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Studies on the Performance of Eri-Silkworm (*Samia cynthia ricini* Boisduval) (Lepidoptera: Saturniidae) Fed on Different Genotypes of Castor (*Ricinus communis* L.)

By

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Abbreviations

ACC- Accession

Approximate Digestibility (AD)

Ash – total ash (mineral) content

Ca- Calcium

CFb- crude fiber

CFt- Crude fat

CoW- Cocoon weight

CP - Crude protein content

CV- coefficient of variation

Dig- Digesta (Total Food Digestion)

DI – Disease incidence

DLY- Dry leaf biomass yield

DS- Disease severity

ECD – Efficincy of conversion of digesta

ECDco- Efficiency of conversion of digesta to cocoon

ECDla- Efficiency of conversion of digesta to larval biomass

ECI – Efficiency of conversion of ingesta

ECIco- Efficiency of conversion of Ingesta to cocoon

ECIla - Efficiency of conversion of Ingesta to larval biomass

EIAR- Ethiopian Institute of gricultural Research

EHNRI- Ethiopian Health and Nutrition Research Institute

ERR- Effective Rate of Rearing

Exc- Excreta

Fecun- Fecundity

FLY- Fresh leaf biomass yield

HaP – Hatching percent of eggs

IL- Internode length

InfL- Infloresecence length

Ing- Total ingesta (Total Food Consumption)

K-potassium

LA- Leaf area

LaD- Larval duration

Larw- Larval weight

LPB- Length of primary branches

MARC- Melkassa Agricultural Research Center

Mg - Magnesium

Mois - Moisture content

N- Nitrogen

NL- Number of leaves

NPB- Number of primary branches

P- Phosphorus

Pr- Probability

PH – plant height

Puw- Pupal weight

RCBP- Rural Capacity Building Project

RCI - Relative Consumption Index

RGR - Relative Growth Rate

RR- Reference Ratio

S.c. ricini – *Samia Cynthia ricini*

SE- Standard error

Shw- Shell weight

SiR- silk (Shell) ratio

ST- Stem thickness

Surv - Survival Rate

SY – Seed yield

SW- 1000 seed weight

Tan- Tannin content

Tocrb-Total carbohydrate

Abstract

The growth, development, reproduction as well as yield of silkworms can be greatly affected by their feed sources. In the present investigation, eight different castor genotypes (Abaro, Acc 106584, Acc 203241, Acc 208624, Ar sel, Bako, GK sel and local genotype) were evaluated for their importance as feed for eri silkworms in Melkassa, East- Shewa zone, Oromia Regional State. The genotypes showed significantly wide variation in their quantitative and qualitative traits in field studies. Similarly, significant differences were obtained in biochemical compositions of castor genotypes as well as rearing performance and feeding efficiency of eri silkworms when different castor genotypes were fed. On the other hand, relationship of biochemical constituents of castor genotypes with rearing performance of eri silkworms revealed strong positive correlation of nitrogen, crude protein and moisture content of castor leaves with all larval, cocoon and grainage parameters of eri silkworms. Among castor genotypes tested, Acc 208623 revealed 13531.9 kg/ha and 3113.1 kg/ha of fresh and dry leaf biomass yield, respectively and 1181.24 kg/ha of seed yield in field condition. Moreover, its leaf composition reflected 75.086 % moisture, 24.908 % crude protein, 41.078 % total carbohydrate, 17.736% crude fiber, 15.000 % ash (total minerals), 205.893 mg/100g tannins as well as 3.985 % nitrogen, 1.908 PPM phosphorus, 8027.6 PPM potassium, 155.089 PPM calcium and 17.456 PPM magnesium. Its silkworm rearing performance indicated 8.05 g matured larval weight, 3.31 g cocoon weight, 2.83 g pupal weight, 0.477 g shell weight and 14.424 % silk ratio, 73.18% effective rate of rearing (ERR), 78.349 % survival rate, 374.00 eggs as fecundity and 87.00 % hatchability of eggs. Moreover, In feeding efficiency analysis conducted for its fifth instar larva, it expressed 6.904 g/larva of ingesta or food consumption, 3.574 g/larva digesta or food digestion, 3.330 g/larva excreta, 51.766 % approximate digestibility, 2.073 reference ratio, 0.862 relative consumption rate, 0.255 relative growth rate, 31.406 % efficiency to convert ingested leaves to larval biomass, 64.649% efficiency to

convert digested food to larval biomass, 19.236 % efficiency to convert ingested food to cocoon and 37.173 % efficiency to convert digested food to cocoon. Therefore, Acc 208623, which has green stem and leaf colors, was found to be superior and recommended to future development works.

1. Introduction

Silk is a functional term used to describe protein fibers that are secreted by arthropods. It is a natural protein fiber and is very soft, lustrous, smooth, strong and durable than any natural or artificial fibre (Shao and Vollrath, 2002). Silk fabrics are sensual and luxurious, and synonymous with the elegance and beauty of fashionable clothing. Stories and images weave magic around the fabric with a sense of excitement and romantic charm for those involved (Lamelu, 1998) (Hiwar, 2001) and (Craig and Riekel, 2002).

Silkworms can be taxonomically classified as Phylum: Arthropoda, Class: Insecta, Order: Lepidoptera, Sub order: Ditrysia, Super family: Bombycoidea and Family: Bombycidae, Saturnidae, Lasiocampidae, Thaumetopoidae, etc. However, Jolly *et al*. (1974) reported about 80 species occurring in Asia and Africa to produce wild silk of economic value.

Further more, silks worms can be broadly classified as mulberry silkworms and wild or non mulberry silkworms. Therefore, mulberry sericulture deals with production of mulberry silk from domesticated silkworm *Bombyx mori* which significantly dominate the international silk trade. However, non-mulberry sericulture is universally known as forest or wild sericulture and deals about silk produced from wild silk producing moths from different lepidopteran families including Saturniidae, Lasiocompidae and Thaumetopoeidae (Peigler, 1993). So, eri, tropical and temperate tasar, muga, gonometa and anaphe are some of the non-mulberry silks produced from non mulberry or wild silkworms (Peigler, 1993).

The industrial and commercial use of silk, the historical and economic importance of production and its application finely contributed to the silkworm promotion all over the world (Ramesh-Babu et al., 2009). Sericulture has provided the basis for the economic development of ancient China. It has the potential to make a significant contribution to the economy of many other countries where there is surplus labor, low-costs of production and a willingness to adopt new technologies (Hanumappa, 1986).

Gu (1999) indicated that there is a good potential for sericulture development, not only in the East Asia, but also in Eastern Europe, Central Asia, Latin America and the Africa Region based up on overall socio-economic and agro-climatic conditions (rainfall, soil, temperature, humidity, light and air). Accordingly, 35-40 countries have been involved in sericulture industry development in the world. More than half of these countries are situated in Asia and more than 85 percent of raw silk or silk yarn are produced by the five major silk producing countries such as China, India, Uzbekistan, Brazil and Thailand recently (Gu, 1999)). In 1999, for example, world production of raw silk from mulberry was just 76,300 tons, of which 97% came from the major six producer countries, viz. China (73%), India (18%), Brazil (2%), Thailand (1.5%), Uzbekistan (1.5%) and Vietnam (1%). The remaining 4% came from other countries, many of which were significant producers in the not-too-distant past. In another way, world silk importers are also Italy, India, Japan and China (Gu, 1999).

On the other hand, a greater portion of the world's population lives in developing nations and depends on agriculture, the primary sector for livelihood (Rani, 2007). However, the productivity levels in the agriculture sector are low. This is not only because of pressure on land, but agriculture in these nations is also often characterized by poor organization, limited capital and investment. Hence, the developing countries are directing their development strategies on the productivity levels in rural areas. So, some of the above mentioned countries are integrating agricultural practices with sericulture as with animal husbandry, dairying, fisheries and horticulture, (Sahay *et al.*, 1997), (Jayaram *et al.*, 1998) and (Tzenov, 2007).

Silk has been used for textiles for thousands of years in Africa too (Raina, 2004a). While not as widely pursued as in Asia, wild silks have been used in Africa for centuries (McKinney and Eicher, 2009, Gowdey, 1953) and some had also exported to Europe (E.g. Anaphe silk from Uganda). The potential of the African indigenous silkmoth species for wild silk production has been well documented in Nigeria (Ashiru, 1991), Uganda (Kato, 2000) and Kenya (Kioko *et al*. 2000; Mbahin *et al*. 2008) and other Central and southern African countries.

In Ethiopia, agricultural production is of a subsistence nature. Poverty and unemployment are the main challenges to the population. Poverty alleviation and employment creation, therefore, requires additional on farm and off farm income generation technologies like raising of silkworms (silk production) (Metaferia et al., 2007).

Silk has played an important part in the social and religious life of Ethiopia from the earliest days of the Kingdom of Axum. This silk was imported in large quantities from India, Arabia and China and stored in vast caverns in the central highlands of Ethiopia and Ethiopian Emperors would make prodigious gifts of silk to other churches. Ceremonial umbrellas, binding of sacred books, covers for wooden altars and spectacular hangings have all been produced from silk over the centuries. Apart from some historical traditions along the Kenyan coast, Ethiopia has long been the only major silk weaving region in eastern Africa. The silk yarns used for both art and function were imported from China (Spring and Hudson, 2002).

Ethiopia is granted with diversified climate, vegetation and topography. This is also true for diversified options of sericulture industry which are adopted on different vegetation (for rearing of silk-worms) and different species of silkworms. However, there were no known records of silk being produced in the country until 1930's (Period of colonization). In 1930's, however, the Italians realized the suitability of climatic condition for rearing of silkworms and availability of necessary resources and conducted silkworm rearing at 11 sites though this had been stopped immediately when they left the country (Belli, 1947). He also reported that the possibility of silkworm rearing in different parts of the country if worms are protected against night cold.

Later on, visits paid by expatriate professionals also confirmed the immense potential of the country for silk production (Huge, unpublished) and sericulture project was reinitiated jointly by Ethiopian Institute of Agricultural Research /EIAR/ and Ministry of Science and Technology /MST/ in early 2000's and an exciting opportunity for producing silk came in to re-emergence with the introduction of eri and mulberry silkworms from different countries and it adds to the ancient skills of weaving and design in Ethiopia (Metaferia *et al.*, 2007).

However, most researchers including expatriate professionals agree that eri silkworm is very suitable for Ethiopian conditions for many reasons: -

- The eri silk worm is hardy, and disease resistant. This is a clear advantage over the mulberry silk worm especially given the typical rearing conditions in rural households which are not highly sanitary.
- Labor requirements for cocoon production can be easily handled at a household level. The technical knowledge required can be acquired through basic training.
- The capital requirement for establishing household level cocoon production is minimal, and much of the required equipment can be constructed locally.
- The production cycle of eri silk can be as short as 46 days, meaning that a household can obtain some income every 46-65 days.
- Eri silk thread is produced by spinning the cocoon fibers. This spinning can be done easily on the drop spindle, which is the ancient but appropriate spinning technique used all over Ethiopia for spinning cotton. Women can gain extra income from their silk business if they spin and sell the thread rather than selling the cocoons.

As a result, silk production from eri silkworm (*S. c. ricini*) is commonly practiced in Ethiopia currently. Even though it is recently introduced in the country, promising results have been recorded in terms of generation of income and creation of employment opportunities. In Ethiopian, availability of adequate labor, suitability of soil and climatic conditions for host plant cultivation as well as eri-silkworm rearing and easy transferability of related technologies developed else where are among the factors contributed to progresses in eri-culture. Moreover, the familiarity of Ethiopians in spinning other fabrics (cotton) is believed to give an added advantage for utilizing the technology (Metaferia *et al.*, 2007) and (Hajare et al., 2007).

The eri silkworm, *S. c. ricini*, which belong to family saturnidae, is the one among the commercially exploited silkworm species and can be reared in doors through out the year to produce eri silk (Joshi, 1992). The practice of eri silk production is termed as eri-culture. Eri-culture involves diverse activities from the cultivation of host plants, rearing of eri-worms and production of silk cocoons (which are agricultural practices) to the silk processing (spinning, dyeing, weaving and making silk fabrics) engage people of all spectrums regardless of age (youth, old, handicapped), sex (female, male) and educational level (Rao *et al.*, 2005).

Further, the by-products from eri-culture also find uses ranging from fertilizers in rural areas to pharmaceuticals industries which could be tapped to increase income of the farmers manifold in the long term. In addition, recent interest in finding new and environmentally benign materials (Craig and Riekel, 2002, Sutherland *et al.*, 2009), new commercial markets such as cosmetics, animal feeds, dietary additives (Reddy, 2008) as well as diverse medical products and optical technologies are beginning to integrate silk materials e.g. (Lizuka, 2002) (Altman *et al.*, 2003) (Kim *et al,* 2003). The unique microstructure, optical properties, molecular composition and mechanical properties of silk spun by the Saturniidae are being recognized for their potential for biomedical

(Acharya *et al.*, 2008) (Akai and Nagashima, 1999) and industrial use (Dash, *et al.*, 2008) (Mandal and Kundu, 2009). It is very helpful to conservation of degrading environments and highly labor intensive and of paramount importance for resource poor farmers in generating income and creating gainful employment to the growing labor force in rural and peri urban areas. Hence, it apparently serves in contributing to improvement of the living standard of the people and as a source of foreign currency earning for developing countries (Raina, 2004b).

The eri-silkworm, *Samia cynthia ricini* Boisduval, is one of the most exploited and commercialized non mulberry silkworms. It is a sericigenous insect exploited for its valuable eri silk. It is a multivoltine and polyphagous species and it can be reared throughout the year depending on the availability feed (Debaraj et al., 2003). The agro-ecology and feed availability are the major requirements which have significant effect on rearing of larvae of this insect and finally cocoon crop yield and quality. The ideal range of temperature for the growth of eri silkworms is from 20^{o}C to 30^{o}C, however, increase in temperature beyond 35^{o}C causes less spinning, mortality of larvae and pupae and poor moth emergence and sterility at adult stage. The ideal humidity for eri silkworm rearing is greater than 50% (Thangavelu and Phukon, 1983) and (Sarkar, 1988).

