3 | 0.2 |
| Total | 51 | 0.217647 | 0.068428 | 31.44% | 0.1 | 0.4 | 0.3 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.01 | 4 | 0.001575 | 0.32 | 0.8645 | | |
| Within groups | 0.23 | 46 | 0.004953 | | | | |
| Total (Corr.) | 0.23 | 50 | | | | | |

Dry season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0 | 10 | 0.29 | 0.06 | 0.20 | 0.20 | 0.40 | 0.20 |
| L2 | 10 | 0.23 | 0.07 | 0.29 | 0.10 | 0.30 | 0.20 |
| L3 | 10 | 0.32 | 0.32 | 1.00 | 0.10 | 1.20 | 1.10 |
| L4 | 10 | 0.20 | 0.08 | 0.41 | 0.10 | 0.30 | 0.20 |
| L5 | 11 | 0.17 | 0.08 | 0.46 | 0.10 | 0.30 | 0.20 |
| Total | 51 | 0.24 | 0.16 | 0.66 | 0.10 | 1.20 | 1.10 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.16 | 4 | 0.038928 | 1.62 | 0.1862 | | |
| Within groups | 1.11 | 46 | 0.024083 | | | | |
| Total (Corr.) | 1.26 | 50 | | | | | |

**Appendix XXI: Shell weight for Eri**

Wet season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0_1 | 10 | 0.30 | 0.13 | 0.44 | 0.20 | 0.60 | 0.40 |
| L2_1 | 10 | 0.24 | 0.12 | 0.49 | 0.10 | 0.50 | 0.40 |
| L3_1 | 10 | 0.26 | 0.10 | 0.37 | 0.20 | 0.50 | 0.30 |
| L4_1 | 10 | 0.21 | 0.06 | 0.27 | 0.10 | 0.30 | 0.20 |
| L5_1 | 10 | 0.23 | 0.07 | 0.29 | 0.10 | 0.30 | 0.20 |
| Total | 50 | 0.25 | 0.10 | 0.40 | 0.10 | 0.60 | 0.50 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.05 | 4 | 0.0117 | 1.2 | 0.3231 | | |
| Within groups | 0.44 | 45 | 0.009733 | | | | |
| Total (Corr.) | 0.48 | 49 | | | | | |

Dry season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0 | 10 | 0.25 | 0.05 | 0.21 | 0.20 | 0.30 | 0.10 |
| L2 | 8 | 0.21 | 0.04 | 0.17 | 0.20 | 0.30 | 0.10 |
| L3 | 10 | 0.29 | 0.06 | 0.20 | 0.20 | 0.40 | 0.20 |
| L4 | 10 | 0.19 | 0.06 | 0.30 | 0.10 | 0.30 | 0.20 |
| L5 | 10 | 0.44 | 0.62 | 1.41 | 0.10 | 2.20 | 2.10 |
| Total | 48 | 0.28 | 0.29 | 1.04 | 0.10 | 2.20 | 2.10 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.38 | 4 | 0.095854 | 1.15 | 0.345 | | |
| Within groups | 3.58 | 43 | 0.083157 | | | | |
| Total (Corr.) | 3.96 | 47 | | | | | |

**Appendix XXII: Shell/pupa ratio for *B. mori***

Wet season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0 | 10 | 0.22 | 0.06 | 0.26 | 0.13 | 0.30 | 0.17 |
| L2 | 10 | 0.17 | 0.04 | 0.24 | 0.10 | 0.23 | 0.13 |
| L3 | 10 | 0.16 | 0.07 | 0.41 | 0.08 | 0.33 | 0.25 |
| L4 | 10 | 0.16 | 0.07 | 0.44 | 0.10 | 0.33 | 0.23 |
| L5 | 10 | 0.16 | 0.06 | 0.37 | 0.09 | 0.29 | 0.20 |
| Total | 50 | 0.18 | 0.06 | 0.35 | 0.08 | 0.33 | 0.25 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.03 | 4 | 0.00639 | 1.78 | 0.1494 | | |
| Within groups | 0.16 | 45 | 0.003589 | | | | |
| Total (Corr.) | 0.19 | 49 | | | | | |

Dry season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0 | 10 | 0.20 | 0.04 | 0.19 | 0.13 | 0.27 | 0.14 |
| L2 | 10 | 0.16 | 0.04 | 0.26 | 0.08 | 0.23 | 0.15 |
| L3 | 10 | 0.24 | 0.23 | 0.96 | 0.08 | 0.86 | 0.78 |
| L4 | 10 | 0.20 | 0.20 | 0.96 | 0.10 | 0.75 | 0.65 |
| L5 | 10 | 0.15 | 0.07 | 0.49 | 0.07 | 0.29 | 0.22 |
| Total | 50 | 0.19 | 0.14 | 0.72 | 0.07 | 0.86 | 0.79 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.05 | 4 | 0.012242 | 0.62 | 0.6518 | | |
| Within groups | 0.89 | 45 | 0.019804 | | | | |
| Total (Corr.) | 0.94 | 49 | | | | | |