Castor (*Ricinus communis* L.) is the primary food plant, which can ensure production of good quality cocoons. However, *Manihot utilissima, Heteropanax fragrance*, *Curica papaya*, *Evodia falxinifolia*, *Sapium eugenifolia*, *Jatropa curcas*, *Gomelina arborea*, etc. are secondary and tertiary host plants during unfavorable seasons (Hajarika et al., 2003) and (Chowdhary, 2006). Similarly, Dayashankar (1982), Devaiah *et al*. (1985) and Sakthivel (2004), have reported the superiority of castor over all other hosts including cassava for larval and cocoon traits.

The castor oil plant, *Ricinus communis* L., the primary food plant of eri silkworms, is a species of flowering plant in the family, Euphorbiaceae. It or is indigenous to the southeastern Mediterranean Basin, Eastern Africa (including Ethiopia) and India, but is widespread throughout tropical regions. It grows widely and abundantly in many parts of the Ethiopia. It is found wild on rocky hillsides, and in waste places, fallow fields, along road shoulders and at the edges of cultivated lands. Castor has also established in waste areas, the edges of cultivated fields, canal banks, etc (Zimmerman *et al.*, 1958).

Castor seed contains 50-55% oil (Weiss, 1971). Castor oil can also be considered as commercial crop from seed and ericulture businesses. So, castor oil is sold either for pharmaceutical or industrial use: as a basic ingredient in the production of nylon, plasticizers, jet engine and other lubricants, heavy duty automotive greases, coatings and inks, paints, varnishes, surfactants, polyurethanes, soaps, polishes, fly papers and many other chemical and cosmetic derivatives. Medicinal and pharmaceutical applications of castor oil are also diverse. However, the seeds and residual cake are highly poisonous to be used as animal feed because it contains toxic protein ricin, which inactivates eukaryotic ribosome irreversibly (Weiss, 1971)) unless processed to remove the poison.

Like any other field crops, it also yields substantial quantity of above ground bio-mass at the end of crop season. Castor stems form good source as pulp in paper industry and forms a good stratum for oyster mushroom culture. Cellulose from the stems is used for making cardboard (Suryanarayana *et al.*, 2002). In addition, the castor stems can be used in hut roofs and other on-farm uses (Hazarika et al.,2006). Moreover, it is well known that 25-30% foliage from castor plantations can also be utilized for eri silkworm rearing without affecting the seed production (Mishra, 1999; Raghavaiah, 2003a; Krishna Rao, *et a*l, 2004). Jayaraj (2004) reported that harvesting 25-40 % leaves does not make any appreciable loss in castor seed yield. Castor cultivation for eri silkworm rearing and seed may work out the businesses to be more economical (Devaiah *et al.*, 1985)).

However, castor shows a wide range of variability in nature. It has been well recognized that morphological features and nutritive values of the leaves differ significantly from variety to variety, season to season and over locations. The morphological traits and nutritional factors could be used in selection of castor genotypes. In addition, the quality of feeds given to insects generally affects the economic products of insects. Similarly, the superiority of castor over the rest host plants of eri silkworms confirms that acceptability and utilization by the worms vary according to feed quality (Solanki and Joshi, 2001).

So, silkworm nutrition is one and the major factor which affect development and productivity of silkworms (Milner, 2004; Ogunbanwo and Okanlawon, 2009). Silkworm nutrition deals about the substances required by silkworm for its growth and metabolic functions and obtained from ingested food and some other nutritional components synthesized through various biochemical pathways including proteinous silk fiber of commercial interest (Takano and Arai, 1978; Hamano *et al.*, 1986; Zhang *et al.*, 2002).

Silkworms have adapted to feeding to derive and store adequate energy, nutrients and water from the food they consume. Silkworm larvae obtain nutrients from leaves to build up body, sustain life, spin cocoons and produce eggs. Feeding silkworms provides energy for growth, development, reproduction and many of its other needs (Krishnaswami, 1978). Such nutritional requirement in food consumption have direct impact on the over all genetic traits such as larval and cocoon weight, amount of silk production, pupation and reproductive traits. In addition, the production of good quality and quantity of silk depends on larval nutrition and healthiness, which are influenced by the nutritive value of the leaves. Thus, successful sericulture depends on increased production of leaves with high nutritive values (Raina *et al.*, 2004a).

Moreover, the quality of castor leaves fed to the larvae of eri-silkworm does have a bearing effect on the quality of the cocoons produced. In silkworms, the effect of environment at one stage of the life cycle will be reflected in the subsequent stages (Ravikumar, 1988). For instance, the lower biomass accumulation leads to lower cocoon and pupal weight. Therefore, the better the quality of leaves, the greater the chances of getting good cocoon harvest. Nutritional status of leaves has also been implicated as a major factor in the survival, oviposition and fertility of eri silkworms and is known to influence the growth as well as cocoon quality. The importance of quality leaves and good nutrition during silkworm rearing has been recognized which effect on growth and development of silkworm and overall silk production (Sannappa and Jayaramaiah, 1999).

It has also been observed that the growth and development of silkworms and quality of silk cocoon produced are directly influenced by the variety and quality of leaves fed to the worms (Krishnaswami *et al.*, 1970). Morphological characters of leaves contribute to acceptability of leaves by by silkworms (Krishnaswami *et al.*, 1970). Gogoi and Goswami (1998) studied castor genotypes and observed variation in leaf yield in different genotypes. Significant positive correlation has been reported between chemical compositions of castor leaf and larval growth as well as cocoon characters (Sannappa and Jayaramaiah, 1999). So, nutrients appear to be important regulators of energy flow at all levels. Nutritional value of food plants either alone or in combination plays an important role in the larval growth and silk productivity. Nutritional status of leaves has been implicated as a major factor in the survival of silkworms. Improvement in larval and cocoon characters has been witnessed with increase in chemical composition of leaves (Pandey, 2003).

Therefore, feed stuffs can be analyzed in to different fractions namely such as water, crude protein, crude fat, crude fiber, crude carbohydrate and ash in proximate analysis of composition of feeds. The Ash, residue left behind after all organic matter has been burnt off, is a measure of the total content of mineral salts in a food. Among minerals (inorganic salts), nitrogen, phosphorus, potassium, magnesium, calcium, iron, silicon, sulphur, aluminium, mangnesium and copper found orderly on the quantity basis from different feeds of silkworms (Maynard and Loosli, 1962).

The protein content in different sericigenous plant is highly variable and about 70% of the silk protein produced by the silkworm is directly derived from the protein of the leaves they fed and it is directly correlated with production efficiency of cocoon shells in silkworms (Fukuda *et al.*, 1960). Proteins are required in all the stages of silkworm esp. a higher quantity of protein is essential for the formation of sericin and fibroin during spinning of the silk cocoons (Fukuda *et al.*, 1960).

The protein also serves as an important component of pre-pupa, egg shell and the cell structure. For example, average proximate composition for pre-pupae was 10.7% protein, 77% water, 1.6% minerals, 5.6% fat, 2.1% total dietary fiber and 2.9% carbohydrate. Silkworm egg is composed of 20% protein, 65% water, 10% fat, 4% carbohydrates and less than 1% inorganic salts. Among them, the protein is the major part of the dry weight. Further many of the protein molecules play a specific role in as comonemt of many enzymes and hormones are polypeptides. In general, proteins are constituents of all living cells and are dietary essentials (Fukuda *et al.*, 1960).

Carbohydrates play an important role as energy sources during the development of embryo and other metamorphic stages. They are utilized for the synthesis of lipids and amino acids too. However, the greater part of the carbohydrate content of leaves is used for physiological combustion (Maynard and Loosli, 1962).

The various kinds of fats are also available in feeds. Some are energy sources. The glucides are the energy foods of the larva, while the stored lipids will be those of the pupa and the moth. Some other fats are the chief structural component of the cell membrane as the protein (Maynard and Loosli, 1962). The crude fiber, however, is indigestible part of foods. Therefore, it is required in lesser amount as they interfere with digestibility of the feeds (Maynard and Loosli, 1962).

The moisture content of leaves plays a very important role in silkworm metabolism as it regulates the rate of ingestion. It determines the digestibility of feed by silkworms. It acts as diluents of nutrients, but not as a phagostimulant (Hazarika *et al.*, 2005). Usually moisture content of 70% above is considered as optimum. Silkworm fed on leaf with higher moisture content (75%) produced heaviest cocoon. Leaf moisture content positively influence the silkworm larval growth and development (Singh *et al.*, 2004). In addition, for silkworms in the fourth instar as an example, the water metabolism is such that the larva keeps its water content at 88 per cent, ingesting leaves containing 70 per cent water and passing excreta containing 50 per cent water. Thus, the percentages of retained and eliminated water should be regulated by the insect, and it is partially caused by the water content of the leaf itself (Hazarika *et al.*, 2005).

On the other hand, minerals constitute very good fraction of silkworm feeds. The role of inorganic salts (minerals) is variable. It has been reported that the silkworm larval structure at different ages utilizes these absorbed minerals (Ito, 1978). Their role in the egg stage is also recognized to regulate the hydrogen ion concentration osmotic pressure. Furthermore, sodium and potassium ions act on protein synthesis. However, the importance of nitrogen has been significantly considered in different stages together with the protein content (Legay, 1958).

In summary, Fukuda *et al*. (1960) stated that the quality of leaves particularly their moisture content, mineral content, protein content and sugar content play a significant role in proper growth and development of silkworm. Krishnaswami (1978) also said silkworm feed with more moisture, protein, sugar and carbohydrates and less minerals and crude fibre content is the best from the silkworm nutrition point of view. Moreover, it is observed that the silkworm which feed on leaves having 70.6% moisture, 29.46% crude protein, 17.93% minerals and 9.78% total sugar showed better cocoon result (Krishnaswami, 1978). Slansky and Scriber (1985) also stated that quality leaves are those having more moisture, protein and carbohydrates. However, Debaraj *et al*,, 2003 observed that leaf quality had little effect on cocoon characters but plays a vital role in the growth and development of silkworm, *B. mori,* larvae.

In general, the quantity and quality of silk is directly dependent on the leaf quality, which influences the healthy growth of silkworm larvae and there by affects the over all cocoon production (Krishnaswami, 1978). In another way, Jayaramaiah and Sannappa (1998) find out a positive significant relationship between foliar constituents and important silkworm components. They indicated that larval duration, weight, survivability and effective rate of rearing (ERR) as well as cocoon yield were found to have significant positive relationship with moisture, carbohydrate, protein, phosphorus, potassium, calcium, magnesium and sulphur.

Plants have also evolved a great array of chemical defenses, the so-called secondary substances. These include "digestibility-reducing" or "quantitative" defenses such as fiber, lignins, silica, tannins, oils, waxes, and resins may render leaves of all growth forms less suitable and digestible (Feeny, 1968). For instance, tannins, which are water-soluble polyphenolic compounds (Proanthocyanidins (condensed tannins) and hexahydroxydiphenic acids (hydrolysable tannins) may have potential anti-nutritional effects, reducing protein digestibility and impairing absorption of some minerals (Pandey, 1995)

Thus, maximization of quality of leaf yield is one of the most important factors for successful and good quality cocoon production (Bose *et al.*, 1991). Therefore, the value of feed depends upon the chemical composition, the digestibility and other factors. Chemical analysis gives information about the quality of the feeding stuffs and also the presence of incriminating factors if any, etc. However, it does not give the satisfactory information regarding availability of the nutrients present in the feeding stuffs to the animals. Therefore, digestibility studies are required (Maynard and Loosli, 1962).

The digestibility of a feed stuff is defined as the portion of feed or any single nutrient of feed which is not recovered in faeces and is absorbed by the system. It depends up on the enzymes present and the physiological environment in which they function; the properties of the feeds which are being processed, including their susceptibility to enzymatic hydrolysis; the action of inhibitory substances which the feeds may contain like glucosides, tannins, alkaloids, etc., and the total processing capacity of the insects digestive system. As a result, two feeds of similar composition, the one that is more digestible will be taken as it has the higher nutritive value, assuming that both require the same expenditure of energy in their digestion and metabolism (Maynard and Loosli, 1962).

However, both chemical composition and digestibility are not all that determine the value of the feed. For example, two feeds may be equal in composition, the digestibility, yet one may be more valuable than the other because its digested matter can be used to better advantage by the body (Maynard and Loosli, 1962).

The suitability of genotypes can be determined through estimation of rate of ingestion, digestibility, conversion efficiency of food and growth rate of the insect (Maynard and Loosli, 1962). Therefore, the quantitative nutritional approach consists of measuring the amount of food consumed, digested and assimilated, excreted, metabolized, and converted into biomass is of highly essential together with qualitative approaches. It is of great importance in identifying the factors that contributes more to how organisms respond to different foods and which food components exert the greatest effects on growth. Similarly, the work of Sannappa and Jayaramaiah (1999) confirmed that nutritional efficiency of eri silkworm differed significantly when reared by using different castor varieties. Total food consumption and food digestion, consumption index, approximate digestibility, growth rate and efficiency of conversion of ingested food varied among castor varieties. Such findings inspired to investigate the reasons of differences on the basis of quantitative and nutritional parameters (Ramesh *et al.*, 2010).

The quality of leaf fed has a great influence on the amount ingested due to the physico-chemical characteristics in relation to the age of the leaf and the characteristics of the varieties (Legay, 1958) and Friend (1958). Moreover, the conversion efficiency of food-ingested and digested are some what dependent on digestibility, leaf moisture content and presence of optimum mineral nutrients (Scriber and Slansky,1981) and (Slansky and Scriber, 1985).

In addition, the growth of the silk glands and their secretory intensity, fertility and fecundity are also very sensitive to quantitative and qualitative changes in the food (Legay, 1958). Moreover, the nutrition of the larva affects the development of the genital rudiments in the larval stage. Ovogenesis is affected to the extent that it not only modifies the weight or total number of eggs laid, but also the weight of the individual egg (Legay, 1958).

Therefore, selection of castor genotypes is an important criterion for better growth and development of eri-silkworm for proper nourishment to obtain better fecundity and higher cocoon productivity (Joshi and Misra, 1982) and (Khan and Hoque, 1987). However, very little information is available regarding the different castor genotypes in Ethiopia. Moreover, the performance of the eri-silkworm with regard to castor genotype differences has not been identified and documented. In general, its potentiality for rearing eri silkworms is not tapped properly. This work, therefore, attempts to assess the extent of morphological and nutritional variability of castor genotypes and to study and know the influence of castor genotypes on feeding efficiency and rearing performance of eri silkworm, *S. c. ricini*.

2. Objectives

2.1. General objective

- To assess morphological and nutritional difference of castor genotypes and their influence on eri silkworm, *Samia cynthia ricini* for silk production in Ethiopia

2.2. Specific objectives

- To study morphological features and foliar constituents of different castor genotypes in relation to rearing performance and feeding efficiency of eri-silkworm;
- To find out a promising castor genotype in relation to economic traits of eri-silkworm.

3. Materials and methods

3.1. Description of the study area

The study was conducted in Melkassa Agricultural Research Center (MARC), which is one of the Research Centers under the Ethiopian Institute of Agricultural Research (EIAR). It is found 117 kms away from Addis Ababa and 17 km to southeast of Nazareth in the East-Shewa zone of Oromia region. It is located 8°24'N latitude and 39°12'E longitude having an elevation of 1500 meters above sea level and a mean annual rainfall of 770 mm.

3.2. Field Evaluation of castor genotypes

Eight selected genotypes of castor viz. Abaro, Acc 106584, Acc 203241, Acc 208624, Ar sel, Bako, GK sel and local (check) were used in the study. These materials were selected from preliminary research observation for the purpose of seed and leaf yields. This study was carried out under rainfed condition with supplemental irrigation during dry periods. The castor genotypes were sown with a spacing of 75 cm x 75 cm between plants and rows on a plot size of 6m x 6m. The field experiment was laid out in a Randomized Complete Block Design (RCBD) with eight treatments and three replications. Each plot had 64 plants.

As per the methods used by Solanki and Joshi (2001), three plants per plot were taken for recording field data. Data were recorded on quantitative traits viz plant height, internode length, no. of branches per plant, leaf area, leaf color, inflorescence length, leaf yield/ha and seed yield/ha. Leaf area was measured by using leaf area meter. Leaf yield was recorded as total from three harvests of the third, fifth and seventh month age of the plant. Leaf rust incidence and severity were also recorded in percentage values.

3.3 Foliar nutritional evaluation of castor genotypes

The methods of Sannappa and Jayaramaiah (1999) were adopted for foliar nutritional analysis on the above mentioned castor genotypes. The leaf samples were collected after 60 days of sowing at three different heights of the plant viz. top, middle and bottom leaves in paper bags. They were shade dried and then transferred to hot air oven maintained at $70^{O}C$ until constant weight was obtained. So, Moisture content of leaf was determined on fresh weight basis. Then, the dried-up leaf samples were grinded in to fine powder and preserved for chemical analysis.

As adopted by Sahlemedhin and Taye (2000), crude protein was estimated by multiplying the estimated value of the total nitrogen by 6.25, while the total nitrogen content of the leaf was determined by the Kjeldahl method. Techniques and procedures A.O.A.C. (1970) were used to determine Crude fiber and Crude fat contents. The method of Ranjhan and Krishna (1981) was used to estimate Total minerals (ash) composition and Total carbohydrates. Accordingly, Total carbohydrates were determined on dry weight basis by method of difference subtracting the percentage values of protein, fat, ash and fiber from 100. In addition, techniques and procedures of Sahlemedhin and Taye (2000) were adopted to analyze the mineral compositions such as phosphorus, potassium, calcium and magnesium were analyzed for each treatment. To get appropriate estimates, the samples were analyzed by laboratories of EHNRI (Ethiopian Health and Nutrition Research Institute) and Debrezeit Agricultural Research Center. Finally, correlation coefficients were also worked out to know the relationship between foliar constituents of castor genotypes and eri-silkworm rearing performance and cocoon traits.

3.4 Evaluation of castor genotypes on rearing performance and feeding efficiency of eri silkworms

As per the rearing recommendations of silkworms by Dayashankar (1982), a white plain eri-silkworm breed was used for this experiment and it was reared on the eight castor genotypes. The silkworm rearing room and equipments were cleaned, washed and disinfected with 2% formalin solution at the rate of 800ml per $10m^2$ before the commencement of the experiment (rearing). This breed was reared following cellular rearing techniques starting from brushing till cocoon spinning on the eight genotypes. Tender leaves of castor were fed four times a day until the larvae ends II instar stage, and semi tender leaves to III instar while more matured leaves were fed to IV and V instar larvae. The experiment was arranged in Completely Randomized Design (CRD) in three replications. In each replication, 50 worms were used and allowed to complete the larval period.

As used by Waldbauer (1968), to find out feeding efficiency of the breed on the castor genotypes, the food offered were weighed daily for all the above mentioned 50 worms per tray. However, a parallel sample of food (according to specific dietary routine) was kept separately to know the amount of food ingested by splitting leaves along the midrib. That is, one half weighed and offered to the larvae and the other half weighed and used to determine the percent dry matter in the leaf material. According to Reddy and Swamy (1999), after twenty four hours of feeding, the uneaten food and pellets/fecal matter in all the replicates were collected separately and dried at $75^{O}C$ to a constant weight. The amount of food ingested was determined by deducting the weight of uneaten food from the weight of parallel sample. The dry weight attained by the larvae was also determined by drying a single larvae per day, one from each replicate and the larvae that is picked up from the replicates was again replaced (of the same age and weight) from the parallel culture. From the data obtained viz., ingesta, digesta, excreta, Approximate Digestibility (AD), Reference Ratio (RR), Relative Consumption Indices (CI), Relative Growth Rate (RGR), Efficiency Conversion of Ingesta (ECI) and Digesta (ECD) for larva, cocoon and shell were calculated as per the gravimetric method.

As used by Neupane *et al*. (1990) and Singh and Benchamin (2002), matured worms were picked and mounted on the mountages for spinning. On the six day of spinning, the cocoons will be harvested, counted and weighed.

Rearing parameters like larval duration (in hours), body weight of mature larvae (g), percentage of larval mortality and hatchability, cocoon traits (cocoon weight, shell weight and silk ratio), effective rate of rearing (%) and fecundity (number of eggs per female) were recorded to find out rearing performance of the worms on the castor genotypes. As a result the following formulae were adopted for estimation when appropriate.

The following formulae, which were adopted by Singh and Benchamin (2002) used for data on rearing performance:-

Survival rate= Number of larva survied larva x 100 /No. of larva brushed

$$\text{Hatching percent} = \frac{\text{(Number of normal eggs- number of non hatched eggs)*100}}{\text{Number of normal eggs}}$$

Silk ratio = Weight of shell x 100/weight of fresh cocoon

Effective rate of rearing (ERR) = (No. of larvae spinning cocoon * 100)/No. of larvae brushed

The following formulae, which were used by Ramesh *et al*., 2010 adopted for feeding efficiency analysis:-

Ingesta = Dry weight of leaf fed-Dry weight of left over leaf

Digesta=Dry weight of leaf ingested-Dry weight of litter

Excreta=Ingesta-Digesta

Mean larval weight= (Final weight – Initial weight)/2 + Initial weight

AD (%)= Dry weight of Digesta x 100/Dry weight of food ingested

RR (%) = Dry weight of food ingested x 100/Dry weight of excreta

RCI = Ingesta/(Mean Dry weight of larva x Larval duration in days)

RGR = Dry weight gain of the larva/Larval duration in days x Mean dry weight of the larva)

ECI to larva= Maximum dry weight of larva x 100/Dry weight of ingesta

ECD to larva= Maximum dry weight of larva x 100/Dry weight of digesta

ECI to cocoon= Dry weight of cocoon x 100/Dry weight of ingesta

ECD to larva= Maximum dry weight of larva x 100/Dry weight of digesta

ECI to shell= Dry weight of shell x 100/Dry weight of ingesta

ECD to Shell = Dry weight of shell x 100/Dry weight of digesta

3.5. Data Analysis

Finally, the data for significance determination were analyzed statistically (one-way CRD) by using SAS software at 5% level of significance. Moreover, correlation coefficients of nutrients of leaves of the castor genotypes with their corresponding rearing performance and cocoon traits of silkworms was carried out to know their inter-relationship similarly by SAS software at 5% level of significance (SAS Institute Inc,1999-2000) .

4. Results

4.1. Field performance of different castor genotypes

Significant variations have been found in agronomic performance among the eight castor genotypes. These differences can be expressed in terms of qualitative and quantitative values.

Qualitative differences among the castor varieties was observed especially in their stem and leaf colors. There was variation for stem color among genotypes (red, purple, and green) and leaf color (Light green, green and reddish green) (Table 1).

Table 1: - Stem and leaf colors of castor genotypes

Castor genotypes	Stem color	Leaf color
Abaro	Purple	Light green
Acc. 106584	Purple	Light green
Acc. 203241	Green	Green
Acc. 208624	Green	Green
ArSel	Red	Reddish green
Bako	Purple	Green
GkSel	Red	Reddish green
Local (Check)	Red	Reddish green

Similarly, significant variations have been observed in quantitative traits among different castor genotypes. The mean values of the agronomical quantitative traits of the eight genotypes are presented in Table 2.

A. Plant height, length of primary branches, stem thickness and Internode and inflorescence length

Plant height, length of primary branches, stem thickness as well as internode and inflorescence length showed statistically significant differences among castor genotypes. Highest plant height recorded was 173.55 cm in GK sel followed by 176.333 cm in Acc 208624 but the shortest plant height was 142.33 cm from genotype Bako. However, the longest primary branch was from Abaro (195.33 cm) followed by Acc 208624 (192.93 cm) and shortest primary branch was from Acc 203241 (43.67 cm). In addition, long internode length was registered by Abaro (9.29 cm) but the shorter was by bako (5.95 cm). Moreover, longer inflorescence length was registered by Abaro (37.55 cm) but the short one was by Acc 203241 (24.11 cm). In another way, thicker stem was obtained from Acc 208624 (3.6367 mm) but the thinner one was Bako (2.8933 mm).

B. Number of primary branches and leaves and leaf area

Significant variation was also found in number of primary branches, number of leaves and leaf area, each of which were measured on per plant basis. Number of primary branches per plant ranged from 4.75 (local) to 10.25 (Acc 208624). Moreover, Number of leaves per plant varied from 32.777 (local) to 46.223 (Acc 208624). Leaf area per plant ranged from 3875.4 cm^2 (Bako) to 12848.9 cm^2 (Acc 208624).

C. Disease incidence and severity

During the dry season of experimental period, disease particularly leaf rust was a serious problem. As a result, leaf rust disease incidence and severity were recorded. Therefore, significant difference was observed among the genotypes. The highest incidence was recorded from Abaro (54.923 %), while the lowest was recorded from GK sel (17.577). Similarly, highest severity was recorded from Abaro (60.00%) but lowest was recorded from Acc 208624 (7.50 %).

D. Leaf and seed yields

Fresh and dry leaf yield as well as seed yield and seed weight have shown statistically significant difference. Minimum fresh leaf yield was obtained from bako (7567.4 kg/ha) but maximum fresh leaf yield was obtained from Acc 208624 (13531.9 kg/ha). Similarly, minimum dry leaf yield was obtained from bako (1848.9 kg/ha) but maximum dry leaf yield was obtained from Acc 208624 (3113.1 kg/ha). In general, Acc 106581, Acc 203241 and Acc Acc 208624 showed significantly higher fresh and dry leaf yield in comparison with local check.

In another way, seed yield ranged from 732.84 kg/ha (local) to 1971.36 kg/ha (Acc 203241). The local check, therefore, was inferior to all genotypes in regard to seed yield. However, 1000 seed weight ranged from 323.33 g (Acc 106584) to 593.33 (Bako). Local check was higher than all genotypes in regard to 1000 seed weight except Abaro and Bako.

Table 2: - Agronomic performance of castor genotypes

Castor genotypes	PH	LPB	ST	IL	InfL	NPB	NL	LA
Abaro	163.33^{ba}	195.33^{a}	3.25^{b}	7.96^{b}	37.55^{a}	8.92^{bc}	35.56^{dc}	7340.0^{c}
Acc106584	158.44^{bc}	109.33^{cb}	3.20^{cb}	6.18^{d}	34.11^{b}	8.08^{dc}	39.11^{bc}	9882.1^{b}
Acc203241	164.00^{ba}	43.67^{d}	3.28^{b}	6.68^{cd}	24.11^{e}	5.25^{e}	40.44^{bc}	4847.4^{d}
Acc208624	176.33^{a}	192.93^{a}	3.64^{a}	7.18^{cb}	22.89^{e}	10.25^{a}	46.22^{a}	12848.9^{a}
Ar sel	169.00^{ba}	185.10^{a}	2.94^{cd}	9.21^{a}	31.67^{c}	9.50^{ba}	43.22^{ba}	9365.7^{b}
Bako	142.33^{d}	88.33^{c}	2.89^{d}	5.95^{d}	29.11^{d}	8.17^{dc}	40.89^{bac}	3875.4^{d}
GK sel	173.55^{a}	116.33^{b}	3.27^{b}	9.29^{a}	30.447^{dc}	7.42^{d}	39.33^{bc}	7982.1^{c}
Local	149.44^{dc}	44.00^{d}	3.03^{cbd}	7.94^{b}	31.22^{dc}	4.75^{e}	32.78^{d}	8039.1^{c}
SE	4.42	7.50	0.09	0.27	0.74	0.34	1.90	375.47
CV (%)	4.72	10.67	4.73	6.14	4.28	7.53	8.27	8.11
Pr	0.001	<.0001	0.001	<.0001	<.0001	<.0001	0.006	<.0001

Note: - Means with the same letter are not significantly different at Pr > 0.05.