**Appendix XXIII: Shell/pupa ratio for Eri**

Wet season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0 | 10 | 0.14 | 0.02 | 0.18 | 0.11 | 0.17 | 0.06 |
| L2 | 10 | 0.14 | 0.06 | 0.40 | 0.06 | 0.25 | 0.19 |
| L3 | 10 | 0.19 | 0.16 | 0.81 | 0.11 | 0.63 | 0.52 |
| L4 | 10 | 0.13 | 0.04 | 0.31 | 0.09 | 0.20 | 0.11 |
| L5 | 10 | 0.13 | 0.04 | 0.32 | 0.05 | 0.20 | 0.15 |
| Total | 50 | 0.15 | 0.08 | 0.54 | 0.05 | 0.63 | 0.58 |
| | | | | | | | |
| ANOVA Table | | | | | | | |
| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
| Between groups | 0.03 | 4 | 0.006428 | 1.01 | 0.4142 | | |
| Within groups | 0.29 | 45 | 0.006387 | | | | |
| Total (Corr.) | 0.31 | 49 | | | | | |

Dry season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0 | 10 | 0.13 | 0.03 | 0.21 | 0.09 | 0.17 | 0.08 |
| L2 | 8 | 0.11 | 0.02 | 0.18 | 0.08 | 0.13 | 0.05 |
| L3 | 10 | 0.14 | 0.02 | 0.17 | 0.11 | 0.18 | 0.07 |
| L4 | 10 | 0.11 | 0.03 | 0.25 | 0.08 | 0.17 | 0.09 |
| L5 | 10 | 0.23 | 0.29 | 1.24 | 0.05 | 1.05 | 1.00 |
| Total | 48 | 0.15 | 0.14 | 0.95 | 0.05 | 1.05 | 1.00 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.11 | 4 | 0.026726 | 1.47 | 0.2267 | | |
| Within groups | 0.78 | 43 | 0.018128 | | | | |
| Total (Corr.) | 0.89 | 47 | | | | | |

**Appendix XXIV: Shell/cocoon ratio for *B. mori***

Wet season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0_1 | 10 | 0.18 | 0.05 | 0.26 | 0.10 | 0.27 | 0.17 |
| L2_1 | 10 | 0.14 | 0.03 | 0.21 | 0.09 | 0.19 | 0.10 |
| L3_1 | 10 | 0.14 | 0.04 | 0.31 | 0.07 | 0.24 | 0.17 |
| L4_1 | 10 | 0.13 | 0.04 | 0.33 | 0.08 | 0.22 | 0.14 |
| L5_1 | 10 | 0.14 | 0.04 | 0.31 | 0.08 | 0.22 | 0.14 |
| Total | 50 | 0.15 | 0.04 | 0.30 | 0.07 | 0.27 | 0.20 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.02 | 4 | 0.004045 | 2.3 | 0.0737 | | |
| Within groups | 0.08 | 45 | 0.001762 | | | | |
| Total (Corr.) | 0.10 | 49 | | | | | |

Dry season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0 | 10 | 0.17 | 0.03 | 0.17 | 0.11 | 0.21 | 0.10 |
| L2 | 10 | 0.14 | 0.03 | 0.25 | 0.07 | 0.19 | 0.12 |
| L3 | 10 | 0.20 | 0.20 | 0.98 | 0.07 | 0.75 | 0.68 |
| L4 | 10 | 0.15 | 0.10 | 0.68 | 0.08 | 0.43 | 0.35 |
| L5 | 10 | 0.11 | 0.06 | 0.53 | 0.02 | 0.22 | 0.20 |
| Total | 50 | 0.15 | 0.11 | 0.68 | 0.02 | 0.75 | 0.73 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.05 | 4 | 0.011658 | 1.06 | 0.3869 | | |
| Within groups | 0.49 | 45 | 0.010989 | | | | |
| Total (Corr.) | 0.54 | 49 | | | | | |

**Appendix XXV: Shell/cocoon ratio for Eri**

Wet season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0_1 | 10 | 0.12 | 0.03 | 0.23 | 0.10 | 0.19 | 0.09 |
| L2_1 | 10 | 0.12 | 0.04 | 0.36 | 0.05 | 0.20 | 0.15 |
| L3_1 | 10 | 0.15 | 0.08 | 0.55 | 0.10 | 0.38 | 0.28 |
| L4_1 | 10 | 0.12 | 0.03 | 0.28 | 0.08 | 0.17 | 0.09 |
| L5_1 | 10 | 0.12 | 0.03 | 0.30 | 0.05 | 0.17 | 0.12 |
| Total | 50 | 0.13 | 0.05 | 0.39 | 0.05 | 0.38 | 0.33 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.01 | 4 | 0.002087 | 0.87 | 0.4869 | | |
| Within groups | 0.11 | 45 | 0.002387 | | | | |
| Total (Corr.) | 0.12 | 49 | | | | | |