Table 2: - Continued ….

Castor genotypes	DI	DS	FLY	DLY	SY	SW
Abaro	54.92^{a}	60.00^{a}	9429.1^{c}	2373.3^{d}	1517.04^{c}	590.00^{a}
Acc106584	29.10^{d}	20.83^{c}	12747.7^{a}	3088.4^{ba}	1364.94^{d}	323.33^{e}
Acc203241	21.57^{f}	18.00^{d}	11663.2^{b}	2828.6^{bc}	1971.36^{a}	503.33^{cb}
Acc208624	19.86^{gf}	7.50^{f}	13531.9^{a}	3113.1^{a}	1181.24^{e}	423.33^{d}
Ar sel	39.26^{c}	20.83^{c}	9327.4^{c}	2380.4^{d}	1359.01^{d}	463.33^{cd}
Bako	51.08^{b}	51.00^{b}	7567.4^{d}	1848.9^{e}	1155.55^{e}	593.33^{a}
GK sel	17.58^{g}	14.17^{e}	8635.1^{c}	2224.1^{d}	1679.01^{b}	520.00^{b}
Local	25.31^{e}	13.33^{e}	10830.6^{b}	2692.9^{c}	732.84^{f}	526.67^{b}
SE	0.86	0.75	328.59	90.29	47.27	14.71
CV (%)	4.61	5.04	5.44	6.09	5.98	5.17
Pr	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Note: - Means with the same letter are not significantly different at Pr > 0.05.

4.2. Biochemical composition of different castor genotypes

Foliar compositions of castor genotypes have shown significant variations among castor genotypes. All castor genotypes differed significantly from one another in respect to biochemical characters considered in this study. Mean values of foliar compositions of the genotypes are presented in table 3 and table 4.

4.2.1. Proximate nutrient composition of different castor genotypes

The variation in nutritional factors of moisture content, ash (total minerals), crude protein, crude fat, total carbohydrate and crude fiber was highly significant among castor genotypes. Moreover, the tannin content (anti nutritional factor) has also demonstrated significant difference among castor genotypes.

Higher moisture content was recorded in the leaves of Acc 106584 (76.224%), Abaro (75.759 %) and Acc 208624 (75.086 %), but the least moisture content was obtained from Bako (66.234 %),). All the genotypes showed higher leaf moisture content than the local check except Acc 203241 and Bako.

In case of ash content (total mineral), highest ash content was estimated from the leaves of Acc 106584 (20.83 %) but the lowest was from Abaro (12.33 %). However, the local check is equivalent with bako in ash content but lower than Acc 106584 and Acc 203241.

Crude protein which is 6.25 times the nitrogen content (Lord, 1968) was highest in bako (26.59 %) follwed by Acc 106584 (25.94 %) and abaro (25.78 %). However, the least crude protein content was estimated from the local check (22.71 %).

Crude fat content ranged from 0.457 % in Ar sel to 1.278 % in Acc 208624. However, local check was lower in crude fat content than Ar sel, Acc 208624 Abaro and Acc 106584.

Crude fibre content recorded was minimum in Abaro (17.64 %) but maximum in GK sel (21.58 %). However, the local check which is at par with Ar sel and Acc 106584 has shown lower fiber content than Acc 203241 and GK sel.

The total carbohydrate which is analyzed on dry weight basis as a difference of the sum of ash, crude protein, crude fat and crude fiber from 100 has also shown significant variation among castor genotypes. The highest total carbohydrate was recorded from Abaro (43.30 %) but lowest from Acc 106584 (32.19 %). This record for local check was lower than Abaro, Ar sel and Acc 208624.

Conversely, the tannin concentration of castor genotypes was ranging from 83.75 mg/100g from Bako to 205.89 mg/100g from Acc 208624. The local check has shown lower in tannin concentration though it was higher than Bako and GK sel.

Table 3: - Proximate nutrient composition of different castor genotypes

Castor genotypes	Mois	Ash	CP	CFt	Tocrb	CFb	Tan
Abaro	75.759^{a}	12.333^{e}	25.783^{ba}	0.939^{b}	43.304^{a}	17.640^{d}	165.573^{c}
Acc106584	76.224^{a}	20.833^{a}	25.936^{ba}	0.860^{c}	32.194^{g}	20.177^{b}	120.173^{e}
Acc203241	69.602^{b}	17.500^{b}	23.768^{de}	0.915^{b}	36.761^{f}	21.056^{a}	185.447^{b}
Acc208624	75.086^{a}	15.000^{d}	24.908^{bc}	1.278^{a}	41.078^{c}	17.736^{dc}	205.893^{a}
Ar sel	71.770^{b}	13.000^{e}	24.477^{dc}	0.457^{g}	42.180^{b}	19.886^{b}	124.387^{d}
Bako	76.234^{a}	16.500^{c}	26.594^{a}	0.553^{f}	38.146^{e}	18.208^{c}	83.753^{h}
GK sel	74.561^{a}	15.333^{d}	25.391^{bc}	0.749^{e}	36.942^{f}	21.584^{a}	94.517^{g}
Local	69.688^{b}	16.500^{c}	22.705^{e}	0.806^{d}	40.173^{d}	19.816^{b}	119.127^{f}
SE	0.863	0.289	0.376	0.013	0.215	0.179	0.261
CV (%)	2.030	3.150	2.613	2.654	0.957	1.588	0.329
Pr	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Note: - Means with the same letter are not significantly different at Pr > 0.05.

4.2.2. Mineral composition of different castor genotypes

The compositions of leaf mineral of nitrogen, phosphorus, potassium, calcium and magnesium have also shown significant diversity among castor genotypes. As it can be observed from the trend of crude protein, the nitrogen content of the leaf material of castor genotypes was significantly different. It was highest in Bako (4.255%) and lowest in local check (3.63 %).

Phosphorus concentration of leaves of castor genotypes was significantly different from castor genotypes with minimum record of 1.6157 PPM in the local check and maximum record of 2.30 PPM in Abaro. On the other hand, the potassium content of castor genotypes ranges from 5906.0 PPM in Ar sel to 8027.6 PPM in Acc 208624. This concentration for the local check was at par with Acc 106584 but lower than the records of Acc 208624 and Bako.

Further more, calcium concentration of castor genotypes has also shown significant difference and ranges from 92.20 PPM (Bako) to 155.089 PPM (Acc 208624). The concentration for local check was lower than Acc 208624 and Acc 106584. On the other hand, magnesium concentration of castor genotypes was minimum in Acc 203241 (10.6167 PPM) and maximum in Bako (17.70 PPM). The local check was lower in magnesium concentration than Bako and Acc 106584.

Table 4: - Mineral composition of different castor genotypes

Castor genotypes	N	P	K	Ca	Mg
Abaro	4.125^{ba}	2.300^{a}	6874.5^{d}	102.033^{f}	13.467^{d}
Acc106584	4.150^{ba}	1.809^{de}	7317.5^{cb}	139.944^{b}	16.878^{b}
Acc203241	3.803^{de}	1.782^{e}	6205.8^{e}	111.878^{e}	10.617^{e}
Acc208624	3.985^{bc}	1.908^{c}	8027.6^{a}	155.089^{a}	17.456^{ba}
Ar sel	3.917^{dc}	2.082^{b}	5906.0^{e}	97.789^{g}	13.033^{d}
Bako	4.255^{a}	2.242^{a}	7503.1^{b}	92.200^{h}	17.700^{a}
GK sel	4.063^{bc}	1.881^{dc}	7163.9^{cd}	112.522^{d}	12.833^{d}
Local	3.633^{e}	1.616^{f}	7205.9^{cb}	127.400^{c}	15.906^{c}
SE	0.060	0.033	106.194	0.039	0.219
CV (%)	2.613	2.886	2.618	0.057	2.571
Pr	<.0001	<.0001	<.0001	<.0001	<.0001

Note: - Means with the same letter are not significantly different at Pr > 0.05.

4.3. Effect of different castor genotypes on rearing performance and feeding efficiency of eri silkworms

4.3.1. Effect of different castor genotypes on rearing performance

In this experiment, all the characters of eri silkworm rearing like hatching percentage, larval duration, larval weight, single cocoon weight, single shell weight, shell (silk) ratio, larval duration, fecundity, effective rate of rearing (ERR) and survival and showed significant differences when eri silkworm fed with different castor genotypes. The results of silkworm rearing characters fed on different castor accessions are summarized in the table 5.

A. Percentage hatching of egg

Hatching of silkworm egg showed wide significant variation fed on different castor genotypes from 81.50 % % to 95.33 %. The maximum hatching was recorded in Acc 106584 (95.333 %) closely followed by GK sel (93.83 %), but lower hatching percent was obtained from Acc 203241 (81.5%). The local genotype recorded better hatching percent than Acc 203241 and Ar sel only.

B. Duration of life stages

Significantly longer larval durations (604.17 hours) were recorded in the worms fed on bako. However, there was no significant difference among other castor genotypes which showed a range of 588.17 hours to 592.17 hours. Moreover, there was no difference in egg and pupal duration which are average 272 hours for egg stage and 514 hours for pupal duration in all the castor genotypes.

C. Larval weight

Matured worms fed on Bako recorded significantly higher larval weight (8.20 g) followed by worms fed on Acc 106584 (8.05 g), Acc 203241(8.05 g), Acc 208624 (8.05 g). The least larval weight was from local check (7.60 g).

D. Cocoon weight, pupal weight, shell weight and silk ratio

In accordance to yield, maximum single cocoon weight was recorded in those larvae which were fed on the leaves of Abaro (3.344 g) followed by Acc 208624 (3.307 g). The minimum single cocoon weight (3.131 g) was recorded from larvae fed on Acc 203241. Similarly, the highest single pupa weight was obtained from those fed on Abaro (2.860 g) and the lowest was obtained from those fed on Acc 203241 (2.684 g).

Single shell weight of a cocoon revealed significant variation when fed with the different castor accession. Abaro revealed significantly higher shell weight (0.4845 g) but local check showed the least shell weight (0.4425 g). In similar to shell weight, silk ratio was found to be significantly higher in Abaro (14.487 %) closely followed by Bako (14.471 %) and Acc 203241 (14.458 %), while the lowest in the local check (14.07 %).

E. Fecundity

Silkworm fed on Acc 106584 showed significantly higher fecundity (409) followed by GK sel (389). The local check (353) was at par with Ar sel (338) and Acc 203241 (338) was lower performing compared to the rest of others.

F. Effective rate of rearing (ERR)

ERR has also revealed a significant difference when eri silkworm fed on different castor genotypes. Eri silkworm fed on Abaro (74.68 %) recorded higher ERR closely followed by Acc 203241 (73.38 %) and bako (73.15 %). The least ERR was obtained from local check (65.36 %).

G. Survival rate

The highest survival rate was recorded in silkworms reared on Acc 208624 (78.35 %) followed by Bako (77.66 %). The least survival rate was recorded from the local check (66.12 %).

Table 5: - Rearing performance of eri silkworm fed on different castor genotypes

Treatment	HaP	LaD	Larw	CoW	Puw	Shw	SiR	Fecun	ERR	Surv
Abaro	88.1667^{b}	584.17 ^{b}	8.17^{ba}	3.344^{a}	2.860^{a}	0.484^{a}	14.487^{a}	382.000^{cb}	74.68^{a}	76.079^{ba}
Acc106584	95.3333^{a}	584.17 ^{b}	8.05^{bc}	3.149^{e}	2.695^{e}	0.453^{e}	14.395^{c}	409.000^{a}	69.32^{c}	76.494^{ba}
Acc203241	81.5000^{d}	588.17 ^{b}	8.05^{bc}	3.131^{e}	2.68^{e}	0.447^{f}	14.281^{d}	337.667^{e}	73.38^{a}	73.864^{b}
Acc208624	87.0000^{b}	588.17 ^{b}	8.05^{bc}	3.307^{b}	2.830^{b}	0.477^{b}	14.424^{bc}	374.000^{cb}	73.18^{a}	78.349^{a}
Ar sel	82.1667^{d}	588.17 ^{b}	7.62^{d}	3.216^{c}	2.751^{c}	0.465^{c}	14.458^{ba}	337.667^{e}	70.32^{ba}	70.868^{c}
Bako	86.5000^{cb}	604.17 ^{a}	8.20^{a}	3.186^{d}	2.725^{d}	0.461^{dc}	14.471^{ba}	368.000^{cd}	73.15^{a}	77.656^{a}
GK sel	93.8333^{a}	592.17 ^{b}	8.02^{c}	3.205^{dc}	2.747^{dc}	0.458^{d}	14.305^{d}	388.667^{b}	69.92^{bc}	77.748^{a}
Local	84.8333^{c}	588.17 ^{b}	7.60^{d}	3.144^{e}	2.702^{e}	0.443^{g}	14.073^{e}	353.000^{ed}	65.36^{d}	66.117^{d}
SE	0.6095308	3.7454	0.0443	0.0086	0.0074	0.0014	0.0177	5.267827	1.1751	0.9520753
CV (%)	1.207708	1.1001	0.9619	0.4653	0.4664	0.5135	0.2131	2.474344	2.4547	2.209129
Pr	<.0001	0.0363	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Note: - Means with the same letter are not significantly different at Pr > 0.05.

4.3.2. Effect of different castor genotypes on eri silkworm feeding efficiency

The different castor genotypes showed significant variation in consumption indices when fed to an eri silkworm. The influence of feeding leaves of different castor genotypes on mean consumption indices of eri silkworm are presented in table 6.

Total food consumption or ingestion

Silkworms consumed significantly higher leaf when reared on leaves of GK sel (7.142 g/larva). Further, local check (7.087 g/larva), Acc 208624 *(*6.904 g/larva), Acc 106584 (6.676 g/larva), Abaro (6.672 g/larva) and Acc 203241 (6.617 g/larva) genotypes found next best with regard to food consumption. The same was very lower with bako (5.925 g/larva).

Total food digestion

Food digested by the eri silkworm was found to vary significantly among the castor genotypes used. Food digestion was more with local leaves (6.661 g/larva) and was closely followed by Acc 106584 (3.589 g/larva) and Acc 208624 (3.574 g/larva). However, the worms fed on leaves of bako genotype recorded lower food digestion (2.598 g/larva).

Excreta

Food excreted by the eri silkworm was found significant among the castor genotypes used. It was more with GK sel leaves (3.713 g/larvae) and was found followed by Acc 203241 (3.440 g/larva) and local genotype (3.427 g/larva).

However, the worms fed on leaves of Acc 106584 genotype showed lower excreta (3.087 g).

Approximate Digestibility (AD)

Significant differences were noticed with respect to AD when leaves of different castor varieties fed to eri silkworms indicating that higher food intake does not necessarily result in higher digestibility. Significantly higher AD was recorded in Acc 106584 (53.704 %) along with Acc 208624 (51.766 %) and local (51.535 %) and Abaro (50.637 %). However, worms fed on Bako showed lower AD (43.840 %).

Reference Ratio (RR)

Reference Ratio (RR) which is indicative of the retention efficiency of food as stated by Anantharaman *et al*. (1995) and Rahmathulla *et al*. (2003) was significantly higher with 106584 (2.161) along with Acc 208624 (2.073) and local (2.069) and Abaro (2.026). The least RR was noticed from Bako (1.781).

Relative Consumption Index (RCI)

Significantly higher RCI was noticed with Acc 106584 (0.932) and local (0.901), but lower RCI was noticed with Ar sel (0.745). So, the local genotype was better than all in this regard except Acc 106584.

Relative Growth Rate (RGR)

There was no significant difference among genotypes as $Pr > 0.05$ though mean variations were obvious with regard to RGR among the castor varieties. Mean RGR was higher with local (0.260) and lesser with Ar sel (0.231).

Efficiency of conversion of Ingesta to larval biomass (ECIla)

The efficiency of ingested leaf converted into silkworm larval biomass varied significantly among castor genotypes. The highest efficiency of conversion of ingesta (ECI) to larva recorded in bako (35.191 %) and least in Acc 106584 (28.950 %). The local check recorded 30.386 % and was the least except Acc 106584.

Efficiency of conversion of digesta to larval biomass (ECDla)

Efficiency Conversion of Digesta (ECD) to larval biomass has revealed no statistical significant variation among the castor genotypes as Pr > 0.05. However, mean values show that more efficient conversion of digested food into larval biomass was recorded in Ar sel (75.953 %) and less efficient conversion was recorded in local genotype (55.638 %).

Efficiency of conversion of Ingesta to cocoon (ECIco)

Efficiency Conversion of Ingesta (ECI) to cocoon revealed significant difference and it was higher in Abaro (19.81 %) followed by Acc 208624 (19.24 %) and bako (18.897 %). It was lower in GK sel (15.83 %) and local genotype (16.06 %).

Efficiency of conversion of Ingesta to cocoon (ECDco)

Efficiency conversion of digesta (ECD) to cocoon varied significantly among the castor genotypes which ranged between 31.30 % (local) to 43.136 % (bako). The more efficient one (bako) was followed by Abaro (39.126%) and Acc 208624 (37.173 %).

Table 6: - Feeding efficiency of eri silkworm fed on different castor genotypes

Castor genotypes	Ing	Dig	Exc	AD	RR	RCI	RGR	ECIla	ECDla	ECIco	ECDco
Abaro	6.6717^{bac}	3.3783^{bac}	3.29333^{c}	50.637^{ba}	2.02567^{bc}	0.81400^{bc}	0.254000^{a}	33.164^{bac}	63.189^{bac}	19.8110^{a}	39.126^{ba}
Acc106584	6.6760^{bac}	3.5893^{ba}	3.08667^{d}	53.704^{a}	2.16100^{a}	0.93200^{a}	0.252000^{a}	28.950^{d}	58.194^{bc}	17.1543^{cb}	31.989^{ed}
Acc203241	6.6170^{bc}	3.1770^{bc}	3.44000^{b}	47.872^{b}	1.92333^{c}	0.78867^{bc}	0.248333^{ba}	33.898^{ba}	67.837^{bac}	16.7040^{cb}	35.109^{becd}
Acc208624	6.9043^{ba}	3.5743^{ba}	3.33000^{cb}	51.766^{a}	2.07333^{ba}	0.86167^{ba}	0.255333^{a}	31.406^{bdc}	64.649^{bac}	19.2360^{a}	37.173^{bc}
Ar sel	6.3707^{dc}	3.0640^{c}	3.30667^{c}	48.095^{b}	1.92633^{c}	0.74467^{c}	0.231333^{b}	34.728^{a}	75.953^{a}	17.5507^{b}	36.493^{bcd}
Bako	5.9250^{d}	2.5983^{d}	3.32667^{cb}	43.840^{c}	1.78100^{d}	0.75967^{c}	0.247667^{ba}	35.191^{a}	72.213^{ba}	18.8970^{a}	43.136^{a}
GK sel	7.1423^{a}	3.4290^{bac}	3.71333^{a}	47.987^{b}	1.92367^{c}	0.85867^{ba}	0.247667^{ba}	31.273^{bdc}	65.898^{bac}	15.8333^{c}	33.032^{ecd}
Local	7.0873^{ba}	3.6607^{a}	3.42667^{b}	51.535^{a}	2.06900^{ba}	0.90100^{a}	0.260333^{a}	30.386^{dc}	55.638^{c}	16.0640^{c}	31.30^{e}
SE	0.1711	0.1532	0.0395	1.0316	0.0421	0.0290	0.00674	0.9941	4.8026	0.4423	1.5229
CV	4.4411	8.0188	2.0344	3.6148	3.6743	6.0272	4.6747	5.3182	12.7102	4.3390	7.3434
Pr	0.0026	0.0027	<.0001	0.0002	0.0003	0.0027	0.1991	0.0039	0.1253	<.0001	0.0008

Note: - Means with the same letter are not significantly different at Pr > 0.05.

4.4. Relationship of different foliar compositions of castor genotypes with eri silkworm rearing performance

The foliar composition of castor genotypes resulted in significantly varying inter-relation ship with performance of eri silkworms when their leaves served as feeds. This relationship between leaf composition values and important eri silkworm traits have been worked out through correlation analysis and the results are summarized in table 7 and table 8.

4.4.1. Relationship of proximate nutrient compositions of leaves with eri silkworm traits

Ash content

The ash content has shown significantly strong negative correlation with cocoon (r= -0.70997), pupal weight (r= -0.71471) and shell weight (r= -0.65413). However, its correlation with hatching percent of eggs (r= 0.39696) and fecundity (r= 0.50333) was significantly strong positive. The rest of silkworm performance characters are not correlated significantly with ash (total minerals).

Crude protein content

The crude protein content was found to provide significantly strong positive correlation with larval weight (r= 0.63141), shell weight (r= 0.47607), silk ratio (r= 0.73177), survival (r= 0.72331), effective rate of rearing (r= 0.65277), hatching percent (r= 0.45913) and fecundity(r= 0.5506) of eri silkworms. Moreover, its relationship (correlation) was positive to the rest eri silkworm characters though the correlation was not significant.

Crude fiber

Crude fiber revealed significant negative correlation with cocoon weight (r=-0.6962), pupal weight (r= -0.68826), shell weight(r= -0.7135) and silk ratio(r= -0.51324). However, crude fiber has non significant correlation with the rest silkworm rearing characters.

Crude fat

Crude fat showed significant positive correlation with cocoon weight (r= 0.40186) and pupal weight (r= 0.42127). However, it was not significantly correlated with other characters.

Moisture content

Moisture content of the leaves has shown significant positive correlation with larval weight (r= 0.59003), shell weight (r= 0.40847), silk ratio (r= 0.62645), survival (r= 0.64672), ERR (r= 0.60208), hatching percent (r= 0.51371) and fecundity (r= 0.61765). Its non significant but positive correlation was also observed from cocoon weight and pupal weight.

Total carbohydrate

It had shown strong positive and significant correlation with cocoon parameters such as cocoon weight (r= 0.67546), pupal weight (r= 0.6894) and shell weight (r= 0.58702). Its non significant negative correlation was found to be with hatching percent (r= -0.29128) and fecundity (r= -0.27207).

Tannin content

Tannin composition of castor leaves has also resulted relationship with eri silkworm rearing performance. Its non significant negative correlation was found to be with hatching percent (r= -0.3589) and fecundity (r= -0.31529). However, it has shown strong positive significant correlation with cocoon weight (r= 0.42655), pupal weight (r= 0.43533) and shell weight (r= 0.37262) of eri silkworms though other cocoon traits do not show significant correlation.

Table 7: - Relationship of proximate nutrient compositions with eri silkworm rearing performance

	Ash	CP	CFb	CFt	Mois	Tocrb	Tan
Larw	0.1637	0.63141*	-0.31783	0.32055	0.59003*	-0.25394	0.1421
Cow	-0.70997*	0.31758	-0.6962*	0.40186*	0.27383	0.67546*	0.42655*
Puw	-0.71471*	0.27834	-0.68826*	0.42127*	0.24099	0.6894*	0.43533*
Shw	-0.65413*	0.47607*	-0.7135*	0.30084	0.40847*	0.58702*	0.37262*
SiR	-0.31076	0.73177*	-0.51324*	-0.07752	0.62645*	0.17334	0.09
LaD	0.02579	0.25317	-0.10526	-0.23523	0.29034	-0.04881	-0.4125*
Surv	0.07065	0.72331*	-0.2456	0.25903	0.64672*	-0.24568	0.05846
ERR	0.23777	0.65277*	-0.27503	0.07511	0.60208*	-0.27039	0.27851
HaP	0.39696*	0.45913*	0.30079	-0.1394	0.51371*	-0.29128	-0.3589*
Fecun	0.50333*	0.5506*	0.20833	-0.06931	0.61765*	-0.27207	-0.31529*

* Significant at Pr $\leq$ 0.05

4.4.2. Relationship of minerals with eri silkworm traits

Nitrogen

The correlation of nitrogen was similar with crude protein. It revealed significantly strong positive correlation with with larval weight (r= 0.63106), shell weight (r= 0.47607), silk ratio (r= 0.73177), survival (r= 0.72316), effective rate of rearing (r= 0.65269), hatching percent (r= 0.45918) and fecundity(r= 0.55043) of eri silkworms. However, its relationship (correlation) was positive to all silkworm characters though the correlation the rest was not significant.

Phosphorus

Phosphorus content of leaves had shown significant positive correlation with larval weight (r= 0.42601), cocoon weight (r= 0.61922), pupal weight (r= 0.58567), shell weight (r= 0.74301), silk ratio (r= 0.82462), effective rate of rearing (r= 0.45853) and survival(r= 0.43577) of eri silkworms. However, it had shown non –significant correlation with hatching percent and fecundity.

Potassium, Calcium and Magnesium

Potassium, calcium and magnesium have been found to have no significant correlation with all eri silkworm rearing characteristics under study at $p < 0.05$.

Table 8: - Relationship of minerals with eri silkworm rearing performance

	N	P	K	Ca	Mg
Larw	0.63106*	0.42601*	0.07933	-0.03916	0.1453
Cow	0.31697	0.61922*	0.12902	0.0411	0.09611
Puw	0.27771	0.58567*	0.15593	0.06061	0.09277
Shw	0.47557*	0.74301*	0.00649	-0.04354	0.11713
SiR	0.73177*	0.82462*	-0.31483	-0.26085	0.13115
LaD	0.25339	0.23824	-0.00715	-0.34519	0.25074
Surv	0.72316*	0.45853*	0.15063	0.05149	0.20033
ERR	0.65269*	0.43577*	0.2007	0.25273	0.23299
HaP	0.45918*	-0.00512	0.07089	0.03107	0.13489
Fecun	0.55043*	-0.02447	0.18255	0.1525	0.31684

* Significant at $Pr \leq 0.05$

5. Discussion

As it can be realized from the results of the present investigation, castor genotypes (Abaro, Acc 106584, Acc 203241, Acc 208624, Ar sel, Bako, GK sel and local check) showed wide variation in their quantitative and qualitative traits. Consequently, these differences resulted in significant variation in rearing performance and feeding efficiency of eri silkworms when leaves of these genotypes were used as a feed source. In this research, especial attention and emphasis for selection of castor genotypes was given to higher leaf biomass yield from field evaluation as well as higher larval parameters, cocoon traits and leaf conversion efficiency of eri silkworms from laboratory studies.

In field condition, different castor genotypes showed different performances. Among the genotypes, Acc 208624 produced better fresh leaf biomass yield of 13531.9 Kg/ha. This is nearly comparable with Kalantri *et al*. (2007) who reported average castor fresh leaf yield of 14,400 Kg/ha. In general regard to castor genotype selection to eri silkworms, this study revealed that Acc 208624 was the best among castor genotypes. Acc 106584 and Acc 203241, which recorded 12747.7 Kg/ha and 11663.2 Kg/ha respectively, were also better than local genotype to be considered as alternative options.

Since accumulation of nutrients in insect greatly influenced by the nutritional richness of the host plant and this storage, the biochemical compostions of leaves of castor genotypes have been studied and they revealed very significant differences among castor genotypes. Among castor genotypes studied, Abaro showed highest total carbohydrates and phosphorus composition with high enough moisture, nitrogen, crude protein and crude fat content. In addition, Acc 208624 recorded highest crude fat, potassium and calcium as well as tannin composition. Further more, Bako recorded highest nitrogen, crude protein and magnesium content. However, local genotype showed lower values for most of nutrients studied.