Dry season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0 | 10 | 0.11 | 0.02 | 0.19 | 0.08 | 0.14 | 0.06 |
| L2 | 8 | 0.10 | 0.02 | 0.17 | 0.08 | 0.12 | 0.04 |
| L3 | 10 | 0.12 | 0.02 | 0.15 | 0.09 | 0.15 | 0.06 |
| L4 | 10 | 0.11 | 0.03 | 0.25 | 0.08 | 0.17 | 0.09 |
| L5 | 10 | 0.21 | 0.27 | 1.28 | 0.05 | 0.96 | 0.91 |
| Total | 48 | 0.13 | 0.12 | 0.96 | 0.05 | 0.96 | 0.91 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.08 | 4 | 0.019367 | 1.27 | 0.297 | | |
| Within groups | 0.66 | 43 | 0.015263 | | | | |
| Total (Corr.) | 0.73 | 47 | | | | | |

**Appendix XXVI: Pupa/cocoon ratio for *B. mori***

Wet season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0_1 | 10 | 0.82 | 0.04 | 0.05 | 0.77 | 0.91 | 0.14 |
| L2_1 | 10 | 0.86 | 0.03 | 0.04 | 0.81 | 0.91 | 0.10 |
| L3_1 | 10 | 0.85 | 0.06 | 0.07 | 0.71 | 0.93 | 0.22 |
| L4_1 | 10 | 0.84 | 0.07 | 0.09 | 0.67 | 0.91 | 0.24 |
| L5_1 | 10 | 0.85 | 0.04 | 0.05 | 0.78 | 0.92 | 0.14 |
| Total | 50 | 0.84 | 0.05 | 0.06 | 0.67 | 0.93 | 0.26 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.01 | 4 | 0.002425 | 0.88 | 0.4855 | | |
| Within groups | 0.12 | 45 | 0.002767 | | | | |
| Total (Corr.) | 0.13 | 49 | | | | | |

Dry season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0 | 10 | 0.83 | 0.03 | 0.04 | 0.78 | 0.89 | 0.11 |
| L2 | 10 | 0.84 | 0.04 | 0.04 | 0.81 | 0.93 | 0.12 |
| L3 | 10 | 0.85 | 0.06 | 0.07 | 0.71 | 0.93 | 0.22 |
| L4 | 10 | 0.83 | 0.10 | 0.12 | 0.57 | 0.91 | 0.34 |
| L5 | 10 | 0.80 | 0.25 | 0.32 | 0.09 | 0.94 | 0.85 |
| Total | 50 | 0.83 | 0.12 | 0.15 | 0.09 | 0.94 | 0.85 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.02 | 4 | 0.004868 | 0.31 | 0.8715 | | |
| Within groups | 0.71 | 45 | 0.015834 | | | | |
| Total (Corr.) | 0.73 | 49 | | | | | |

**Appendix XXVII: Pupa/cocoon ratio for Eri**

Wet season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0_1 | 10 | 0.86 | 0.04 | 0.05 | 0.77 | 0.90 | 0.13 |
| L2_1 | 10 | 0.87 | 0.04 | 0.04 | 0.80 | 0.93 | 0.13 |
| L3_1 | 10 | 0.85 | 0.08 | 0.10 | 0.62 | 0.90 | 0.28 |
| L4_1 | 10 | 0.89 | 0.03 | 0.04 | 0.83 | 0.92 | 0.09 |
| L5_1 | 10 | 0.87 | 0.04 | 0.04 | 0.83 | 0.95 | 0.12 |
| Total | 50 | 0.87 | 0.05 | 0.06 | 0.62 | 0.95 | 0.33 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.01 | 4 | 0.002323 | 0.96 | 0.4365 | | |
| Within groups | 0.11 | 45 | 0.00241 | | | | |
| Total (Corr.) | 0.12 | 49 | | | | | |

Dry season Summary Statistics

| | Count | Average | Standard deviation | Coeff. of variation | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| L0 | 10 | 0.87 | 0.02 | 0.03 | 0.84 | 0.91 | 0.07 |
| L2 | 8 | 0.89 | 0.04 | 0.04 | 0.83 | 0.95 | 0.12 |
| L3 | 10 | 0.87 | 0.02 | 0.02 | 0.85 | 0.90 | 0.05 |
| L4 | 10 | 0.89 | 0.03 | 0.04 | 0.83 | 0.92 | 0.09 |
| L5 | 10 | 0.87 | 0.04 | 0.05 | 0.83 | 0.95 | 0.12 |
| Total | 48 | 0.88 | 0.03 | 0.04 | 0.83 | 0.95 | 0.12 |

ANOVA Table

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | | |
|---|---|---|---|---|---|---|---|
| Between groups | 0.00 | 4 | 0.001008 | 1.04 | 0.3991 | | |
| Within groups | 0.04 | 43 | 0.000971 | | | | |
| Total (Corr.) | 0.05 | 47 | | | | | |