Such studies on nutrient composition of castor leaves are not dealt in Ethiopia until today. However, similar studies on different castor genotypes have been conducted in abroad several authors and they have found out significant differences among different genotypes (e.g. Jayaramaiah and Sannappa, 1998). However, Chakravorty and Neog (2006) emphasized the importance of nitrogen, crude protein and carbohydrate content for silkworm rearing. Accordingly, nitrogen, crude protein and total carbohydrate contents all together were comparatively higher in genotype Abaro from this study, which recorded 4.125 %, 25.783 % and 43.304 % respectively. The average nitrogen content was greater than the findings of Jayaramaiah and Sannappa (1998) who reported 2.4 – 3.0 % nitrogen from different castor genotypes. Similarly, the crude protein and total carbohydrate contents recorded from the present study were higher than records of Baruah and Baruah (2007) on different Som accessions for muga silkworms who obtained less than 16% crude protein and less than 25 % total carbohydrate.

On the other hand, the present study on rearing performance of eri silkworms conducted by feeding different castor genotypes indicated very significant differences. As a result, Abaro provided highest cocoon weight, shell weight, pupal weight and silk ratio as well as ERR with medium and above medium record for hatching percent of eggs, larval weight, fecundity and survival to eri silkworms. In addition, Acc 208624 provided highest survival rate with above medium records for the rest silkworm rearing characters. Further more, Bako provided highest larval weight with higher silk ratio and survival. However, local genotype recorded medium and below medium values for most rearing performance indicators.

Therefore, the present study revealed that Abaro, which showed 3.344 g single cocoon weight, 0.484 g single shell weight and 14.487 % shell ratio, was the most promising castor genotype in respect to cocoon traits followed by Acc 208624 and Bako. The present finding is comparable to Thangavelu and Phukon (1983) and Patil *et al.* (1998 and 2009), who reported that variation in performance of eri silkworm with respect to cocoon traits is mainly due to host plant varieties and obtained maximum single cocoon weight, shell weight and shell ratio of 3.817g, 0.4433g and 11.63% respectively.

In a similar setting of the experiment, analysis of feeding efficiency of eri silkworms fed on castor genotypes was carried out by using the 5th instar larva. This is because 97 % of the total food intake in silkworms is made during the last two instars. During 5th instar, however, 80-85 % of the total leaves as silkworms are very active metabolically at this stage (Rahmathulla *et al.*, 2005). Hence, the present analysis in regard to feeding efficiency of eri silkworms was confined to 5th instar or stage and it has revealed significant differences. Among castor genotypes studied, Abaro revealed highest efficency of ingesta to cocoon with higher efficiency of ingesta to larva and efficiency of digesta to cocoon and approximate digestibility. In addition, Acc 106584 provided highest approximate digestibility, reference ratio and relative consumption index. Further more, Acc 208624 revealed higher ingesta, digesta, approximate digestibility, reference ratio and consumption index as well as efficiency of ingesta to cocoon when fed to eri silkworms. Bako provided highest efficiency of ingesta to larva and efficiency of digesta to cocoon. On the other hand, local genotype showed lower conversion efficiency though it was good enough in other parameters.

In case of castor genotypes of Ar sel and Bako ingesta and digesta fluctuated at around or below medium, but their conversion to larval biomass and cocoon were relatively good enough. It is because low food intake may be offset by a high utilization of ingested or digested food. Conversely, Acc 106584, GK sel and local genotype, high food intake reveal that it may not necessarily lead to efficiency in the utilization of ingested or digested food being attributable to leaf nutrient composition. Therefore, this study revealed that Abaro and Acc 208624 provided significantly higher feeding and conversion efficiency to eri silkworms. Similarly, the findings of Basaiah (1988) and Reddy and Swamy (1999) in India showed same trend as above with regard to feeding efficiency when eri worms were fed on different castor varieties. This difference could also be attributable to the overall variation in the quality of castor leaves as reported by Legay (1958). Further, the report of Govindan *et al* (2003) who recorded 26.38 % - 28.35 % of conversion of ingested food to cocoon and 38.37 % - 40.26 % conversion of digested food to cocoon can be comparable with the records obtained from the present study that showed 15.83 %- 19.81% and 31.3 - 43.14% conversion of ingested food to cocoon and conversion of digested food to cocoon respectively from different castor varieties.

A non significant difference in relative growth rate and efficiency of digesta to larva may be attributed to less difference in larval duration since it was only the 5^{th} instar stage is considered for feeding efficiency analysis. Moreover, growth rate at the final stage of silkworms is relatively lower as compared to earlier stage. Moreover, a non significant effect on the efficiency of conversion digested food to larval biomass could be attributable to a physiological effect that has no significant effect on larval growth rate.

Further, it is believed that increase in rearing performance, feeding efficiency and cocoon yield will be related with of an increase in the accumulation of biochemical constituents in the body tissue of the silkworm obtained from different castor genotypes. As a result, the inter-relationship of performance of eri silkworms and the biochemical composition of leaves of castor genotypes have been analyzed by correlation analysis through SAS software. The results of correlation analysis suggest that different traits of eri silkworm have significantly different relationship with various biochemical constituents of castor leaves.

As a result, cocoon traits such as cocoon weight, pupal weight, shell weight and shell ratio found to have significant positive relationship with crude protein, crude fat, moisture, total carbohydrate, and tannin as well as nitrogen and phosphorus contents. The relationship obtained from such traits with foliar composition parameters of moisture, total carbohydrate, nitrogen and phosphorus were in conformity with Jayaramaiah and Sannappa (1998). On the other hand, these traits of silkworms found to have significant negative correlation with ash (total minerals) and crude fiber composition of leaves. Moreover, larval characteristics like larval weight, survival and effective rate of rearing showed a significant positive correlation or interaction with crude protein, moisture, nitrogen and phosphorus contents.

Further more, grainage parameters like hatching percent and fecundity showed significant positive correlation with ash, crude protein, moisture and nitrogen composition of castor leaves. This relationship obtained from egg production and foliar composition parameters of moisture, total carbohydrate, nitrogen and phosphorus were also in conformity with Jayaramaiah and Sannappa (1998). Similarly, crude fiber content of leaves was negatively attributed to all the required characteristics of silkworms. On the other hand, ash composition of leaves has negatively correlated to most economic traits of silkworms.

Therefore, it is clearly established that the quality of leaves particularly their crude protein, moisture content, total carbohydrate as well as nitrogen and phosphorus are highly required for both larval and cocoon characteristics. Moreover, the reduction in crude fiber and ash from selection of castor genotypes will be considered in future.

However, concentration of condensed tannin has been found to correlate positively to cocoon, pupal and shell weight. Thus, it does not function as anti-nutritional factor; rather the opposite had become true. It could be justified by their more alkaline mid-gut because insoluble tannin-protein complexes can be broken down and absorbed as nutrients at alkaline pH levels (Feeny, 1968). Similar findings have been observed by (Feeny, 1968 and 1969), which to indicate that some lepidopteran larvae feed on plants with high levels of condensed tannins because of their more alkaline mid-guts when compared to lepidoptera that feed on herbs. Otherwise, like other herbivores, eri silkworm may have its own enzymes that counter and reduce the effectiveness of tannins.

6. Conclusion and Recommendation

6.1. Conclusion

The present study reveals that the selection of castor genotypes for rearing eri silkworm based up on field performance and biochemical constituents of the castor genotypes as well as rearing performance and feeding efficiency of eri silkworms is very important in order to get better larval development, cocoon production and grainage parameters improvement.

In the field condition, different castor genotypes showed significantly different performances. Therefore, selection based on leaf biomass to use for eri silkworm rearing revealed that Acc 208624, Acc 106584 and Acc 203241 better than local genotype followed by Abaro.

On the other hand, Abaro was the most promising castor genotype in respect to rearing performance of eri silkworm especially in regard to cocoon traits followed by Acc 208624 and Bako. Similarly, analysis of feeding efficiency eri silkworms fed different castor genotypes revealed Abaro and Acc 208624 as most important genotypes.

Moreover, the biochemical composition of leaves has also revealed significant differences among castor genotypes. Moreover, the relationship of biochemical constituents of castor genotypes with larval characteristics showed a significant positive correlation or interaction with crude protein, moisture, nitrogen and phosphorus contents. Their interaction with cocoon traits found to have significant positive relationship with crude protein, crude fat, moisture, total carbohydrate and tannin as well as nitrogen and phosphorus contents. On the other hand, grainage parameters showed significant positive correlation with ash, crude protein, moisture and nitrogen composition of castor leaves.

Therefore, by considering all parameters, crude protein, moisture and nitrogen contents can be established as the basic ones to characterize castor genotypes. Consideration of high or above medium nitrogen, crude protein, and moisture content as will lead us to concentrate our investigation on Abaro and Acc 208624.

Therefore, Abaro was found to be the best in all studied conducted in laboratory condition (biochemical composition, rearing and feeding efficiency). However, it performed poor in field condition as it was very susceptible to leaf rust disease. On the other hand, Acc 208624 was best in field studies but it was next to Abaro in laboratory studies.

6.2. Recommendations

As a result of field and laboratory studies, Acc 208624 will be recommended for eri silkworm rearing and development activities for the future. However, Abaro will be considered where and when leaf rust disease problems are low or with availability of appropriate leaf rust disease management options. On the other hand, in case of selection of castor genotypes was to be made for seed yield, Acc 203241 and GK sel will be recommended.

More research should also be carried out to support the current findings in consideration with the following issues: -

- Rust disease management options
- The specific role of crude proteins, total carbohydrates as well as well as their specific components like amino acids, soluble proteins, soluble sugars, etc.
- The role and functioning of tannins should further be explored in that tannins could be inter-linked with enzymes and the like.
- Appropriate integration of eri silk rearing with castor oil seed production

7. References

A.O.A.C. (1970). *Methods of Analysis*, 9th edn. Association of Official Agricultural Chemists, Washington, 789pp.

Acharay, C., Ghosh, S. K. and Kundu, S. C. (2008). Silk fibroin protein from mulberry and non-mulberry silkworms: cytotoxicity, biocompatibility and kinetics of L929 murine fibroblast adhesion. *J Mater Sci.* **3**:25-35

Akai, H. and Nagashima, T. (1999). Fine-structural characteristics of Anaphe cocoon filament. *Int. J. Wild Silkmoth and Silk* **4:** 25-32.

Altman,O.G., Diaz, F., Jakuba, C., Calabro, T., Horan, R. L., Chen, J., Lu, H., Richmond, J. and Kaplan, D. L. (2003). Silk-based biomaterials.*Biomaterials* **24:**401-416.

Ashiru, M.O. (1991). Adult morphology of the silkworm *Anaphe veneta* Butler (Lepidoptera: Notonidae). **In**: *Wild Silk Moths,* pp. 89- 95 (Akai, H. and Kiuchi, M., eds) . International Society for wild silk moths, Ibaraki.

Baruah, A.B. and Baruah, P.K. (2007). Studies on the status of biochemical constituents in four morphotypes of muga food plant som (*Persea bombycina*). **In**: *Proceedings of International Conference on "Sericulture Challenges in the 21st Century and the 3rd BACSA meeting*, September 2007, Vratza.

Basaiah, J.M. (1988). *Consumption and utilization of castor and tapioca by eri silkworm Samia Cynthia ricini Boisduval*. M.Sc. Thesis, University of Agricultural Sciences, Bangalore.

Belli, C. (1947). Mission of the Ente Nazionale sericole of Italy. *Sericologia* **10**:13-17

Bose, P.C., Majumder, S.K. and Sengupta, K. (1991). A comparative biochemical study of six mulberry (*Morus alba* L.) varieties. *Indian. J. Seri.* **30:** 83-87.

Chakravorty, R. and Neog, K. (2006). Food plants of eri silkworm, *Samia ricini* DONOVAN: Their rearing performance and prospects for exploitation. **In**: Proceeding of National workshop on Eri food plants, pp. 1-7, Guwahati.

Chowdhury, S.N. (1982). *Eri Silk Industry*. Directorate of Sericulture and Weaving, Government of Assam, Guwahati, pp. 60-65.

Chowdhary, S.N. (2006). Host plants of eri silkworm (*Samia ricini* Boiduval): Their distribution economic and prospects for exploitation. **In**: Proceeding of National workshop on Eri food plants, 2006, pp. 28-37, Guwahati.

Craig, C. L. and Riekel, C. (2002). Comparative architecture of silks, fibrous proteins and their encoding genes in insects and spiders. *Comparative Biochemistry and Physiology*. **133:** 493-507.

Dash R, Mandal, M., Ghosh, S.K. and Kundu, S. C. (2008). Antioxidant potential of silk proteins against hydrogen peroxide-induced oxidative stress in skin fibroblasts. *BMB Rep.* **41:**236-233.

Dayashankar, K.N. (1982). Performance of eri silkworm, *Samia cynthia ricini* Boisduval on different host plants and economics of rearing on castor under Dharwad conditions. *M.Sc. Thesis*, University of Agricultural Sciences, Bangalore, pp.60-86.

Debaraj, Y., Singh, B.K., Das, P.K. and Suryanarayan, N. (2003). Payam: An evergreen host plant of eri silkworm. *Indian silk* **5**:5-6.

Devaiah, M.C., Rajashekhargouda, R., Suhas, Y. and Govindan, R. (1985). Growth and silk production in *Samia cynthia ricini* Boisduval as fed on four different host plants. *Ind.J. Seril* **24**: 33-35

Feeny, P.P. (1968). Effect of oak leaf tannins on larval growth of the winter moth *Operophtera brumata*. J. Insect Physiol. **14:** 805-817.

Feeny, P.P. (1969). Inhibitory effect of oak leaf tannins on the hydrolysis of proteins by trypsin. *Phytochemistry* **8**: 2119-2126.

Friend, W.G. (1958). Nutritional requirements of phytophagous insects. *Ann. Rev. Ent.* **3**: 57-74.

Fukuda, T., Kamegame, T. and Matsuda, M. (1963). A correlation between the mulberry leaves consumed by the mulberry silkworm larvae in different ages of the larval growth and production of cocoon fiber spun by silkworm larvae and the eggs laid by the silkworm. *Bull. Seric. Exp. Stn.* **8**: 165-171.

Fukuda, T., Suto, M. and Higuchin, Y. (1960). Silkworm raising on the artificial food. *J. Seric. Sci.* **29:**1-13.

Gogoi, B. and Goswami, B.C. (1998). Studies on certain aspects of wild eri silkworm (*Philosamia cynthia* Drury) with special reference to its rearing performance. *Sericologia* **38**:465-468.

Gowdey, C.C. (1953). Utilisation of an indigenous silkworm *(Anaphe infracta* Walsingham*)* in Uganda. *Bul. Entomol. Res.* **3**: 269-274.

Gu, G. D. (1999): Study on the output of cocoon and raw silk and distribution of sericultural area in the world. *Sericult. Sci.* **25**: 105–114.

Hajare, T.N., Jadhav, A.D, Venugopalan, M., Patil, N.G., Chaturvedi, A. and Maji, A.K. (2007). Evaluation of sericulture for augmenting agricultural income of marginal farmers in semi-arid region of India. **In**: *Proceedings of International Conference on Sericulture Challenges in the 21st Century and the 3rd BACSA meeting*, September 2007, Vratza.

Hajarika, U., Barah, A., Phukan, J.C. and Benshamin, K.V. (2003). Study on the effect of different food plants and seasons on the larval development and cocoon characters of silkworm *Samia cynthia ricini* Boisduval. *Bull. Ind. Acad. Seric.* **7**:77- 85.

Hamano, K., Miyazawa, K. and Mukiyama, F. (1986). Racial difference in the feeding habit of the silkworm, *Bombyx mori*. J. *Seric. Sci.* **55**: 68-72.

Hanumappa, H.G. (1986). Sericulture for Rural Development. Himalaya Publishing House, Bombay, pp. 12-34

Hazarika, U., Barah, A. and Chakravorty, R. (2005). Physiological and biochemical response of castor (*Ricinus communis* Linn.) to application of NPK and their correlation with economic parameters of eri silkworm (*Samia ricini* DONOVAN). **In**: *Proceeding of 20th Congress of the International sericulture commission,* Bangalore, **2**: 94-98.

Hazarika, U., Chakravorty, R. and Borah, A. (2006). Economics of perennial castor cultivation. *Ind. Silk*. pp. 181-187

Hiwar, C.J. (2001). Agro Cottage Industry: Sericulture. Daya Publishing House. New Delhi. pp. 1-117.

Lizuka, E. (2002). Properties of wild silk and its usefulness. *Int. J. Wild Silk moth and Silk* **7:** 31-36.

Ito, T. (1978). Silkworm nutrition. **In**: *The Silkworm: an Important Laboratory Tool,* pp. 150–151 (Tazima, Y., ed). Kodansha ltd., Tokyo.

Jayaraj, S. (2004). Eri culture in Tamil Nadu, Kerala and Pondichery states: Some experiences. **In**: *Proceeding of Workshop on Prospects and Development of Ericulture*, University of Agricultural Sciences, Dharwad, pp.10-29.

Jayaram, H., Mallikarjuna, V., Lakshmanan, Ganapathi, S., Rao, R. and Geetha, D.R. (1998). Labour employment under different mulberry farm holdings-a comparative study. *Ind.J.Seric.* **38:** 55-56.

Jayaramaiah, M. and Sannappa, B. (1998). Correlation Coefficients Between Foliar Constituents of Castor Genotypes and Economic Parameters of the Eri Silkworm, *Samia cynthia ricini* Boisduval (Lepidoptera: Saturniidae). *The third Int. Conf. Wild Silkmoths*, pp. 162-194.

Jolly, M.S., Sen, S.K. and Ahsan, M.N. (1974). *Tasar Culture,* 1st edn. Central Silk Board, Bombay, pp. 1-266.

Joshi, K.L. (1992). Evaluation of Diets for Larvae of the Eri Silkworm, *Samia cynthia ricini* (Lepidoptera:Saturniidae). *Ind. J. Seric.* **31**: 49-51

Joshi, K.L. and Misra, S.D. (1982). Silk Percentage and effective rate of rearing of eri silkmoth, *Philosamia ricini* Hutt. (Lepidoptera: Saturniidae). *Entomol*. **7**:107-110

Kalantri, L.B., Jadhav, A.D., Hajare, T.N., Salunkhe, D.Y., Undale, J.P., Balsaraf, A.U., Sathe, T.V. (2007). Progress and prospects of sericulture industry in Maharashtra, India. **In**: *Proceedings of International Conference on Sericulture Challenges in the 21st Century and the 3rd BACSA meeting*, September 2007, Vratza.

Kato, H. (2000). Structure and thermal properties of *Anaphe*, *Cricula* and *Attacus* cocoon filaments. *Int. J. Wild Silkmoths and Silk* **5**: 11-20.

Khan, A.R. and Hoque, A.A. (1987). Effect of Castor-Papaya Leaf Combinations on the Oviposition and Fertility of the Eri Silkworm, *Philosamia ricini* (Hutt) (Lepidoptera:Saturniidae). *Ind.J. Seric.* **26**: 79-81

Kim, D.H., Viventi, J., Amsden, J.J., Xiao, J., Vigeland, L., Kim, Y.S., Blanco, J.A., Panilaitis, B., Frechette, E.S., Contreras, D., Kaplan, D.L., Omenetto, F.G., Huang, Y., Hwang, K.C., Zakin, M.R., Litt, B. and Rogers, J.A. (2003). Dissolvable films of silk fibroin for ultrathin conformal bio-integrated electronics. *Nat Materials* **9:** 511–517.

Kioko, E.N., Raina, S.K. and Mueke, J.M. (2000). Survey on diversity of wild silk moths species in East Africa. *E. Afr. J. Sci.* **2**: 1-6.

Krishna Rao, J.V., Sathyanarayana, K., Teotia, R.S. and Mukund, V.K. (2004). Ericulture in India. **In**: *Proceedings of International Seminar on "Castor seed, Castor oil and its value added Products", 8th February 2004*, Ahemdabad, pp. 39-45.

Krishnaswami, S. (1978). New Technology of Silkworm Rearing. Bull.Cent. Seric. Res.Train. Inst., Mysore, pp. 1-24.

Krishnaswami, S., Asan, M. and Sriharn, T.P. (1970). Studies on the quality of mulberry leaves and silkworm cocoon crop production. *Ind. J. Seric.* **9**:11- 25

Lamelu, A.G. (1998). *Illustrated textbook on sericulture-translated from Japanese*. Siences pulishing Inc. Enfield, New Hampshiere, pp.10-35

Legay, J. M. (1958). Recent advances in silkworm nutrition. *A. Rev. Ent.*, **3**: 75-86.

Mandal, B.B. and Kundu, S.C. (2009). Non-mulberry silk gland fibroin protein 3D scaffold for enhanced differentiation of human mesenchymal stem cells into osteocytes. *Acta Biomaterialia* **5:** 3007-3020.

Maynard, A.L. and Loosli, L., (1962). Animal Nutrition, 5th edn.. McGraw Hill Book Co., Inc., New York, pp: 533.

Mbahin, N., Raina S.K., Kioko, E.N. and Mueke, J.M. (2008). Spatial distribution of cocoon nests and egg clusters of the silkmoth *Anaphe panda* (*Boisduval*) (Lepidoptera: Thaumetopoeidae) and its host plant *Bridelia micrantha* (Euphorbiaceae) in the Kakamega Forest of western Kenya. *Int. J.Trop.Insec.Sci.* **27**:138-144.

McKinney, E. and Eicher, J.B. (2009). Unexpected Luxury: Wild Silk Textle Production among the Yoruba of Nigeria. *J. Cloth and Culture* **7:** 40-55.

Metaferia, H.Y., Amanuel, T. and Kedir, S. (2007). Scaling up of silk production technologies for employment and income generation in Ethiopia. **In**: *Success With Value Chain: proceedings of scaling up and scaling out of agricultural technologies in Ethiopia, an international conference, 9-11 May 2006* (Tsedeke Abate ed). Ethiopian Institute of Agricultural Research, Addis Ababa.

Milner, J.A. (2004). Nutrition and gene regulation: Molecular targets for bioactive food components. J. Nutr. **134**: 2492-2498.

Mishra, S.D. (1999). Aruna Variety, a unique host for the Eri silkworm: Two revenues from the same source. Ind. J. Seric. **38**: 95-101.

Neupane, F.P., Thapa, R.B. and Parajulee, M.N. (1990). Life and seasonal histories of the eri silkworm, *Samia cynthia ricini* Hutt. (Lepidoptera: Saturniidae) in Nepal. *J. Inst. Agri.: Anim. Sci.* **11**:113–120.

Ogunbanwo, S.T. and Okanlawon, B.M. (2009). Influence of nutrients utilization and cultivation conditions on the production of lactic acid by homolactic fermenters. *Biotechnology* **8**: 107-113.

Pandey, R.K. (1995). Do leaf tannins affect non mulberry silkworm? *Ind. Silk* **34**: 21-23.

Pandey, R.K. (2003). Eri culture in Uttar Pradesh. *Ind.Silk* **41**: 21-24.

Patil, G.M., Kulkarni, K.A., Patil, R.K. and Badiger, K.S. (1998). Performance of Eri Silkworm, *Samia Cynthia Ricini* Boisd. on different castor genotypes. *Int. Conf. Wild Silkmoths*. PP. 193-195

Patil, R.R., Kusugal, S. and Ankad, G. (2009). Performance of eri silkworm, *Samia cynthia ricini* Boisd. on few food plants. *Karnataka J. Agric. Sci.* ***22**: 220-221*.

Peigler, R. (1993). Wild silks of the world. *Amer. Entomol.* **39**: 151-161.

Raghavaiah, C.V. (2003a). Strategy for promotion of Eri Silk through utilization of castor for foraging. *Ind.Silk* **42**: 33-35.

Raghavaiah, C.V. (2003b). Prospects of Eri silk (*Philosomia ricini*) production along with castor beans *(Ricinus communis L.)* and Tapioca *(Manihot utilisimma)* production in Andhra Pradesh. *Ind.Silk* **42**: 33-35

Rahmathulla, V.K., Rufaie, H.Z., Himanthraj, M.T., Vindhya, G.S. and Rajan, R.K. (2005). Food ingestion, assimilation and conversion efficiency of mulberry silkworm, *Bombyx mori* L. *Int. J. Ind. Entmon.* **11**: 1-12.

Raina, S.K. (2004a). A Practical Guide for Raising and Utilization of Silk Moths and Honey Bees in Africa. ICIPE science press, Nairobi, 182pp.

Raina, S.K. (2004b). *On developing incentives for community participation in forest conservation through the use of commercial insects in Kenya.* ICIPE science press, Nairobi, pp. 200-213.

Ramesha, C., Anuradha, C.M., Lakshmi, H., Kumari, S.S., Seshagiri, S.V. Goel, A.K. and Kumar, C.S. (2010). Nutrigenetic traits analysis for the identification of nutritionally efficient silkworm germplasm breeds. *Biotechnology* **9**: 131-140.

Ramesh-Babu, K., Ramakrishna, S., Harish-Kumar-Reddy, Y., Lakshmi, G., Naidu, N.V., Sadak-Basha, S. and Bhaskar, M. (2009). Metabolic alterations and molecular mechanism in silkworm larvae during viral infection: *A rev. Afr. J. Biotechnol.* **8**: 899-907.

Rani, J.U. (2007). Employment generation to women in drought prone areas: A study with reference to the development of sericulture in Anantapur district of Andhra Pradesh. *J. Soc. Sci.* **14:** 1-7.

Ranjhan, S.K. and Krishna, G. (1981). Laboratory Manual for Nutrition Research, Vikas pub. House Pvt. Ltd., New Delhi, pp. 45-67.

Rao, R.M., Prasad, R.N. and Suryanarayan, N. (2005). Ericulture an additional income for tapioca (cassava) growers and good nourishment to the man-nutrition's tribal populace. **In**: Proceeding of 20th congress of the International sericulture commission, Bangalore, pp. 94- 98.

Ravikumar, C. (1988). Western ghats as a bivoltine region prospects, challenges and strategies for its development. *Ind. Silk* **26**: 39-54.

Reddy, D.N. and Swamy, K.C. (1999). Effect of host on the consumption rate, leaf – cocoon and leaf egg ratio of eri silkworm, *Samia cynthia ricini* Boisduval (Lepidoptera:Saturniidae). *Entomol.* **24**: 67-70

Reddy, R.M. (2008). Value addition span for silkworm cocoon - time for utility optimization. *Int. J. Indust. Entomol.* **17:**109-113.

Sahay, A., Singh, B.K., Deori, S. and Mukherjee, P.J. (1997). Eri culture: Nature's gift. *Ind. Silk **3**:*12-15

Sahlemedhin Sertsu and Taye Bekele (2000). *Procedures for soil and plant analysis.* Technical paper, Ethiopian Agricultural Research Organization, Addis Ababa, pp. 60-83

Sakthivel, N. (2004). Eri culture on castor and tapioca in Tamil Nadu. **In**: *Proceeding on workshop of prospects and development of ericulture,* University of Agricultural Sciences, Dharwad, pp. 78-81.

Sannappa, B. and Jayaramaiah, J. (1999). Mineral Constituents of Selected Genotypes of Castor, *Ricinus communis* L. *Mysore J.agric.Sci.* **33**: 157-161

Sarkar, D.C. (1988). Ericulture in India. Central Silk Board, Grafo Printers, pp.1- 49.

SAS Institute Inc (1999-2000). SAS/STAT users' guide. SAS Institute. Cary.

Scriber, J. M. and Slansky, F. (1981). The Nutritional Ecology of Immature Insects. *Ann. Rev. Entomol.* **26**: 183-211

Shao, Z. and Vollrath, F. (2002). Surprising strength of silkworm silk. *Nature* **418:** 741-742.

Singh, B.K., Sahu,J., Krishna Rao, J.V. and Das, P.K. (2004). Sustainable development of traditional States through improved rearing practices. **In**: *Proceedings of National Workshop on Potential and Strategies for Sustainable development of Vanya Silks in the Himalayan States*, Dehradun, pp. 236-239.

Singh, K.C. and Benchamin, K.V. (2002). Biology and ecology of the eri silkmoth *Samia ricini* Donovan (Saturniidae): *Bullet. Ind. Acad. Seric.* **6**: 20-33.

Slansky, F. and Scriber, J.M. (1985). Food consumption and utilization. **In**: *Comprhensive Insect Physiology, Biochemistry and Pharmacology*, pp. 88-151. (Kerkut, G.A. and Gilbert, L.I. eds.), Bangalore.

Solanki, S.S. and Joshi, P. (2001).Inheritance study of some morphological traits in castor (*Ricinnus communis* L.). *Ind. J. Genet.* **61**:136-139.

Spring, C. and Hudson, J. **(**2002). *Silk in Africa: Ethiopia*. University of Washington Press, Seattle.

Suryanarayana, N., Sarmah, M.C., Sahu, A.K., Kumar, A. and Das, P.K. (2002). Status paper on promotion of eri culture in India. **In**: *Proceedings of National Workshop on Sericulture Germplasm Management and Utilization*, CSGRC, Hosur, pp. 50–53

Sutherland, T.D., Young, J.H., Weisman, S., Hayashi, C.Y. and Merritt, J. (2009). Insect Silk: One name, many materials. *Ann.Rev.Entomol.* **55:** 171-188.

Takano, K. and Arai, N. (1978). Studies on the food values on the basis of feeding and cocoon productivity in the silkworm, *Bombyx mori*. Sericol. Sci. **47**: 134-142.

Thangavelu, K. and Phukon, J.C. (1983). Food Preference of Eri Silkworm *Philosamia ricini* Hutt (Saturnidae: Lepidoptera). *Entomol.* **8**: 311-315

Tzenov, P. (2007). Present status and utilization of sericulture germplasm and comparative studies of different silkworm hybrids performance for sericultural enterprise development in the Black, Caspian seas and Central Asia (BACSA) region. **In**: *Proceedings of International Conference on Sericulture Challenges in the 21st Century and the 3rd BACSA meeting*, September 2007, Vratza

Waldbauer, G.P. (1968). The consumption and utilization of food by insects. *Adv. Insec. Physiol.* **3**: 229-282.

Weiss, E.A. (1971). Castor, Seasame and Sunflower. **In**: Castor (Moshkin, V.A. ed.), Oxford University Press, pp. 256-347.

Zhang, Y.H., Xu, A.Y., Wei, Y.D., Li, M.W., Hou, C.X. and Zhang, G.Z. (2002). Studies on feeding habits of silkworm germplasm resources for artificial diet without mulberry. *Acta Sericologia Sinica* **28**: 333-336.

Zimmerman, L.H., Miller, M.D. and Knowles, P.F. (1958). Castor bean in California. *Calif. Agr. Expt. Sta.* pp. 460-468.

8. Appendices

Appendix*1. The GLM Procedure for field studies*

Dependent Variable: PH

R-Square	Coeff Var	Root MSE	PH Mean
0.779782	4.723990	7.655463	162.0550

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	52.981300	26.490650	0.45	0.6453
Treatment	7	2852.325200	407.475029	6.95	0.0011

Dependent Variable: LPB

R-Square	Coeff Var	Root MSE	LPB Mean
0.972906	10.66513	12.99857	121.8792

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	1130.94083	565.47042	3.35	0.0649
Treatment	7	83810.75958	11972.96565	70.86	<.0001

Dependent Variable: ST

R-Square	Coeff Var	Root MSE	ST Mean
0.796279	4.733501	0.150940	3.188750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	0.06557500	0.03278750	1.44	0.2701
Treatment	7	1.18112917	0.16873274	7.41	0.0008

Dependent Variable: IL

R-Square	Coeff Var	Root MSE	IL Mean
0.919847	6.139047	0.463370	7.547917

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	0.20243333	0.10121667	0.47	0.6337
Treatment	7	34.29439583	4.89919940	22.82	<.0001

Dependent Variable: LA

R-Square	Coeff Var	Root MSE	LA Mean
0.966478	8.106312	650.3346	8022.570

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	1802221.7	901110.9	2.13	0.1557
Treatment	7	168910507.2	24130072.5	57.05	<.0001

Dependent Variable: NL

R-Square	Coeff Var	Root MSE	NL Mean
0.712362	8.269636	3.282563	39.69417

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	6.1174333	3.0587167	0.28	0.7571
Treatment	7	367.4848500	52.4978357	4.87	0.0058

Dependent Variable: NPB

R-Square	Coeff Var	Root MSE	NPB Mean
0.943210	7.528802	0.586619	7.791667

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	1.09895833	0.54947917	1.60	0.2373
Treatment	7	78.91666667	11.27380952	32.76	<.0001

Dependent Variable: InfL

R-Square	Coeff Var	Root MSE	InfL Mean
0.955937	4.275270	1.288495	30.13833

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	11.2518583	5.6259292	3.39	0.0631
Treatment	7	493.0060000	70.4294286	42.42	<.0001

Dependent Variable: FLY

R-Square	Coeff Var	Root MSE	FLY Mean
0.952642	5.437648	569.1338	10466.54

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	327936.96	163968.48	0.51	0.6134
Treatment	7	90891864.19	12984552.03	40.09	<.0001

Dependent Variable: DLY

R-Square	Coeff Var	Root MSE	DLY Mean
0.923197	6.088196	156.3883	2568.713

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	35840.231	17920.115	0.73	0.4982
Treatment	7	4079950.588	582850.084	23.83	<.0001

Dependent Variable: DI

R-Square	Coeff Var	Root MSE	DI Mean
0.992938	4.611384	1.491072	32.33458

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	0.499733	0.249867	0.11	0.8945
Treatment	7	4375.965729	625.137961	281.18	<.0001

Dependent Variable: DS

R-Square	Coeff Var	Root MSE	DS Mean
0.996925	5.041832	1.296171	25.70833

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	3.145833	1.572917	0.94	0.4153
Treatment	7	7621.291667	1088.755952	648.05	<.0001

Dependent Variable: SY

R-Square	Coeff Var	Root MSE	SY Mean
0.969086	5.975097	81.86620	1370.123

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	41863.207	20931.603	3.12	0.0756
Treatment	7	2899439.765	414205.681	61.80	<.0001

Dependent Variable: SW

R-Square	Coeff Var	Root MSE	SW Mean
0.948951	5.169925	25.48342	492.9167

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	1108.3333	554.1667	0.85	0.4470
Treatment	7	167895.8333	23985.1190	36.93	<.0001

Appendix *2. The GLM Procedure for foliar composition studies*

Dependent Variable: Ash

R-Square	Coeff Var	Root MSE	Ash Mean
0.973962	3.149631	0.500000	15.87488

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	149.6232506	21.3747501	85.50	<.0001

Dependent Variable: N

R-Square	Coeff Var	Root MSE	N Mean
0.831971	2.613250	0.104300	3.991208

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	0.86181329	0.12311618	11.32	<.0001

Dependent Variable: P

R-Square	Coeff Var	Root MSE	P Mean
0.958554	2.886498	0.056360	1.952542

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	1.17543062	0.16791866	52.86	<.0001

Dependent Variable: K

R-Square	Coeff Var	Root MSE	K Mean
0.948413	2.618074	183.9340	7025.547

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	9951770.946	1421681.564	42.02	<.0001

Dependent Variable: Ca

R-Square	Coeff Var	Root MSE	Ca Mean
0.999993	0.056878	0.066751	117.3570

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	10016.23929	1430.89133	321140	<.0001

Dependent Variable: Mg

R-Square	Coeff Var	Root MSE	Mg Mean
0.984050	2.571177	0.378894	14.73621

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	141.7156920	20.2450989	141.02	<.0001

Dependent Variable: CP

R-Square	Coeff Var	Root MSE	CP Mean
0.832062	2.612957	0.651808	24.94521

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	33.67951329	4.81135904	11.32	<.0001

Dependent Variable: CFb

R-Square	Coeff Var	Root MSE	CFb Mean
0.968449	1.587671	0.309798	19.51275

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	47.13507917	6.73358274	70.16	<.0001

Dependent Variable: CFt

R-Square	Coeff Var	Root MSE	CFt Mean
0.994338	2.654007	0.021756	0.819750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	1.33005317	0.19000760	401.42	<.0001

Dependent Variable: Mois

R-Square	Coeff Var	Root MSE	Moistthr Mean
0.825288	2.029925	1.494342	73.61563

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	168.7727528	24.1103933	10.80	<.0001

Dependent Variable: Tocrb

R-Square	Coeff Var	Root MSE	ToCrb Mean
0.991909	0.957406	0.371927	38.84742

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	271.3250638	38.7607234	280.20	<.0001

Dependent Variable: Tan

R-Square	Coeff Var	Root MSE	Tan Mean
0.999918	0.329083	0.452024	137.3588

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	39931.43445	5704.49064	27918.6	<.0001

Appendix 3. *The GLM procedure for rearing performance and feeding efficiency of eri silkworms*

Appendix 3.1. The GLM Procedure for Rearing performance studies

Dependent Variable: HaP

R-Square	Coeff Var	Root MSE	HaP Mean
0.967087	1.207708	1.055738	87.41667

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	524.0000000	74.8571429	67.16	<.0001

Dependent Variable: LaD

R-Square	Coeff Var	Root MSE	LaD Mean
0.560296	1.100141	6.487167	589.6667

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	858.0000000	122.5714286	2.91	0.0363

Dependent Variable: Larw

R-Square	Coeff Var	Root MSE	Larw Mean
0.922828	0.961864	0.076649	7.968750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	1.12406250	0.16058036	27.33	<.0001

Dependent Variable: Cow

R-Square	Coeff Var	Root MSE	Cow Mean
0.972608	0.465296	0.014937	3.210227

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	0.12675666	0.01810809	81.16	<.0001

Dependent Variable: Puw

R-Square	Coeff Var	Root MSE	Puw Mean
0.970317	0.466417	0.012822	2.749130

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	0.08599393	0.01228485	74.72	<.0001

Dependent Variable: Shw

R-Square	Coeff Var	Root MSE	Shw Mean
0.979384	0.513507	0.002368	0.461098

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	0.00426134	0.00060876	108.58	<.0001

Dependent Variable: SiR

R-Square	Coeff Var	Root MSE	SiR Mean
0.964263	0.213091	0.030603	14.36167

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	0.40433595	0.05776228	61.67	<.0001

Dependent Variable: Surv

R-Square	Coeff Var	Root MSE	Surv Mean
0.896409	2.209129	1.649043	74.64672

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	376.5018008	53.7859715	19.78	<.0001

Dependent Variable: Fecun

R-Square	Coeff Var	Root MSE	Fecund Mean
0.908356	2.474344	9.124144	368.7500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	13202.50000	1886.07143	22.66	<.0001

***Appendix* 3.2. The GLM Procedure for feeding efficiency of silkworms**

Dependent Variable: Ing

R-Square	Coeff Var	Root MSE	Ing Mean
0.701176	4.441079	0.296411	6.674292

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	3.29851162	0.47121595	5.36	0.0026

Dependent Variable: Dig

R-Square	Coeff Var	Root MSE	Dig Mean
0.699584	8.018763	0.265331	3.308875

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	2.62308329	0.37472618	5.32	0.0027

Dependent Variable: Exc

R-Square	Coeff Var	Root MSE	Exc Mean
0.897736	2.034379	0.068465	3.365417

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	0.65839583	0.09405655	20.07	<.0001

Dependent Variable: AD

R-Square	Coeff Var	Root MSE	AD Mean
0.797699	3.614804	1.786782	49.42958

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	201.4204825	28.7743546	9.01	0.0002

Dependent Variable: RR

R-Square	Coeff Var	Root MSE	RR Mean
0.779103	3.674380	0.072952	1.985417

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	0.30032850	0.04290407	8.06	0.0003

Dependent Variable: RCI

R-Square	Coeff Var	Root MSE	RCI Mean

0.700510	6.027237	0.050179	0.832542

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	0.09423262	0.01346180	5.35	0.0027

Dependent Variable: RGR

R-Square	Coeff Var	Root MSE	RGR Mean
0.415433	4.674696	0.011667	0.249583

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	0.00154783	0.00022112	1.62	0.1991

Dependent Variable: ECIlar

R-Square	Coeff Var	Root MSE	ECIlar Mean
0.684182	5.318195	1.721741	32.37454

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	102.7520586	14.6788655	4.95	0.0039

Dependent Variable: ECDlar

R-Square	Coeff Var	Root MSE	ECDlar Mean
0.461780	12.71016	8.318346	65.44642

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	949.8816045	135.6973721	1.96	0.1253

Dependent Variable: EClcoc

R-Square	*Coeff Var*	*Root MSE*	*EClcoc Mean*
0.833822	*4.338968*	*0.766101*	*17.65629*

Source	*DF*	*Type I SS*	*Mean Square*	*F Value*	*Pr > F*
Treatment	*7*	*47.11845496*	*6.73120785*	*11.47*	*<.0001*

Dependent Variable: ECDcoc

R-Square	*Coeff Var*	*Root MSE*	*ECDcOC Mean*
0.747668	*7.343396*	*2.637815*	*35.92092*

Source	*DF*	*Type I SS*	*Mean Square*	*F Value*	*Pr > F*
Treatment	*7*	*329.8711885*	*47.1244555*	*6.77*	*0.0008*

Appendix 4. *Plates showing field and laboratory observation*

Plate1. Castor plants in the field

Plate 2. Powdered castor leaf ready for nutrient analysis

Plate 3. Larvae managed to maintain humidity

Plate 4. Cleaning of silkworm larvae

Plate 5. Third instar larvae

Plate 6. Matured or fifth instar larvae

Plate 7. Larvae spinning silk cocoon

Plate 8. Cocoons harvested and cut for shell ratio assessment

Plate 9. Castor leaves ready for feeding to silkworms

Plate 10. Left over leaves after feeding

DECLARATION

I, the undersigned, declare that this thesis is my own original work and has not been presented for a degree to any other university and that all the sources of materials used for the thesis have been duly acknowledged.

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Date: ________________________